The HUTCHINSON

Encyclopedia of Science

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The Hutchinson Encyclopedia of Science

Preface

The Hutchinson Encyclopedia of Science is a reference book, with entries arranged in A-Z format. To go directly to a particular entry, click on the link in the table of contents. There are also links between entries - click on any underlined word to jump to the related entry.

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Hawking, Stephen (William)
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Humboldt, (Friedrich Wilhelm Heinrich) Alexander
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hunting dog
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hydrocyanic acid
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hydroelectric power
hydrofoil
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hydrogen burning
hydrogencarbonate
hydrogen cyanide
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hydrography
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hydrology
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hydrolysis (earth science)
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hydrophilic
hydrophily
hydrophobia
hydrophobic
hydrophone
hydrophyte
hydroplane
hydroponics
hydrosphere

hydrothermal
hydrothermal vein
hydrothermal vent
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hydroxyl group
hydroxypropanoic acid
hyena
hygiene
hygrometer
hyoscine
hyperactivity
hyperbola
hypercharge
hypermetropia
hypertension
hypertext
hyperthyroidism
hypertrophy
hypha
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hypnotherapy
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hypodermic syringe
hypogeal
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hypotension
hypotenuse
hypothalamus
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Iceland spar
iceman
ichneumon fly
icon (computing)
icosahedron
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idiot savant
igneous rock
ignis fatuus
ignition coil
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ileum
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immediate access memory
immiscible

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immunocompromised
immunodeficient
immunoglobulin
immunosuppressive
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impala
impedance
imperial system
impetigo
implantation
import file
impotence
imprinting
impulse
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incisor
inclination
inclusive fitness
incontinence
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infarct
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inferiority complex
inferior planet
inferno
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infinite series
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infrared astronomy
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internal-combustion engine
International Atomic Energy Agency
International Date Line
International Organization for Standardization
International Space Station
International Union for the Conservation of Nature
Internet
interplanetary matter
interpreter
intersex
interstellar cirrus
interstitial
intertropical convergence zone
intestine
intracytoplasmic sperm injection
intrauterine device
intravenous
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Kekulé von Stradonitz, Friedrich August
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Ludwig, Carl Friedrich Wilhelm
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lymphocyte
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lynx
lyophilization
Lyra
lyrebird
lyretail
Lysenko, Trofim Denisovich
lysine
lysis
lysosome
Lyssavirus

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MA (physics)
McAdam, John Loudon
macadamia
macaque
macaw
McClintock, Barbara
maceration
Mach, Ernst
machine
machine code
machine tool
Mach number
Macintosh
Macintosh, Charles
mackerel
MacMillan, Kirkpatrick
macro
macro-
macromolecule
macrophage
mad cow disease
madder
mafic rock
Magdalenian
Magellan
Magellanic Clouds
maggot
magic bullet
magic square
maglev
magma
magnesia
magnesium
magnesium oxide
magnet
magnetic compass
magnetic declination
magnetic dip
magnetic dipole
magnetic field
magnetic flux
magnetic induction
magnetic-ink character recognition
magnetic material
magnetic pole
magnetic resonance imaging
magnetic storm
magnetic strip
magnetic tape
magnetism
magnetite
magneto
magnetohydrodynamics
magnetometer
magnetosphere
magnetron
magnet therapy
magnification

magnitude (astronomy)
magnolia
magpie
mahogany
Maiden Castle
maidenhair
maidenhair tree
mail merge
mainboard
mainframe
main sequence
malabsorption syndrome
malachite
malaria
malic acid
malignant hypertension
mallard
mallee
mallow
malnutrition
malt
maltase
Maltese dog
maltose
mamba
mammal
mammary gland
mammography
mammoth
manatee
Manchester terrier
mandarin
Mandelbrot, Benoit B
mandragora
mandrake
mandrill
manganese
manganese ore
manganese(IV) oxide
mangelwurzel
mango
mangrove
mania
manic depression
manioc
manometer
Man Ray
Manson, Patrick
manta
mantis
mantissa
mantle
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Mapplethorpe, Robert
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maquis
marabou
marble
Marburg disease
Marconi, Guglielmo
mare
margay
marginal land
marguerite
Mariana Trench
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Mariner
Mariotte, Edme
marjoram
Markov, Andrei Andreyevich
Markov chain
mark sensing
marl
marlin
marmoset
marmot
marram grass

Mars (astronomy)
Mars Global Surveyor
marsh
Marshall Space Flight Center
marsh gas
marsh marigold
marsh rose
Mars Observer
Mars Pathfinder
marsupial
marten
martin (zoology)
Martin, Archer John Porter
maser
Maskelyne, Nevil
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mass (physics)
mass action, law of
massage
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mass extinction
mass number
mass production
mass spectrograph
mastiff
mastodon
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mathematical induction
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matrix (biology)
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matter
Mauchly, John William
Mauna Kea
Maunder minimum
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Maxwell, James Clerk
Maxwell-Boltzmann distribution
Maxwell's screw rule
mayfly
Mayo, William James
mayweed
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MDMA
ME (medicine)
meal-worm
mealy bug
mean
meander
mean deviation
mean free path
mean life
measles
mechanical advantage
mechanical equivalent of heat
mechanics
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Medawar, Peter Brian
media (computing)
median
medical ethics
medicine
medicine, alternative
medicine, history
medlar
medulla
medusa
meerkat
meerschaum
mega-
megabyte
megalith
megamouth
megapode
megaton
megavitamin therapy
meiosis

Meitner, Lise
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melamine
melanin
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melting point
membrane
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Mendel, Gregor Johann
mendelevium
Mendeleyev, Dmitri Ivanovich
Mendelism
menhaden
menhir
Ménière's disease
meningitis
meningococcus
meniscus
meniscus (biology)
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mental disability
mental illness
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Mercalli scale
Mercator, Gerardus
merchant navy
Mercury (astronomy)
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mercury fulminate
Mercury project
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MERLIN array
mermaid's purse
mesa
mescaline
Mesmer, Friedrich Anton (or Franz)
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Mesolithic
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Mesozoic
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Messerschmitt, Willy (Wilhelm Emil)
Messier, Charles
Messier catalogue
metabolism
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metal detector
metal fatigue
metallic bond
metallic character
metallic glass
metallographic examination
metalloid
metallurgy
metamorphic rock
metamorphism
metamorphosis (biology)
metazoa
Metchnikoff, Elie
meteor
meteor-burst communications
meteorite
meteorology
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methanal

methane
methanogenic bacteria
methanoic acid
methanol
methionine
methyl alcohol
methylated spirit
methyl benzene
methyl orange
metre (science)
metric system
metric ton
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MHD
mho
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mica
Michaelmas daisy
Michelson, Albert Abraham
MICR
micro-
microbe
microbiology
microchip
microclimate
microcomputer
microfiche
microform
micrometer (instrument)
micrometre
micro-organism
microphone
microprocessor
micropropagation
micropyle
microscope
microsurgery
microtubules
microwave heating
microwave radiation
Mid-Atlantic Ridge
midge
MIDI
midnight sun
mid-ocean ridge
midwifery
mifepristone
mignonette
migraine
migration
Milankovitch hypothesis
mildew
mile
milfoil
milk
milking machine
milk teeth
Milky Way
Millennium Bug
Miller, Stanley Lloyd
millet
milli-
millibar
Millikan, Robert Andrews
milliliter
millimeter of mercury
million
millipede
Milner, Kit (Christopher)
Milstein, César
mimicry
mimosa
Mimosa
mineral
mineral extraction
mineralogy
mineral oil
mineral salt
minicomputer

mining (industry)
mink
minnow
Minoan civilization
minor planet
mint (botany)
minute
Miocene
mips
Mir
Mira
mirage
mirror
miscarriage
missel thrush
missile
Mississippian
mistletoe
mistral
Mitchell, Juliet
Mitchell, R(eginald) J(oseph)
mite
mitochondria
mitosis
mixed farming
mixture (chemistry)
m.k.s. system
ml
mm
mmHg
MMT (Multiple-Mirror Telescope)
mnemonic (computing)
moa
mobile ion
mobile phone
Möbius, August Ferdinand
Möbius strip
mockingbird
mock orange
mode (mathematics)
model (computing)
model (simulation)
modem
moderator
modulation (radio)
module
modulus
Moholy-Nagy, Laszlo
Mohorovicic discontinuity
Mohs scale
Moissan, (Ferdinand Frédéric) Henri
mol
molar
molar solution
molar volume
mole (chemistry)
mole (zoology)
mole cricket
molecular biology
molecular clock
molecular cloud
molecular formula
molecular mass
molecular solid
molecular weight
molecule
mole rat, naked
mollusk
molybdenite
molybdenum
moment of a force
moment of inertia
momentum
monazite
mongolism
mongoose
monitor (zoology)
monkey
monkeypox

monkey puzzle
monocarpic
monoclonal antibody
monocotyledon
monoculture
monocyte
Monod, Jacques Lucien
monoecious
monohybrid inheritance
monolith
monomer
mononucleosis
monorail
monosaccharide
monosodium glutamate
monotreme
monozygotic twin
monsoon
monstera
montbretia
Montgolfier
month
Montréal Protocol
Moon
moon
Moon probe
moonstone
moor
moorhen
moose
mopane worm
moped
moraine
morbidity
morel
Morgagni, Giovanni Battista
Morgan, Thomas Hunt
Morgan horse
moribund
morning glory
morphine
morphing
morphogen
morphology (biology)
Morse, Samuel Finley Breese
Morse code
Morton, William Thomas Green
mosquito
moss
Mössbauer, Rudolf (Ludwig)
Mössbauer effect
moth
motherboard
mother-of-pearl
motility
motion
motion sickness
motor
motorboat
motorcycle
motor effect
motor nerve
motor neuron disease
mouflon
mould
moulding
moulting
mountain
mountain ash
mountain gorilla
mountain lion
Mount Palomar
Mount Stromlo Observatory
Mount Wilson
mouse (computing)
mouse (zoology)
mousebird
Moustier, Le
mouth

movie camera
moving-coil meter
mp (chemistry)
MS-DOS
MTBF
mucous membrane
mucus
mudfish
mudnester
mudpuppy
mudskipper
mudstone
muffler (exhaust)
mulberry
mule
Mullard Radio Astronomy Observatory
mullein
Muller, Hermann Joseph
Müller, Johannes Peter
Müller, Paul Hermann
mullet
multimedia
multiple birth
multiple proportions, law of
multiple sclerosis
multiplexer
multistage rocket
multitasking
multi-user
mummy
mumps
Münchhausen's syndrome
muntjac
muon
murmur
Murray, Joseph Edward
Murray cod
muscle
muscle relaxant
muscovite
muscular dystrophy
mushroom
musical instrument digital interface
music therapy
musk
musk deer
musk ox
muskrat
mussel
mustard
mutagen
mutation (biology)
mutton bird
mutual induction
mutualism
Muybridge, Eadweard
myasthenia gravis
mycelium
Mycenaean civilization
mycorrhiza
myelin sheath
myelitis
Myers, F(rederic) W(illiam) H(enry)
myiasis
myna
myoglobin
myopia
myopia, low-luminance
myrmecophyte
myrrh
myrtle
mystery reproductive syndrome
myxoedema
myxomatosis

N

N (abbreviation)
nacre

Nadar
nadir
naevus
nagana
nail
NAND gate
nano-
nanotechnology
Nansen, Fridtjof
naphtha
naphthalene
Napier, John
nappy rash
narcissism
narcissus
narcosis
narcotic
Narmada Valley Project
narwhal
NASA
nastic movement
nasturtium
National Aeronautics and Space Administration
national park
native companion
native metal
natural frequency
natural gas
natural logarithm
natural radioactivity
natural selection
nature-nurture controversy
nature preserve
naturopathy
nausea
nautical mile
nautilus
navel
navigation
navigation, biological
NDA
nearsightedness
nebula
neck (anatomy)
necrosis
nectar (botany)
nectarine
needlefish
negative number
negative/positive
nematode
neo-Darwinism
neodymium
neon
neoplasm
neoprene
neoteny
neper
nephritis
nephron
Neptune (astronomy)
neptunium
Nernst, (Walther) Hermann
nerve
nerve cell
nervous breakdown
nervous system
nest
nettle
nettle rash
network
neuralgia
neural network
neurasthenia
neuritis
neurology
neuron
neurosis
neurotoxin

neurotransmitter
neutralization
neutral oxide
neutrino
neutron
neutron beam machine
neutron bomb
neutron star
Newfoundland (dog)
New Madrid seismic fault zone
New Photography
newt
New Technology Telescope
newton
Newton, Isaac
Newtonian physics
Newtonian telescope
Newton's laws of motion
Newton's rings
niacin
niche
Nichrome
nickel
nickel ore
Nicolle, Charles Jules Henri
nicotine
nicotine patch
nicotinic acid
Niepce, Joseph Nicéphore
nightingale
nightjar
nightshade
niobium
nit
nitrate
nitrate pollution
nitre
nitric acid
nitric oxide
nitrification
nitrite
nitrocellulose
nitrogen
nitrogen cycle
nitrogen fixation
nitrogen oxide
nitroglycerine
nitrous acid
nitrous oxide
Nobel, Alfred Bernhard
nobelium
Nobel Prize
noble gas
noble gas structure
node
nodule
noise (physics)
nomadic pastoralism
non-metal
non-renewable resource
nonsteroidal anti-inflammatory drug
nonvolatile memory
noradrenaline
Norfolk terrier
NOR gate
normal distribution curve
North Atlantic Drift
northern lights
Northrop, John Howard
Norwich terrier
nose
nosebleed
nosocomial
nostril
NOT gate
notifiable disease
notochord
nova
Novocaine

NSAID
NTP
nuclear energy
nuclear fusion
nuclear magnetic resonance
nuclear medicine
nuclear notation
nuclear physics
nuclear reaction
nuclear reactor
nuclear safety
nuclear waste
nucleic acid
nucleolus
nucleon
nucleotide
nucleus (astronomy)
nucleus (biology)
nucleus (physics)
nuclide
nuée ardente
numbat
number (mathematics)
number line
numerator
nursing
nut (botany)
nut and bolt
nutation (astronomy)
nutation (botany)
nutcracker
nuthatch
nutmeg
nutria
nutrition
nylon
nymph (entomology)

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oak
oarfish
oarweed
oasis
oat
obesity
object program
observatory
obsession
obsessive-compulsive disorder
obsidian
obstetrics
obtuse angle
occluded front
occultation
occupational psychology
ocean
oceanarium
ocean current
Ocean Drilling Program
oceanography
ocean trench
ocelot
OCR
octahedron, regular
octal number system
octane rating
Octans
octet rule
octopus
oedema
Oedipus complex
oersted
Oersted, Hans Christian
oesophagus
oestrogen
oestrus
Offa's Dyke
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ohm
Ohm, Georg Simon
Ohm's law
oil
oil, cooking
oil crop
oil palm
oil spill
okapi
okra
old age
oleander
olefin
Oligocene epoch
oligosaccharide
olive
olivenite
Olivetti
olivine
olm
Omar Khayyám
omnivore
onager
Onassis, Aristotle Socrates
onchocerciasis
oncogene
oncology
onco-mouse
onion
online system
ontogeny
onyx
oocyte
oolite
Oort, Jan Hendrik
Oort cloud
oosphere
ooze
opah
opal
open cluster
open-hearth furnace
open source
operating system
operational amplifier
operon
Ophiuchus
ophthalmia neonatorum
ophthalmology
opiate, endogenous
opioid analgesic
opium
opossum
Oppenheimer, J(ulius) Robert
opposition
optical aberration
optical activity
optical character recognition
optical fibre
optical illusion
optical instrument
optic nerve
optics
optoelectronics
opuntia
oral contraceptive
orange
orang-utan
orbit (anatomy)
orbit (astronomy)
orbital, atomic
orchid
order (biology)
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ordinate
Ordovician period
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orfe

organ (anatomy)
organelle
organic chemistry
organic compound
organic farming
organizer
organophosphate insecticide
OR gate
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oriole
Orion (astronomy)
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orrery
orris root
orthochromatic
orthodontics
orthopaedics
ortolan
oryx
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oscillograph
oscilloscope
osier
osmium
osmoregulation
osmosis
osprey
ossification
osteology
osteomyelitis
osteopathy
osteoporosis
ostrich
Ostwald, (Friedrich) Wilhelm
Otis, Elisha Graves
otitis
otosclerosis
otter
Otto cycle
Oughtred, William
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output device
ouzel
ovary
overfishing
overtone
oviparous
ovoviviparous
ovulation
ovule
ovum
owl
ox
oxalic acid
oxbow lake
oxidation (chemistry)
oxidation (earth science)
oxidation number
oxide
oxlip
oxpecker
oxyacetylene torch
oxygen
oxygen debt
oxytocin
oyster
oyster catcher
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Ozalid process
ozone

ozone depleter
ozone layer

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paca
pacemaker
Pacific Ocean
packet switching
paediatrics
page printer
paging
pain
painkiller
paint
Palaeocene epoch
palaeomagnetism
palaeontology
Palaeozoic era
palate
palisade cell
palladium (chemistry)
palliative
palm
palsy
pampas grass
panchromatic
pancreas
panda
Pangaea
pangolin
pansy
Panthalassa
panther
pantothenic acid
Papanicolaou test
papaya
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papovavirus
pappus
Pap test
parabola
Paracelsus, Philippus Aureolus
paracetamol
parachute
paradigm
paraffin
parakeet
paraldehyde
parallax
parallel device
parallel lines and parallel planes
parallelogram
parallelogram of forces
parallel processing
paralysis
parameter
paranoia
paranormal
paraplegia
parapsychology
paraquat
parasite
parasympathetic nervous system
parathyroid
paratyphoid fever
Paré, Ambroise
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parental care
parity (computing)
Parkes Observatory
Parkinson, Norman
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parthenocarpy
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particle detector
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partridge
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Pascal
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Pascal, Blaise
Pascal's triangle
pasqueflower
passion flower
passive margin
passive smoking
Pasteur, Louis
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pastoral farming
patchouli
patch test
patella
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Pauling, Linus Carl
Pavlov, Ivan Petrovich
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peach
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peanut
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pecan
peccary
pectoral
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Pegasus (astronomy)
pegmatite
pekan
pekingese
Peking man
pelargonium
pelican
pellagra
pellitory-of-the-wall
Peltier effect
pelvis
pendulum
Penfield, Wilder Graves
penguin
penicillin
peninsula
penis
Penn, Irving
Pennsylvanian period
pennyroyal
pentadactyl limb
pentagon
pentanol
penumbra
peony
pepper
peppermint
pepsin
peptide
percentage
perch
perennating organ
perennial plant
perforation
perfume
perfusion
perianth
pericarp

peridot
peridotite
perigee
periglacial environment
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period (menstruation)
period (physics)
periodic table of the elements
periodontal disease
peripheral device
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peristalsis
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periwinkle (plant)
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Permian
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perpendicular
perpetual motion
Perseus (astronomy)
persicaria
persimmon
personal computer
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perspective
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Peru Current
Perutz, Max Ferdinand
pessary
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pesticide
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petit Brabançon
petrel
petrochemical
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petroleum
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Peugeot
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peyote
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Phanerozoic eon
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phase (astronomy)
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phenol
phenotype
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phenylketonuria
pheromone
phlebitis
phloem
phlox
phobia
Phobos
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phosphate
phospholipid
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phosphoric acid
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photocopier
photodiode
photodynamic therapy

photoelectric cell
photoelectric effect
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photogravure
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photosynthesis
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phyllite
phyllotaxis
phylloxera
phylogeny
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physiotherapy
phytomenadione
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Piaget, Jean
Piccard, Auguste Antoine
PIC device
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PID
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pigeon
pigeon hawk
pig iron
pika
pike
pikeperch
pilchard
Pill, the
pilotfish
pimento
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PIN
pine
pineal body
pineapple
pinhole camera
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Pinker, Steven
pinna
pinnate leaf
pint
pinworm
pion
Pioneer
pipefish
pipette
pipit
piranha
Pisces
Piscis Austrinus
pistachio
pistil
pistol
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pit bull terrier
pitch (chemistry)
pitch (mechanics)
pitchblende
pitcher plant
pitot tube
pitta
pituitary gland
pixel
placebo
placenta
placer deposit
plage

plague
plaice
plain
Planck, Max Karl Ernst Ludwig
Planck's constant
plane
planet
planetarium
planetary embryo
planetary nebula
planimeter
planisphere
plankton
plant
plantain
plantation
plant cell
plant classification
plant hormone
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plaque
plasma (biology)
plasma (physics)
plasmapheresis
plasmid
plaster of Paris
plastic (chemistry)
plastic surgery
plastid
plate
plateau
platelet
plate tectonics
platinum
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playa
Pleiades (astronomy)
Pleistocene epoch
plesiosaur
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Plexiglas
Plimsoll line
Pliocene Epoch
pliosaur
plotter
plough
plover
plucking
plum
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plumule
Pluto (astronomy)
plutonic rock
plutonium
plywood
pneumatic drill
pneumatophore
pneumoconiosis
pneumonectomy
pneumonia
pneumothorax
p-n junction diode
pochard
pod
podiatry
podzol
poikilothermy
Poincaré, (Jules) Henri
poinsettia
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pointer
point of sale
point-of-sale terminal
poise
poison
Poisson, Siméon-Denis
polar bear
polar coordinates
polarimetry

Polaris
polarized light
polarography
Polaroid camera
polar reversal
polder
pole
polecat
Pole Star
poliomyelitis
Politzer, Hugh David
pollack
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pollen
pollen tube
pollination
pollution
Pollux (astronomy)
polonium
polyanthus
polychlorinated biphenyl
polyester
polyethylene
polygon
polygraph
polyhedron
polymer
polymerization
polymorph
polymorphism (genetics)
polymorphism (mineralogy)
polymytosis
polynomial
polyp (medicine)
polyp (zoology)
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polyploid
polypropylene
polysaccharide
polystyrene
polytetrafluoroethene
polythene
polyunsaturate
polyurethane
polyvinyl chloride
pome
pomegranate
pomeranian
Pompeii
pondweed
pony
poodle
poplar
poppy
population (biology)
population control
population cycle
porbeagle
porcupine
pore
porphyria
porphyry
porpoise
Porsche, Ferdinand
port (computing)
port (transport)
Porter, Rodney Robert
Portuguese man-of-war
positron
positron emission tomography
possum
post-coital contraception
post-mortem
postpartum
post-viral fatigue syndrome
potash
potassium
potato
potato blight

potential difference
potential, electric
potential energy
potentiometer
potto
poultry
pound
poundal
powder metallurgy
power (mathematics)
power (optics)
power (physics)
power house
prairie
prairie dog
praseodymium
prawn
praying mantis
Precambrian era
precession of the equinoxes
precipitation (chemistry)
precipitation (meteorology)
pre-eclampsia
pregnancy
prehistoric art
prehistoric life
prematurity
premedication
premenstrual syndrome
premolar
presbyopia
prescription (medicine)
preservative
pressure
pressure cooker
pressurized water reactor
prickly heat
prickly pear
Priestley, Joseph
Prigogine, Ilya
primary sexual characteristic
primate (zoology)
prime factor
prime number
primrose
principal focus
printed circuit board
printer
printing
prion
prism (mathematics)
prism (optics)
privet
probability
procedure
processing cycle
processor
Procyon
productivity, biological
progesterone
progestogen
prognosis
prograde orbit
program
program counter
program loop
programming
programming language
program trading
progression
projectile
projection
projector
prokaryote
prolapse
PROLOG
PROM
promethium
prominence

pronghorn
proof spirit
propane
propanol
propanone
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Rayleigh, John William Strutt

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red blood cell
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Richter, Charles Francis
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Riemann, Georg Friedrich Bernhard
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Rodchenko, Alexander Mikhailovich
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Röntgen, Wilhelm Konrad
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Ross, Ronald
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Rubik, Ernö
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Sabin, Albert Bruce
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Sagan, Carl Edward
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Savery, Thomas
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Scheele, Karl Wilhelm
Schiaparelli, Giovanni Virginio
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Schliemann, Heinrich
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Schrödinger, Erwin
Schumacher, Fritz
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Schweitzer, Albert
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Seacole, Mary
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Shannon, Claude Elwood
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Shepard, Alan Bartlett
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Sherrington, Charles Scott
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Soddy, Frederick
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Thorndike, Edward Lee
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transformer
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transhumance
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transmission electron microscope
transparency
transpiration
transplant
transsexual
Trans-Siberian Railway
transuranic element
transverse wave
trapezoid
trauma
travel medicine
treadmill
tree
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tree diagram
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trefoil
trematode
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Trevithick, Richard
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trichloromethane
tricuspid valve
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triglyceride
trigonometry
trillium
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trimester
triple bond
triple nose-leaf bat
triticale
tritium
Triton (astronomy)
troglodyte
trogon
troilite
Trojan
trolleybus
trophic level
tropical cyclone
tropical disease
tropics
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Troy
troy system
truffle
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truncation error
trypanosomiasis
trypsin
tsetse fly
Tsiolkovsky, Konstantin Eduardovich
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tuberculosis
tuberose
Tucana
tucu-tuco
tufa
tulip
Tull, Jethro
tumour
tuna
tundra
tung oil
tungsten
tungsten ore
Tunguska Event
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tunnel
tunny
turbine
turbocharger
turbofan
turbojet
turbot
turbulence
turgor
Turing, Alan Mathison
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turmeric
turnaround document
turnip
turnpike road
turnstone
turpentine
turquoise
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turtle (reptile)
TVP
twin
two's complement number system

two-stroke cycle
typesetting
typewriter
typhoid fever
typhoon
typhus
tyrannosaurus
tyre
tyrosine

U

uakari
UHF
UHT
ulcer
ulna
ultrabasic
ultrafiltration
ultra-heat treatment
ultrasonics
ultrasound scanning
ultraviolet astronomy
ultraviolet radiation
Ulysses
umbilical cord
umbra
umbrella bird
umbrella tree
uncertainty principle
unconformity
unconscious
undernourishment
ungulate
unicellular organism
unidentified flying object
unified field theory
uniformitarianism
unit (quantity)
universal indicator
universal joint
universe
Unix
unleaded petrol
unsaturated compound
unsaturated solution
ununnilium
unununium
upthrust
uraninite
uranium
uranium ore
Uranus (astronomy)
urea
ureter
urethra
Urey, Harold Clayton
urial
uric acid
urinary system
urine
urology
Ursa Major
Ursa Minor
urticaria
user ID
user interface
US Naval Observatory
UTC
uterus
utility program
UV

V

v
V
V (numeral)
vaccine

vacuole
vacuum
vacuum cleaner
vagina
valence
valence electron
valerian
validation
valley
Valley of Ten Thousand Smokes
valve (biology)
valve (technology)
valvular heart disease
vampire bat
vanadium
Van Allen, James Alfred
Van Allen radiation belts
van de Graaff, Robert Jemison
van de Graaff generator
van der Waals' law
Vane, John Robert
Vanguard
vanilla
van't Hoff, Jacobus Henricus
vapour
vapour density
vapour pressure
variable (computing)
variable (mathematics)
variable star
variance (statistics)
variation (biology)
varicose veins
variegation
variety
varve
vascular bundle
vascular plant
vas deferens
vasectomy
VDT
vector graphics
vector quantity
Vega
vegetation
vegetative reproduction
vein
Vela
veldt
velocity
vena cava
venereal disease
Venn diagram
ventilation
ventral surface
ventricle
Ventris, Michael George Francis
Venturi tube
Venus (astronomy)
Venus flytrap
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verdigris
verification
vermilion
vernal equinox
vernalization
vernier
verruca
vertebra
vertebral column
vertebrate
vertex
vertical takeoff and landing craft
vertigo
Very Large Array
very long-baseline array
very long-baseline interferometry
Vesalius, Andreas
vestigial organ

Vesuvio
Vesuvius
vetch
VHF
viburnum
vicuna
video camera
video cassette recorder
video disc
video game
videotape recorder
videotex
Viking
villus
vincristine
vine
violet
viper
Virginia creeper
Virgo
Virtanen, Artturi Ilmari
virtual
virtual memory
virtual reality
virus (computing)
virus (medicine)
viscacha
viscera
viscose
viscosity
vision
vision defect
visual display terminal
vitalistic medicine
vitamin
vitamin A
vitamin B_1
vitamin B_6
vitamin B_{12}
vitamin B_2
vitamin C
vitamin D
vitamin E
vitamin H
vitamin K
vitreous humour
vitriol
viviparous
vivisection
VLBA
VLF
vocal cords
vol.
volatile
volatile memory
volcanic rock
volcano
vole
volt
Volta, Alessandro Giuseppe Antonio Anastasio
voltage amplifier
voltaic cell
voltmeter
volume
volumetric analysis
von Braun, Wernher Magnus Maximilian
Von Neumann, John
Voskhod
Vostok
Voyager
Vries, Hugo (Marie) de
V-shaped valley
VSTOL
vulcanization
Vulpecula
vulture

W

W
W (abbreviation)
wadi
wagtail
Waksman, Selman Abraham
Wald, George
Waldsterben
wallaby
Wallace line
wallflower
wall pressure
walnut
walrus
Wang, An
WAP
wapiti
warble fly
warbler
Warburg, Otto Heinrich
warfarin
warning coloration
wart
wart hog
washing soda
Washington Convention
wasp
waste
waste disposal
watch
water
water beetle
water boatman
water-borne disease
waterbuck
water bug
watercress
water cycle
waterfall
water flea
waterfowl
water gas
water glass
water hyacinth
water lily
water meadow
water measurer
watermelon
water mill
water of crystallization
water pollution
water scorpion
water softener
waterspout
water strider
water supply
water table
Watson, James Dewey
Watson, John Broadus
watt
wattle
wave (earth science)
wave (physics)
wave-cut platform
waveguide
wavelength
wave power
wax
waxbill
waxwing
wayfaring tree
Wb
weak acid
weak base
weak nuclear force
weakon
weapon
weasel
weather
weather forecast

weathering
weaver
Web browser
weber
wedge
weedkiller
weever fish
weevil
Wegener, Alfred Lothar
weight
weightlessness
Weil's disease
weir
Weismann, August Friedrich Leopold
welding
Welsh corgi
welwitschia
Werner, Abraham Gottlob
Werner, Alfred
Werner's syndrome
westerlies
Westinghouse, George
Weston, Edward
weta
wetland
wetted perimeter
whale
whaling
wheat
wheatear
Wheeler, (Robert Eric) Mortimer
whelk
whey
whimbrel
whiplash injury
whippet
Whipple, Fred Lawrence
Whipple, George Hoyt
whippoorwill
whip snake
whirligig beetle
whirling disease
whirlwind
whitebait
whitebeam
white blood cell
white dwarf
whitefish
whitefly
Whitehead, Alfred North
whiteout
white spirit
whitethroat
whiting
Whitney, Eli
Whittle, Frank
whooping cough
whortleberry
whydah
wide-angle lens
wide area network
Wiener, Norbert
Wien's displacement law
wigeon
Wilczek, Frank
wildebeest
wilderness
Wilding, Dorothy
wildlife trade
wild type
Wilkins, Maurice Hugh Frederick
will-o'-the-wisp
willow
willowherb
willow warbler
willy-willy
Wilms's tumour
Wilson, Edward Osborne
wilting

WIMP (computing)
Winchester drive
wind
wind-chill factor
wind farm
windmill
window
Windows
windpipe
wind power
wind turbine
wing
wintergreen
wire
wireless
wireless LAN
wireworm
wisent
wisteria
witch hazel
woad
Wöhler, Friedrich
wolf
wolfram
wolframite
Wollaston, William Hyde
wolverine
womb
wombat
wood
woodcock
woodland
woodlouse
woodpecker
wood pitch
Woodward, Robert Burns
wood wasp
woodworm
wool
Woolcott, Marion Post
Woolley, (Charles) Leonard
word
word processing
work
workstation
World Conservation Union
World Meteorological Organization
World Wide Fund for Nature
World Wildlife Fund
worm
WORM
wormwood
W particle
wrack
wrasse
wren
Wright
Wright, Sewall
write protection
wrought iron
wt
Wundt, Wilhelm Max
WWF
WYSIWYG

X

x (maths)
xanthophyll
X chromosome
xenon
xenophobia
xerography
xerophyte
X/Open
X-ray
X-ray astronomy
X-ray diffraction
X-ray diffraction analysis

X-ray fluorescence spectrometry
X-ray telescope
xylem

Y

yak
yam
yapok
yard
yardang
yarn
yarrow
yaws
Y chromosome
yd
year
year 2000
yeast
yeast artificial chromosome
yeheb nut
yellow archangel
yellow fever
yellowhammer
Yerkes Observatory
yeti
yew
yield point
Yixian formation
yolk
yolk sac
Young, John Watts
Young, Thomas
ytterbium
yttrium
yucca

Z

Z (physics)
zebra
zebu
Zelenchukskaya
zenith
zeolite
Zhubov scale
zidovudine
Ziegler, Karl
ZIFT
Zimbabwe (architecture)
zinc
zinc ore
zinc oxide
zinc sulphide
zinnia
zipper
zircon
zirconium
zodiac
zodiacal light
zoidogamy
zone standard time
zone system
zone therapy
zoo
zoology
zoom lens
zoonosis
Z particle
Zsigmondy, Richard Adolf
zucchini
Zweig, George
Zwicky, Fritz
zwitterion
Zworykin, Vladimir Kosma
zygote

A

in physics, symbol for ampere, a unit of electrical current.

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aardvark

(Afrikaans 'earth pig')

nocturnal mammal *Orycteropus afer*, the only species in the order Tubulidentata, found in central and southern Africa. A timid, defenceless animal about the size of a pig, it has a long head, a piglike snout, large ears, sparse body hair, a thick tail, and short legs.

It can burrow rapidly with its clawed front feet. It spends the day in its burrow, and at night digs open termite and ant nests, licking up the insects with its long sticky tongue. Its teeth are unique, without enamel, and are the main reason for the aardvark being placed in its own order. When fully grown, it is about 1.5 m/5 ft long and its tongue is 30 cm/12 in long.

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aardwolf

nocturnal mammal *Proteles cristatus* of the hyena family, Hyaenidae. It is yellowish grey with dark stripes and, excluding its bushy tail, is around 70 cm/30 in long. It is found in eastern and southern Africa, usually in the burrows of the aardvark. It feeds almost exclusively on termites, eating up to 300,000 per day, but may also eat other insects and small mammals.

Males mate monogamously but females, which have a much larger range, will mate with other males.

---

abacus

ancient calculating device made up of a frame of parallel wires on which beads are strung. The method of calculating with a handful of stones on a 'flat surface' (Latin *abacus*) was familiar to the Greeks and Romans, and used by earlier peoples, possibly even in ancient Babylon; it survives in the more sophisticated bead-frame form of the Russian *schoty* and the Japanese *soroban*. The abacus has been superseded by the electronic calculator.

The wires of a bead-frame abacus define place value (for example, in the decimal number system each successive wire, counting from right to left, would stand for ones, tens, hundreds, thousands, and so on) and beads are slid to the top of each wire in order to represent the digits of a particular number. On a simple decimal abacus, for example, the number 8,493 would be entered by sliding three beads on the first wire (three ones), nine beads on the second wire (nine tens), four beads on the third wire (four hundreds), and eight beads on the fourth wire (eight thousands).

---

abalone

edible marine snail of the worldwide genus *Haliotis*, family Haliotidae. Abalones have flattened, oval, spiralled shells, which have holes around the outer edge and a bluish mother-of-pearl lining. This lining is used in ornamental work.

---

abdomen

in vertebrates, the part of the body below the thorax, containing the digestive organs; in insects and other arthropods, it is the hind part of the body. In mammals, the abdomen is separated from the thorax by the diaphragm, a sheet of muscular tissue; in arthropods, commonly by a narrow constriction. In mammals, the female reproductive organs are in the abdomen. In insects and spiders, it is characterized by the absence of limbs.

Abel, John Jacob (1857-1938)

US biochemist, discoverer of adrenaline. He studied the chemical composition of body tissues, and this led, in 1898, to the discovery of adrenaline, the first hormone to be identified, which Abel called epinephrine. He later became the first to isolate amino acids from blood.

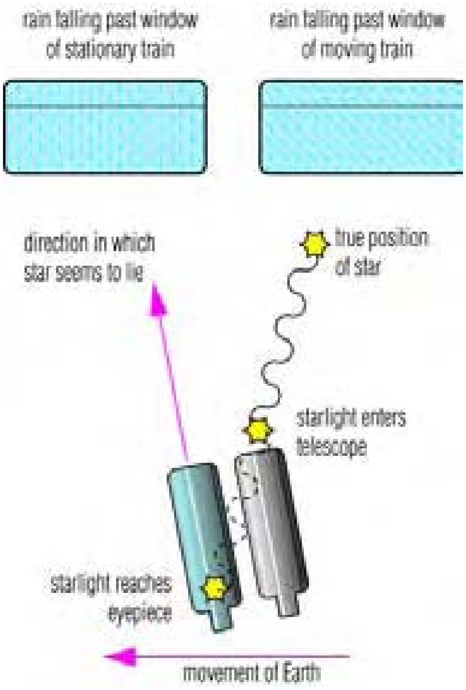
---

aberration of starlight

apparent displacement of a star from its true position, due to the combined effects of the speed of light and the speed of the Earth in orbit around the Sun (about 30 kps/18.5 mps).

During a year the apparent position of a star describes a curve around its true position. This curve is an ellipse except when the star lies on the ecliptic (when it is a line along which the star appears to move backwards and forwards) or when it is in the pole of the ecliptic (when it is a circle). As aberration depends upon the ratio between the velocity of light and the velocity of the Earth, the determination of this 'constant of aberration' provides a method of calculating an approximate value for one of these velocities if the other is known.

aberration of starlight


rain falling past window of stationary train
rain falling past window of moving train
direction in which star seems to lie
true position of star
starlight enters telescope
starlight reaches eyepiece
movement of Earth

(Image © Research Machines plc)

The aberration of starlight is an optical illusion caused by the motion of the Earth. Rain falling appears vertical when seen from the window of a stationary train; when seen from the window of a moving train, the rain appears to follow a sloping path. In the same way, light from a star 'falling' down a telescope seems to follow a sloping path because the Earth is moving. This causes an apparent displacement, or aberration, in the position of the star.

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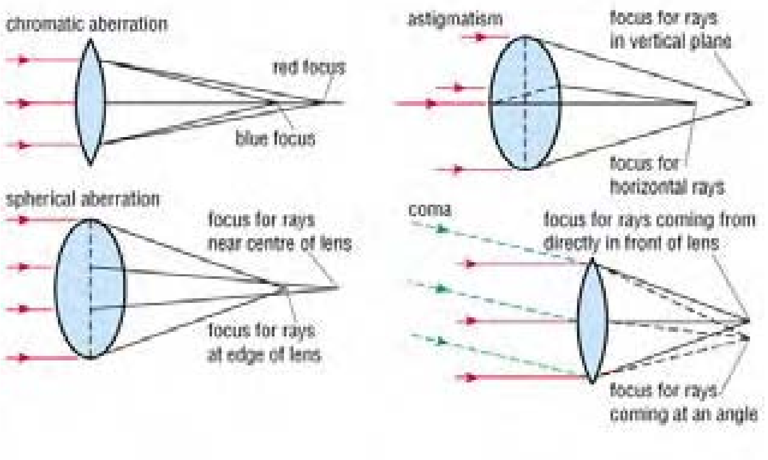
aberration, optical

any of a number of defects that impair the image in an optical instrument. Aberration occurs because of minute variations in lenses and mirrors, because no lens or mirror can perfectly focus all light rays entering the instrument at different angles, and (with lenses) because different parts of the light spectrum are refracted by varying amounts.

In **chromatic aberration** the image is surrounded by coloured fringes, because light of different wavelengths is brought to different focal points by a lens. In **spherical aberration** the image is blurred because different parts of a spherical lens or mirror have different focal lengths. In **astigmatism** the image appears elliptical or cross-shaped because of an irregularity in the curvature of the lens. In **coma** the images appear progressively elongated towards the edge of the field of view. Elaborate computer programs are now used to design lenses in which the aberrations are minimized.

aberration, optical


chromatic aberration
red focus
blue focus
astigmatism
focus for rays in vertical plane
focus for horizontal rays
spherical aberration
focus for rays near centre of lens
focus for rays at edge of lens
coma
focus for rays coming from directly in front of lens
focus for rays coming at an angle

(Image © Research Machines plc)

The main defects, or aberrations, of optical systems. Chromatic aberration, or coloured fringes around images, arises because light of different colours is focused at different points by a lens, causing a blurred image. Spherical aberration arises because light that passes through the centre of the lens is focused at a different point from light passing through the edge of the lens. Astigmatism arises if a lens has different curvatures in the vertical and horizontal directions. Coma arises because light passing directly through a lens is focused at a different point to light entering the lens from an angle.

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abiotic factor

non-living variable within the ecosystem, affecting the life of organisms. Examples include temperature, light, and water. Abiotic factors can be harmful to the environment, as when sulphur dioxide emissions from power stations produce acid rain.

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abortion

(Latin aborire 'to miscarry')

ending of a pregnancy before the fetus is developed sufficiently to survive outside the uterus. Loss of a fetus at a later stage is termed premature stillbirth. Abortion may be natural (miscarriage) or deliberate (termination of pregnancy).

deliberate termination

In the first nine weeks of pregnancy, medical termination may be carried out using the 'abortion pill' (mifepristone), which acts against the hormones sustaining the pregnancy, in conjunction with a prostaglandin to stimulate uterus contractions. There are also various procedures for surgical termination, such as dilatation and curettage, depending on the length of the pregnancy.

Worldwide, an estimated 150,000 pregnancies are terminated each day by induced abortion. One-third of these abortions are performed illegally and unsafely, and cause one in eight of all women's deaths during pregnancy.

abortion as birth control

Abortion as a means of birth control has long been controversial. The argument centres largely upon whether a woman should legally be permitted to have an abortion and, if so, under what circumstances. Another aspect is whether, and to what extent, the law should protect the fetus.

Those who oppose abortion generally believe that human life begins at the moment of conception, when a sperm fertilizes an egg. This is the view held, for example, by the Roman Catholic Church. Those who support legal abortion may believe in a woman's right to choose whether she wants a child, and may take into account the large numbers of deaths and injuries from unprofessional back-street abortions.

Others approve abortion for specific reasons. For example, if a woman's life or health is jeopardized, or there is a strong likelihood that the child will be born with severe mental or physical disability, an abortion may be recommended. Other grounds for abortion include pregnancy resulting from sexual assault such as rape or incest.

Abortion: Background and Issues

background

Spontaneous abortion is common in pregnancy and raises no serious moral or philosophical issues. Induced abortion is a different matter. In earlier centuries, as now, deliberately procured termination of pregnancy was fraught with religious, legal, moral, and philosophical consequences.

infanticide

Traditionally, however, the destructive act of greatest concern was infanticide. Although many earlier societies tolerated or even encouraged the killing or abandonment of the newly born to keep the population down, within Christendom infanticide was always reckoned sinful, as every live-born human was believed to have a soul. In Britain, severe punishments were enforced from the early 17th century against mothers guilty of infanticide.

induced abortion

Induced abortion was long judged immoral and/or sinful. In the Hippocratic Oath physicians swore not to procure abortions (though initially chiefly to uphold professional status). There was widespread suspicion in pre-industrial times of 'wise women' for allegedly using abortifacient herbs, such as pennyroyal, and many quack remedies were in fact disguised abortifacients.

abortion criminalized

Specific legislation against abortion was rare, however, before the 19th century. In Britain, the first act came in 1803. In the USA, Connecticut criminalized abortion in 1821 and by 1868 36 states had anti-abortion statutes, such legislation remaining on the statute book till the 1960s.

Britain and Europe

A British act of 1861 further criminalized abortion unless performed by a licensed doctor on medical grounds. Comparable legislation was passed in Europe. Its effect was to create a growing trade in 'back street' abortions, often conducted illegally but lucratively by the medical profession. As the desire to limit families grew, and in the absence of safe, legal, and cheap contraception, abortion became the most popular method of family limitation in Germany and Russia, and perhaps Britain and the United States till the 1930s.

British legislation

In Britain, the 1861 Act remained in force until the Abortion Act of 1967, which legalized abortion where advised by a physician on medical grounds. The medical profession (and Parliament) adamantly rejected 'abortion on demand' or abortion as a woman's right - though in practice the 1967 Act quickly brought about abortion on demand. Since then, various attempts have been made (on religious or antipermissive grounds) to tighten the Act. Campaigners argue for the rights of the unborn child.

US legislation

Between 1967 and early 1973 a dozen states in the USA adopted abortion laws permitting abortion when performed by a licensed physician who judged that there was a substantial risk that continuance of pregnancy would gravely impair the physical or mental health of the mother, that the child would be born with serious defects, or when pregnancy resulted from rape or incest.

Roe v. Wade

The right to abortion was more firmly established in 1973, when the Supreme Court ruled (in *Roe v. Wade*) that the constitutional right to privacy (Fourteenth Amendment to the Constitution) gave the full right to abortion during the first three months of pregnancy. During the second trimester, abortion would be legal if required for maternal health. Once the fetus became viable (the beginning of the third trimester), it was lawful to prohibit abortion, depending on exceptions relating to the protection of the woman's life or health. *Roe v. Wade* thus invalidated the laws restricting abortion in almost every state. Anti-abortion pressure groups continue to campaign against the judgement.

against God's law?

Nowadays, opposition to abortion in Western societies comes essentially from Christian groups. Scriptural Protestants tend to see abortion as a sin, but as a matter for the individual conscience.

Roman Catholic view

The Roman Catholic Church has a long tradition of condemnation of abortion. Between the time of Pope Innocent III (1161-1216) and Sixtus V (1521-1590), decretals were issued prohibiting abortion, with excommunication as the penalty. In 1869, Pius IX (1792-1878) reaffirmed Vatican opposition to all abortion, even on therapeutic grounds (for example, when the mother's life was gravely endangered). The 1930 encyclical Casti Connubii condemned direct abortion, even when medical opinion believed that both mother and baby would die without it. The Second Vatican Council (1965) condemned it once again.

the social issues

Outside Catholicism, from the mid-20th century there has been increased moral and social acceptance of abortion in the West. It is widely justified, by the public and by ethicists, to protect the life or health of the mother; to remedy injuries due to incest or rape; and to prevent defective babies. Feminists have supported it to promote a woman's right to control her own reproductive capacity and her body, but difficulties remain.

the beginning of life

One major problem is the question of precisely when human life truly begins. It is a judgement that must be made as much on philosophical and human as on biological grounds. It is difficult to decide whether, or how far, or from what point, a fetus has all the rights and values of every other human being, or whether it should be viewed principally as a part of the mother.

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abrasion

in earth science, type of erosion in which rock fragments scrape and grind away a surface. It is also known as corrasion. The rock fragments may be carried by rivers, wind, ice, or the sea. Striations, or grooves, on rock surfaces are common abrasions, caused by the scratching of rock by debris carried in glacier ice.

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abrasive

(Latin 'to scratch away')

substance used for cutting and polishing or for removing small amounts of the surface of hard materials. There are two types: natural and artificial abrasives, and their hardness is measured using the Mohs scale. Natural abrasives include quartz, sandstone, pumice, diamond, emery, and corundum; artificial abrasives include rouge, whiting, and carborundum.

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abscess

collection of pus in solid tissue forming in response to infection. Its presence is signalled by pain and inflammation.

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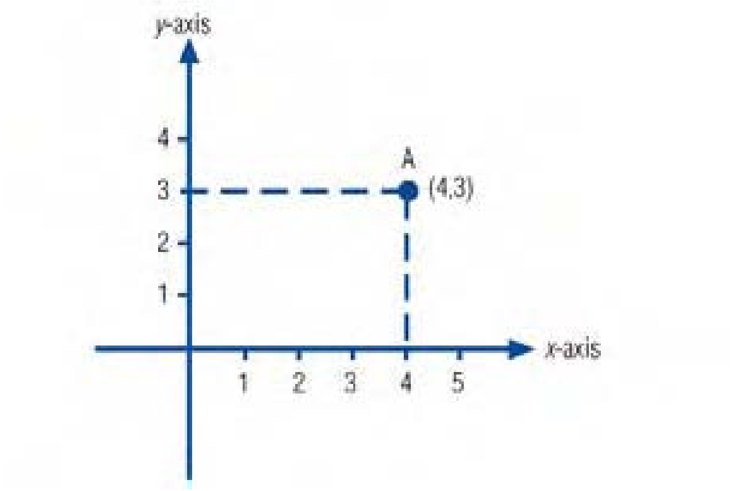
abscissa

in coordinate geometry, the *x*-coordinate of a point - that is, the horizontal distance of that point from the vertical or *y*-axis. For example, a point with the coordinates (4, 3) has an abscissa of 4. The *y*-coordinate of a point is known as the ordinate.

abscissa



(Image © Research Machines plc)

The horizontal distance from the y-axis in coordinate geometry. In this diagram the abscissa is 4.

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abscissin

or abscissic acid

plant hormone found in all higher plants. It is involved in the process of abscission and also inhibits stem elongation, germination of seeds, and the sprouting of buds.

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abscission

in botany, the controlled separation of part of a plant from the main plant body - most commonly, the falling of leaves or the dropping of fruit controlled by abscissin. In deciduous plants the leaves are shed before the winter or dry season, whereas evergreen plants drop their leaves continually throughout the year. Fruitdrop, the abscission of fruit while still immature, is a naturally occurring process.

Abscission occurs after the formation of an abscission zone at the point of separation. Within this, a thin layer of cells, the abscission layer, becomes weakened and breaks down through the conversion of pectic acid to pectin. Consequently the leaf, fruit, or other part can easily be dislodged by wind or rain. The process is thought to be controlled by the amount of auxin present. Fruitdrop is particularly common in fruit trees such as apples, and orchards are often sprayed with artificial auxin as a preventive measure.

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absolute

(of a value) in computing, real and unchanging. For example, an **absolute address** is a location in memory and an **absolute cell reference** is a single fixed cell in a spreadsheet display. The opposite of absolute is relative.

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absolute value

or modulus

in mathematics, the value, or magnitude, of a number irrespective of its sign. The absolute value of a number n is written $|n|$ (or sometimes as mod n), and is defined as the positive square root of n^2. For example, the numbers -5 and 5 have the same absolute value:

$|5| = |-5| = 5$

For a complex number, the absolute value is its distance to the origin when it is plotted on an Argand diagram, and can be calculated (without plotting) by applying Pythagoras' theorem. By definition, the absolute value of any complex number $a + ib$ (where a and b are real numbers and i is the square root of -1) is given by the expression:

$|a + ib| = \sqrt{(a^2 + b^2)}$

---

absolute zero

lowest temperature theoretically possible according to kinetic theory, zero kelvin (0 K), equivalent to -273.15°C/-459.67°F, at which molecules are in their lowest energy state. Although the third law of thermodynamics indicates the impossibility of reaching absolute zero, in practice temperatures of less than a billionth of a degree above absolute zero have been reached. Near absolute zero, the physical properties of some materials change substantially; for example, some metals lose their electrical resistance and become superconducting.

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absorption

in physics, taking up of matter or energy of one substance by another, such as a liquid by a solid (ink by blotting paper) or a gas by a liquid (ammonia by water). In physics, absorption is the phenomenon by which a substance retains the energy of radiation of particular wavelengths; for example, a piece of blue glass absorbs all visible light except the wavelengths in the blue part of the spectrum; it also refers to the partial loss of energy resulting from light and other electromagnetic waves passing through a medium. In nuclear physics, absorption is the capture by elements, such as boron, of neutrons produced by fission in a reactor.

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absorption lines

in astronomy, dark lines in the spectrum of a hot object due to the presence of absorbing material along the line of sight. Absorption lines are caused by atoms absorbing light from the source at sharply defined wavelengths. Numerous absorption lines in the spectrum of the Sun (Fraunhofer lines) allow astronomers to study the composition of the Sun's outer layers. Absorption lines in the spectra of stars give clues to the composition of interstellar gas and dust.

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absorption spectroscopy

or absorptiometry

in analytical chemistry, a technique for determining the identity or amount present of a chemical substance by measuring the amount of electromagnetic radiation the substance absorbs at specific wavelengths; see spectroscopy.

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abutilon

one of a group of 90 related species of tropical or semitropical ornamental plants. The Indian mallow or velvet leaf (*Abutilon theophrastus*) is one of the more common; it has bell-shaped yellow flowers and is the source of a jutelike fibre. Many of the species are pollinated by hummingbirds. (Genus *Abutilon*, family Malvaceae.)

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abyssal plain

broad, relatively flat expanse of sea floor lying 3-6 km/2-4 mi below sea level. Abyssal plains are found in all the major oceans, and they extend from bordering continental rises to mid-oceanic ridges. Abyssal plains are covered in a thick layer of sediment, and their flatness is punctuated by rugged low abyssal hills and high sea mounts.

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abyssal zone

dark ocean region 2,000-6,000 m/6,500-19,500 ft deep; temperature 4°C/39°F. Three-quarters of the area of the deep-ocean floor lies in the abyssal zone, which is too far from the surface for photosynthesis to take place. Some fish and crustaceans living there are blind or have their own light sources. The region above is the bathyal zone; the region below, the hadal zone.

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abzyme

in biotechnology, an artificially created antibody that can be used like an enzyme to accelerate reactions.

AC

in physics, abbreviation for alternating current.

acacia

any of a large group of shrubs and trees that includes the thorn trees of the African savannah and the gum arabic tree (*Acacia senegal*) of North Africa, and several North American species of the southwestern USA and Mexico. The hardy tree commonly known as acacia is the false acacia (*Robinia pseudacacia*, of the subfamily Papilionoideae). True acacias are found in warm regions of the world, particularly Australia. (Genus *Acacia*, family Leguminosae.)

A. dealbata is grown in the open air in some parts of France and the warmer European countries, and is remarkable for its clusters of fluffy, scented yellow flowers, sold by florists as mimosa. The leaves of the genus are normally bipinnate (leaflets on both sides of each stem and stems growing on both sides of a larger stem), and the flowers grow in a head.

acacia

(Image © Research Machines plc)

Thorn trees with Mount Kilimanjaro in the background, in Tanzania. Thorn trees, of the genus *Acacia*, are an important component of the plant life of the dry, subtropical African savannah.

Acacia (False)

Go to site

In-depth information about the hardy tree commonly known as acacia. There is a detailed description of the plant, its habitat, and its poisonous properties. It also includes detailed notes on the possible medicinal uses of the plant, ranging from food for cattle to sugar-making.

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acanthus

herbaceous plant with handsome lobed leaves. Twenty species are found in the Mediterranean region and Old World tropics, including bear's-breech (*Acanthus mollis*) whose leaves were used as a motif in classical architecture, especially on Corinthian columns. (Genus *Acanthus*, family Acanthaceae.)

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accelerated freeze drying

common method of food preservation, in which foodstuffs are quickly frozen and then subjected to reduced atmospheric pressure to cause the ice in them to sublimate (turn into water vapour). See food technology.

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acceleration

rate of change of the velocity of a moving body. It is usually measured in feet per second per second (ft s^{-2}) or meters per second per second (m s^{-2}). Because velocity is a vector quantity (possessing both magnitude and direction) a body travelling at constant speed may be said to be accelerating if its direction of motion changes. According to Newton's second law of motion, a body will accelerate only if it is acted upon by an unbalanced, or resultant, force. Acceleration due to gravity is the acceleration of a body falling freely under the influence of the Earth's gravitational field; it varies slightly at different latitudes and altitudes. The value adopted internationally for gravitational acceleration is 32.174 ft s^{-2}/9.806 ms^{-2}.

The average acceleration a of an object travelling in a straight line over a period of time t may be calculated using the formula: a = change of velocity/t or, where u is its initial velocity and v its final velocity: $a = (v - u)/t$. A negative answer shows that the object is slowing down (decelerating).

acceleration, secular

in astronomy, continuous and non-periodic change in orbital velocity of one body around another, or the axial rotation period of a body.

An example is the axial rotation of the Earth. This is gradually slowing down owing to the gravitational effects of the Moon and the resulting production of tides, which have a frictional effect on the Earth. However, the angular momentum of the Earth-Moon system is maintained, because the momentum lost by the Earth is passed to the Moon. This results in an increase in the Moon's orbital period and a consequential moving away from the Earth. The overall effect is that the Earth's axial rotation period is increasing by about 15 millionths of a second per year, and the Moon is receding from the Earth at about 4 cm/1.5 in per year.

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accelerator

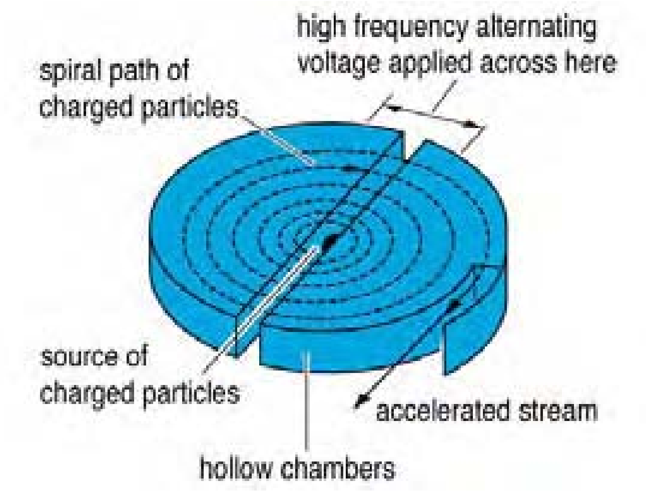
in physics, a device to bring charged particles (such as protons and electrons) up to high speeds and energies, at which they can be of use in industry, medicine, and pure physics. At low energies, accelerated particles can be used to produce the image on a television screen and (by means of a cathode-ray tube) generate X-rays, destroy tumour cells, or kill bacteria. When high-energy particles collide with other particles, the fragments formed reveal the nature of the fundamental forces.

The first accelerators used high voltages (produced by Van de Graaff generators) to generate a strong, unvarying electric field. Charged particles were accelerated as they passed through the electric field. However, because the voltage produced by a generator is limited, these accelerators were replaced by machines where the particles passed through regions of alternating electric fields, receiving a succession of small pushes to accelerate them. The first of these accelerators was the **linear accelerator** or **linac**. The linac consists of a line of metal tubes, called drift tubes, through which the particles travel. The particles are accelerated by electric fields in the gaps between the drift tubes.

Another way of making repeated use of an electric field is to bend the path of a particle into a circle so that it passes repeatedly through the same electric field. The first accelerator to use this idea was the **cyclotron** pioneered in the early 1930s by US physicist Ernest Lawrence. One of the world's most powerful accelerators is the 2 km/1.25 mi diameter machine at Fermilab near Batavia, Illinois, USA. This machine, the Tevatron, accelerates protons and antiprotons and then collides them at energies up to a thousand billion electron volts (or 1 TeV, hence the name of the machine). The largest accelerator until recently was the Large Electron Positron Collider at CERN near Geneva, operational 1989-2000, which had a circumference of 27 km/16.8 mi around which electrons and positrons were accelerated before being allowed to collide. The same tunnel will be occupied by the Large Hadron Collider (LHC), due to begin operation in 2007. It will accelerate protons or ions and allow them to collide with each other.

The world's longest linac is also a colliding beam machine: the Stanford Linear Collider, in California, in which electrons and positrons are accelerated along a straight track, 3.2 km/2 mi long, and then steered to a head-on collision with other particles, such as protons and neutrons. Such experiments have been instrumental in revealing that protons and neutrons are made up of smaller elementary particles called quarks.

accelerator



(Image © Research Machines plc)

The cyclotron, an early accelerator, consisted of two D-shaped hollow chambers enclosed in a vacuum. An alternating voltage was applied across the gap between the hollows. Charged particles spiralled outward from the centre, picking up energy and accelerating each time they passed through the gap.

Accelerator Physics Group

Go to site

Virtual library dedicated to accelerator physics, with pages on design and components, as well as direct links to laboratories throughout the world.

accelerometer

apparatus, either mechanical or electromechanical, for measuring acceleration or deceleration – that is, the rate of increase or decrease in the velocity of a moving object.

The mechanical types have a spring-supported mass with a damper system, with indication of acceleration on a scale on which a light beam is reflected from a mirror on the mass. The electromechanical types use (1) a slide wire, (2) a strain gauge, (3) variable inductance, or (4) a piezoelectric or similar device that produces electrically measurable effects of acceleration.

Accelerometers are used to measure the efficiency of the braking systems on road and rail vehicles; those used in aircraft and spacecraft can determine accelerations in several directions simultaneously. There are also accelerometers for detecting vibrations in machinery.

access time

in computing, the time taken by a computer, after an instruction has been given, to read from or write to memory.

acclimation

or acclimatization

physiological changes induced in an organism by exposure to new environmental conditions. When humans move to higher altitudes, for example, the number of red blood cells rises to increase the oxygen-carrying capacity of the blood in order to compensate for the lower levels of oxygen in the air.

In evolutionary terms, the ability to acclimate is an important adaptation as it allows the organism to cope with the environmental changes occurring during its lifetime.

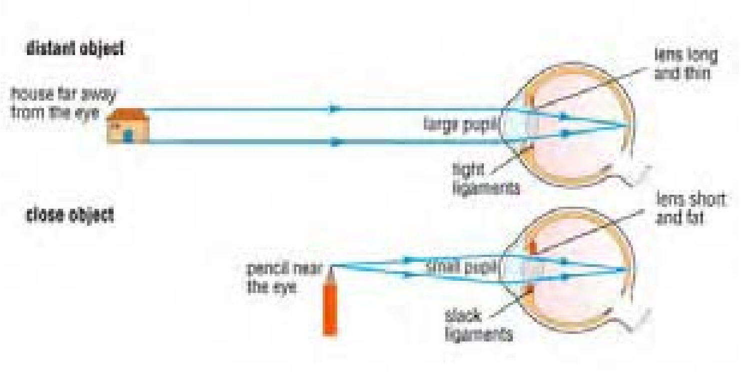
accommodation

in biology, the ability of the eye to focus on near or far objects by changing the shape of the lens.

For an object to be viewed clearly its image must be precisely focused on the retina, the light-sensitive layer of cells at the rear of the eye. Close objects can be seen when the lens takes up a more spherical shape, far objects when the lens is flattened. These changes in shape are caused by the movement of ligaments attached to a ring of ciliary muscles lying beneath the iris.

From about the age of 40, the lens in the human eye becomes less flexible, causing the defect of vision known as **presbyopia** or lack of accommodation. People with this defect need different spectacles for reading and distance vision.

accommodation



(Image © Research Machines plc)

The mechanism by which the shape of the lens in the eye is changed so that clear images of objects, whether distant or near, can be focused on the retina.

accretion

in astrophysics, process by which an object gathers up surrounding material by gravitational attraction, thus simultaneously increasing in mass and releasing gravitational energy. Accretion onto compact objects, such as white dwarfs, neutron stars, and black holes, can release large amounts of gravitational energy and is believed to be the power source for active galaxies. Accreted material falling towards a star may form a swirling disc of material known as an accretion disc that can be a source of X-rays. Earth, and other planetary bodies in the Solar System, are thought to have formed by accretion of nebular material and planetesimals.

accretion disc

in astronomy, flattened ring of gas and dust orbiting an object in space, such as a star or black hole. The orbiting material is accreted (gathered in) from a neighbouring object such as another star. Giant accretion discs are thought to exist at the centres of some galaxies and quasars.

If the central object of the accretion disc has a strong gravitational field, as with a neutron star or a black hole, gas falling onto the accretion disc releases energy, which heats the gas to extreme temperatures and emits short-wavelength radiation, notably X-rays.

accumulator

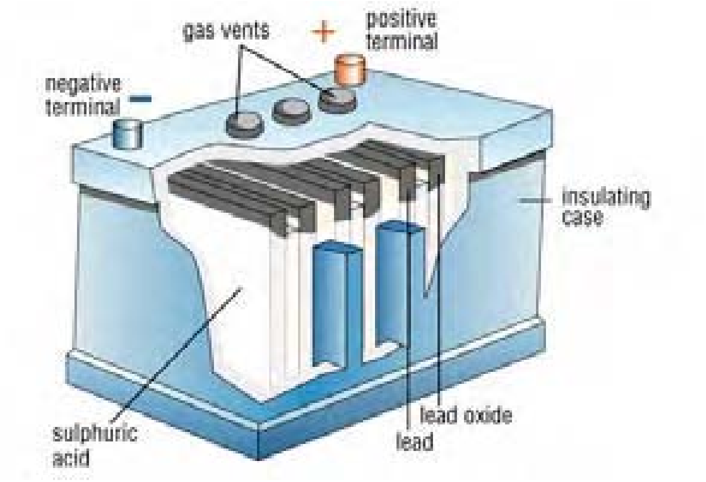
in computing, a special register, or memory location, in the arithmetic and logic unit of the computer processor. It is used to hold the result of a calculation temporarily or to store data that is being transferred.

accumulator

in electricity, a storage battery - that is, a group of rechargeable secondary cells. A familiar example is the lead-acid car battery.

An ordinary 12-volt car battery consists of six lead-acid cells which are continually recharged when the motor is running by the car's alternator or dynamo. It has electrodes of lead and lead oxide in an electrolyte of sulphuric acid. Another common type of accumulator is the 'nife' or NiFe cell, which has electrodes of nickel and iron in a potassium hydroxide electrolyte.

accumulator



(Image © Research Machines plc)

The lead-acid car battery is a typical example of an accumulator. The battery has a set of grids immersed in a sulphuric acid electrolyte. One set of grids is made of lead (Pb) and acts as the anode and the other set made of lead oxide (PbO_2) acts as the cathode.

accuracy

in mathematics, a measure of the precision of a number. The degree of accuracy depends on how many figures or decimal places are used in rounding off the number. For example, the result of a calculation or measurement (such as 13.429314) might be rounded off to three decimal places (13.429), to two decimal places (13.43), to one decimal place (13.4), or to the nearest whole number (13). The first answer is more accurate than the second, the second more accurate than the third, and so on.

Accuracy also refers to a range of errors. For example, an accuracy of ± 5% means that a value may lie between 95% and 105% of a given answer.

acer

group of over 115 related species of trees and shrubs of the temperate regions of the northern hemisphere, many of them popular garden specimens. They include sycamore and maple. Some species have pinnate leaves (leaflets either side of a stem), including the box elder (*Acer negundo*) of North America. (Genus *Acer*.)

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acesulfame-K

non-carbohydrate sweetener that is up to 300 times as sweet as sugar. It is used in soft drinks and desserts.

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acetaldehyde

common name for ethanal.

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acetate

common name for ethanoate.

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acetic acid

common name for ethanoic acid.

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acetone

common name for propanone.

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acetylcholine

ACh

chemical that serves as a neurotransmitter, communicating nerve impulses between the cells of the nervous system. It is largely associated with the transmission of impulses across the synapse (junction) between nerve and muscle cells, causing the muscles to contract.

ACh is produced in the synaptic knob (a swelling at the end of a nerve cell) and stored in vesicles until a nerve impulse triggers its discharge across the synapse. When the ACh reaches the membrane of the receiving cell it binds with a specific site and brings about depolarization - a reversal of the electric charge on either side of the membrane - causing a fresh impulse (in nerve cells) or a contraction (in muscle cells). Its action is shortlived because it is quickly destroyed by the enzyme cholinesterase.

Anticholinergic drugs have a number of uses in medicine to block the action of ACh, thereby disrupting the passage of nerve impulses and relaxing certain muscles, for example in premedication before surgery.

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acetylene

common name for ethyne.

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acetylsalicylic acid

chemical name for the painkilling drug aspirin.

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achene

dry, one-seeded fruit that develops from a single ovary and does not split open to disperse the seed. Achenes commonly occur in groups - for example, the fruiting heads of buttercup *Ranunculus* and clematis. The outer surface may be smooth, spiny, ribbed, or tuberculate, depending on the species.

Achernar

or Alpha Eridani

brightest star in the constellation Eridanus, and the ninth-brightest star in the sky. It is a hot, luminous, blue star with a true luminosity 250 times that of the Sun. It is 144 light years away from the Sun.

Achilles tendon

tendon at the back of the ankle attaching the calf muscles to the heel bone. It is one of the largest tendons in the human body, and can resist great tensional strain, but is sometimes ruptured by contraction of the muscles in sudden extension of the foot.

Ancient surgeons regarded wounds in this tendon as fatal, probably because of the Greek legend of Achilles, which relates how the mother of the hero Achilles dipped him when an infant into the River Styx, so that he became invulnerable except for the heel by which she held him.

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achromatic lens

combination of lenses made from materials of different refractive indexes, constructed in such a way as to minimize chromatic aberration (which in a single lens causes coloured fringes around images because the lens diffracts the different wavelengths in white light to slightly different extents).

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acid

in chemistry, compound that releases hydrogen ions (H^+ or protons) in the presence of an ionizing solvent (usually water). Acids react with bases to form salts, and they act as solvents. Strong acids are corrosive; dilute acids have a sour or sharp taste, although in some organic acids this may be partially masked by other flavour characteristics. The strength of an acid is measured by its hydrogen-ion concentration, indicated by the pH value. All acids have a pH below 7.0.

Acids can be classified as monobasic, dibasic, tribasic, and so forth, according to their basicity (the number of hydrogen atoms available to react with a base) and degree of ionization (how many of the available hydrogen atoms dissociate in water). Dilute sulphuric acid is classified as a strong (highly ionized), dibasic acid.

Inorganic acids include boric, carbonic, hydrochloric, hydrofluoric, nitric, phosphoric, and sulphuric. Organic acids include ethanoic (acetic), benzoic, citric, methanoic (formic), lactic, oxalic, and salicylic, as well as complex substances such as nucleic acids and amino acids.

Sulphuric, nitric, and hydrochloric acids are sometimes referred to as the mineral acids. Most naturally occurring acids are found as organic compounds, such as the fatty acids $R—COOH$ and sulphonic acids $R—SO_3H$, where R is an organic group.

acid

To remember how to mix acid and water safely:

Add acid to watuh, just as you oughta!

Acids

Go to site

Offers a clear explanation of the nature and functions of acids. A general definition is followed by more detailed descriptions of some common acids.

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acid rain

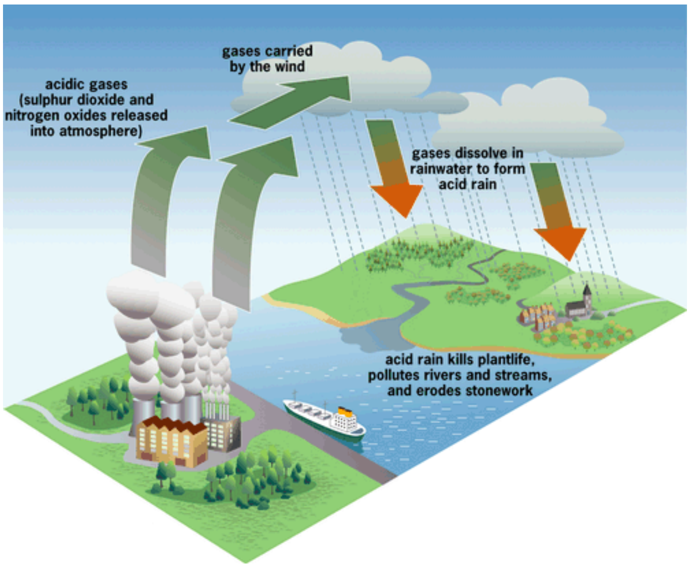
acidic precipitation thought to be caused mainly by the release into the atmosphere of sulphur dioxide (SO_2) and oxides of nitrogen (NO_x), which dissolve in pure rainwater making it acidic. Sulphur dioxide is formed by the burning of fossil fuels, such as coal, that contain high quantities of sulphur; nitrogen oxides are produced by various industrial activities and are present in car exhaust fumes.

Acidity is measured on the pH scale, where the value of 0 represents liquids and solids that are completely acidic and 14 represents those that are highly alkaline. Distilled water is neutral and has a pH of 7. Normal rain has a value of 5.6. It is slightly acidic due to the presence of carbonic acid formed by the mixture of CO_2 and rainwater. Acid rain has values of 5.6 or less on the pH scale.

Acid deposition occurs not only as **wet precipitation** (mist, snow, or rain), but also comes out of the atmosphere as dry particles (**dry deposition**) or is absorbed directly by lakes, plants, and masonry as gases. Acidic gases can travel over 500 km/310 mi a day, so acid rain can be considered an example of transboundary (international) pollution.

Acid rain is linked with damage to and the death of forests and lake organisms in Scandinavia, Europe, and eastern North America. It is increasingly common in countries such as China and India that are industrializing rapidly. It also results in damage to buildings and statues.

acid rain


gases carried by the wind
acidic gases (sulphur dioxide and nitrogen oxides released into atmosphere)
gases dissolve in rainwater to form acid rain
acid rain kills plantlife, pollutes rivers and streams, and erodes stonework

(Image © Research Machines plc)

How acid rain is formed in industrial areas and distributed over long distances, where it can kill trees and damage buildings and statues.

Your Environment

Go to site

Britain's Environment Agency's page on the environment, with access to data collected and studied by the Agency on the topics of 'Bathing water quality', 'River habitats', and 'River gauging stations'. There is also more general information on the current 'stresses and strains' on the environment.

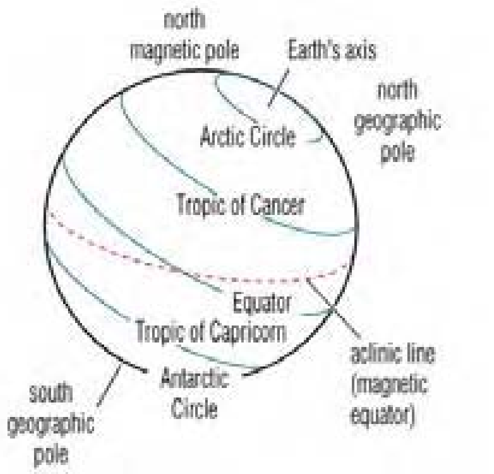
acid salt

chemical compound formed by the partial neutralization of a dibasic or tribasic acid (one that contains two or three replaceable hydrogen atoms). Although a salt, it still contains replaceable hydrogen, so it may undergo the typical reactions of an acid. Examples are sodium hydrogen sulphate ($NaHSO_4$) and acid phosphates.

aclinic line

magnetic equator, an imaginary line near the Equator, where a compass needle balances horizontally, the attraction of the north and south magnetic poles being equal.

aclinic line


north magnetic pole
Earth's axis
north geographic pole
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
aclinic line (magnetic equator)
south geographic pole
Antarctic Circle

(Image © Research Machines plc)

The magnetic equator, or the line at which the attraction of both magnetic poles is equal. Along the aclinic line, a compass needle swinging vertically will settle in a horizontal position.

acne

skin eruption, mainly occurring among adolescents and young adults, caused by inflammation of the sebaceous glands, which secrete an oily substance (sebum), the natural lubricant of the skin. Sometimes the openings of the glands become blocked, causing the formation of pus-filled swellings. Teenage acne is seen mainly on the face, back, and chest.

There are other, less common types of acne, sometimes caused by contact with irritant chemicals (chloracne).

Acne Vulgaris (Pimples)

Go to site

Practical advice for acne sufferers. The causes of the condition and its diagnosis are explained with the aid of pictures and there are tips on washing the face and treating acne.

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aconite

or monkshood or wolfsbane

herbaceous plant belonging to the buttercup family, with hooded blue-mauve flowers, native to Europe and Asia. It produces aconitine, a poison with pain-killing and sleep-inducing properties. (*Aconitum napellus*, family Ranunculaceae.)

There are about 100 species throughout the northern temperate regions, all hardy herbaceous plants containing poison. Summer aconite (*Aconitum uncinatum*) is a common North American flower. Winter aconite (*Eranthis hyemalis*) belongs to another genus of the buttercup family; it has yellow buttercuplike flowers with six petals which appear in February and March; the leaves follow later.

Aconitum Carmichaelii

Go to site

Selection of photographs of this herbaceous plant from the University of Washington. It includes close-up images of the flower and bud, and one showing the structure of the plant.

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acorn

fruit of the oak tree, a nut growing in a shallow cup.

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acouchi

any of several small South American rodents, genus *Myoprocta*. They have white-tipped tails, and are smaller relatives of the agouti.

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acoustics

in general, the experimental and theoretical science of sound and its transmission; in particular, that branch of the science that has to do with the phenomena of sound in a particular space such as a room or theatre. In architecture, the sound-reflecting character of an internal space.

Acoustic engineering is concerned with the technical control of sound, and involves architecture and construction, studying control of vibration, soundproofing, and the elimination of noise. It also includes all forms of sound recording and reinforcement, the hearing and perception of sounds, and hearing aids.

Acoustic Illusions

Go to site

Dedicated to the Shepard effect: a scale that gives the listener the impression of an endlessly rising melody, when in fact the pitch of the tones does not rise. Sound files illustrate this, and accompany an account of an experiment in which the Shepard effect was applied to J S Bach's *Das Musikalische Opfer/ Musical Offering*.

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acquired character

feature of the body that develops during the lifetime of an individual, usually as a result of repeated use or disuse, such as the enlarged muscles of a weightlifter.

French naturalist Jean Baptiste Lamarck's theory of evolution assumed that acquired characters were passed from parent to offspring. Modern evolutionary theory does not recognize the inheritance of acquired characters because there is no reliable scientific evidence that it occurs, and because no mechanism is known whereby bodily changes can influence the genetic material. The belief that this does not occur is known as central dogma.

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acquired immune deficiency syndrome

full name for the disease AIDS.

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acre

traditional English land measure equal to 4,840 square yards (4,047 sq m/0.405 ha). Originally meaning a field, it was the area that a yoke of oxen could plough in a day.

As early as Edward I's reign, the acre was standardized by statute for official use, although local variations in Ireland, Scotland, and some English counties continued. It may be subdivided into 160 square rods (one square rod equalling 25.29 sq m/30.25 sq yd).

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acridine

$C_{13}H_9N$

heterocyclic organic compound that occurs in coal tar. It is crystalline, melting at 108°C/226.4°F. Acridine is extracted by dilute acids but can also be obtained synthetically. It is used to make dyes and drugs.

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acrophobia

phobia involving fear of heights.

Acrux

or Alpha Crucis

brightest star in the constellation of Crux, marking one of the four points of the Southern Cross, and the 13th-brightest star in the night sky. It is a double star comprising two blue-white stars, and is 360 light years away from the Sun. Together with nearby Gacrux, it points towards the south celestial pole.

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acrylic acid

common name for propenoic acid.

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actinide

any of a series of 15 radioactive metallic chemical elements with atomic numbers 89 (actinium) to 103 (lawrencium). Elements 89 to 95 occur in nature; the rest of the series are synthesized elements only. Actinides are grouped together because of their chemical similarities (for example, they are all bivalent), the properties differing only slightly with atomic number. The series is set out in a band in the periodic table of the elements, as are the lanthanides.

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actinium

chemical symbol Ac

(Greek aktis 'ray')

white, radioactive, metallic element, the first of the actinide series, atomic number 89, relative atomic mass 227; it is a weak emitter of high-energy alpha particles.

Actinium occurs with uranium and radium in pitchblende and other ores, and can be synthesized by bombarding radium with neutrons. The longest-lived isotope, Ac-227, has a half-life of 21.8 years (all the other isotopes have very short half-lives). Chemically, it is exclusively trivalent, resembling in its reactions the lanthanides and the other actinides. Actinium was discovered in 1899 by the French chemist André Debierne (1874-1949).

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action potential

in biology, a change in the potential difference (voltage) across the membrane of a nerve cell when an impulse passes along it. A change in potential (from about -60 to +45 millivolts) accompanies the passage of sodium and potassium ions across the membrane.

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activation energy

in chemistry, the minimum energy required in order to start a chemical reaction. Some elements and compounds will react together merely by bringing them into contact (spontaneous reaction). For others it is necessary to supply energy (heat, radiation, or electrical charge) in order to start the reaction, even if there is ultimately a net output of energy. This initial energy is the activation energy.

The point at which the reaction begins is known as the energy barrier. When the energy barrier is reached, the chemical bonds in the reactants are broken, enabling them to proceed from reactants to products.

In some reactions, such as the combustion of fuels, the activation energy required for the chemical reaction to take place is very small, resulting in a rapid reaction. Other chemical reactions, such as the rusting of iron (a type of oxidation) have a very large energy barrier and take place slowly.

A chemical equation only describes the **energy of reaction**; the activation energy is not shown. The total chemical energy involved can be represented in an **energy level diagram**; this also shows whether a reaction is exothermic (giving off energy) or endothermic (absorbing energy).

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active galaxy

in astronomy, type of galaxy that emits vast quantities of energy from a small region at its centre, the active galactic nucleus (AGN). Active galaxies are subdivided into radio galaxies, Seyfert galaxies, BL Lacertae objects, and quasars.

Active galaxies are thought to contain black holes with a mass 10^8 times that of the Sun, drawing stars and interstellar gas towards them in a process of accretion. The gravitational energy released by the in-falling material is the power source for the AGN. Some of the energy may appear as a pair of opposed jets emerging from the nucleus. The orientation of the jets to the line of sight and their interaction with surrounding material determines the type of active galaxy that is seen by observers. See also starburst galaxy.

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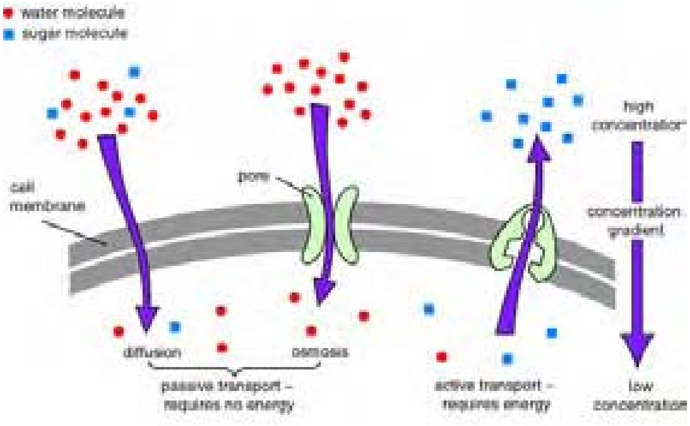
active transport

movement of molecules or ions across a cell membrane using energy provided by respiration. Examples of substances that can be actively transported across membranes are sodium ions and glucose.

Energy is needed because the movement occurs against a concentration gradient, with substances being moved from an area of low concentration to an area where there is a higher concentration. Active transport is therefore quite different from diffusion, which requires no input of energy. In diffusion the movement is in the opposite direction - from an area of high concentration to an area where the concentration is low. An example of diffusion is the movement of oxygen into the blood vessels of the lungs.

active transport



(Image © Research Machines plc)

Different types of transport across a cell membrane. Diffusion and osmosis are passive modes of transport, requiring no energy, moving from areas of high concentration to areas of low concentration. Active transport requires energy to transport molecules from low concentration to high concentration.

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acupuncture

in alternative medicine, a system of inserting long, thin metal needles into the body at predetermined points to relieve pain, as an anaesthetic in surgery, and to assist healing. The needles are rotated manually or electrically. The method, developed in ancient China and increasingly popular in the West, is thought to work by stimulating the brain's own painkillers, the endorphins.

Acupuncture is based on a theory of physiology that posits a network of life-energy pathways, or 'meridians', in the human body and some 800 'acupuncture points' where metal needles may be inserted to affect the energy flow for purposes of preventative or remedial therapy or to produce a local anaesthetic effect. Numerous studies and surveys have attested the efficacy of the method, which is widely conceded by orthodox practitioners despite the lack of an acceptable scientific explanation.

Acupuncture.com

Go to site

Thorough introduction to the alternative world of acupuncture with descriptions of the main notions and powers of herbology, yoga, Qi Gong, and Chinese nutrition. Consumers are given access to lists of practitioners and an extensive section on acupuncture research. Practitioners can browse through journal listings and the latest industry news and announcements.

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acute

in medicine, term used to describe a disease of sudden and severe onset which resolves quickly; for example, pneumonia and meningitis. In contrast, a **chronic** condition develops and remains over a long period.

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acute angle

angle between 0° and 90°; that is, an amount of turn that is less than a quarter of a circle.

Ada

high-level computer-programming language, developed and owned by the US Department of Defense, designed for use in situations in which a computer directly controls a process or machine, such as a military aircraft. The language took more than five years to specify, and became commercially available only in the late 1980s. It is named after English mathematician Ada Augusta Byron.

Adams, Ansel Easton (1902-1984)

US photographer. He is known for his printed images of dramatic landscapes and organic forms of the American West. Light and texture were important elements in his photographs. He was associated with the zone system of exposure estimation and was a founder member of the 'f/64' group which advocated precise definition.

In 1916 Adams made his first trip to the Yosemite National Park, California; the Yosemite and the High Sierras remained a major focus of his work throughout his life. Aiming to establish photography as a fine art, he founded the first museum collection of photography, at New York City's Museum of Modern Art 1937.

Adams, Ansel

Go to site

Introduction to the famous US photographer, including images, essays, and biographical information. The site also includes a gallery of his work and a virtual exhibition.

Adams, John Couch (1819-1892)

English astronomer. He mathematically deduced the existence of the planet Neptune in 1845 from the effects of its gravitational pull on the motion of Uranus, although it was not found until 1846 by J G Galle. Adams also studied the Moon's motion, the Leonid meteors, and terrestrial magnetism.

Adams, John Couch

Go to site

Biography and portrait of the famous 19th-century English astronomer. Details of Adam's work leading to the discovery of Neptune and other work on orbits and gravitation are also available at this site. It also features reference sources in the form of books and journals that contain Adams's work and biographical details.

Adamson, Robert

Scottish photographer. He collaborated with fellow Scottish photographer David Octavius Hill. See Hill and Adamson.

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adaptation

(Latin adaptare 'to fit to')

in biology, any feature in the structure or function of an organism that allows it to survive and reproduce more effectively in its environment. Much adaptation is inherited and is the result of many thousands of years of evolution. It is thought to occur as a result of random variation in the genetic make-up of organisms coupled with natural selection. Species become extinct when they are no longer adapted to their environment.

Adaptations to cope with changing seasons can be quite different from one organism to another. Some plants die back to survive the winter and have specially protected structures such as tight buds on a twig or a bulb underground. These structures may store food so that growth can start rapidly in spring. A carrot, for example, stores sugars for this reason. Some animals, such as swallows, may migrate, while other animals, such as the dormouse, may hibernate, allowing the body temperature and heart rate to drop in the winter.

Adaptations also occur as a result of an animal evolving into an efficient predator. A predator may have forward facing eyes, acute vision and sense of smell, and have claws, talons, or a beak for killing. The prey also adapt as a result of evolution. Prey may have eyes on the side of their heads for a wide field of view, acute hearing and sense of smell, be easily startled, be nocturnal, and be camouflaged.

In evolution, adaptation is the result of natural selection. Inherited variation usually occurs in a species. If the environment changes in some way, such as the winters becoming more severe, those individuals possessing genes that allow them to survive and reproduce more successfully pass their genes to their offspring more than those that do not. Some genes therefore become more common in the species, leading to an evolutionary change that enables the species to be better adapted to the changed environment.

Desert Plant Survival

Go to site

Attractive and readable page on the mechanisms plants use to survive in the hostile environment of the desert. Part of a larger site on desert survival, this page describes the main features of the xerophytes (plants, such as cacti, that have altered their physical structure for the sake of survival) and the phreatophytes, which adapt to their arid habitat by growing roots long enough to reach the water table.

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adaptive radiation

in evolution, the formation of several species, with adaptations to different ways of life, from a single ancestral type. Adaptive radiation is likely to occur whenever members of a species migrate to a new habitat with unoccupied ecological niches. It is thought that the lack of competition in such niches allows sections of the migrant population to develop new adaptations, and eventually to become new species.

The colonization of newly formed volcanic islands has led to the development of many unique species. The 13 species of Darwin's finch on the Galapagos Islands, for example, are probably descended from a single species from the South American mainland. The parent stock evolved into different species that now occupy a range of diverse niches, while on the mainland comparable niches are filled by other groups of birds.

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addax

light-coloured antelope*Addax nasomaculatus* of the family Bovidae. It lives in North Africa around the Sahara Desert where it exists without drinking on scanty vegetation. It is about 1.1 m/3.5 ft tall at the shoulder, and both sexes have spirally twisted horns. Its hooves are broad, enabling it to move easily on soft sand.

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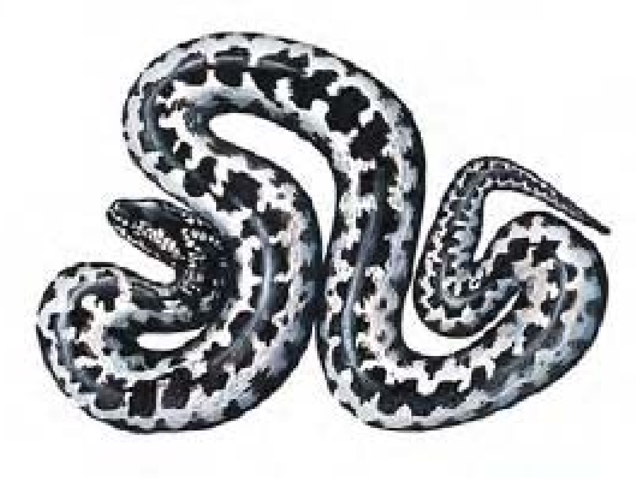
adder

(Anglo-Saxon naedre 'serpent')

European venomous snake, the common viper*Vipera berus*. Growing on average to about 60 cm/24 in in length, it has a thick body, a triangular head, with a characteristic V-shaped mark and, often, zigzag markings along the back. It feeds on small mammals and lizards. The puff adder *Bitis arietans* is a large, yellowish, thick-bodied viper up to 1.6 m/5 ft long, living in Africa and Arabia.

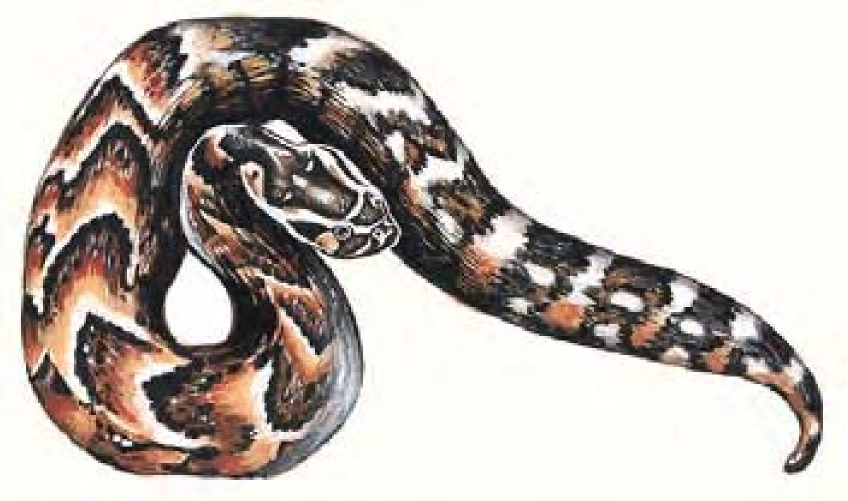
adder



(Image © Research Machines plc)

The common adder, or viper, is widely distributed in Europe as far east as Siberia. It is a short, sturdy snake that lives on the ground. Being slow-moving, adders do not chase prey, but wait in a concealed position to ambush lizards, mice, voles, shrews, and frogs.

adder



(Image © Research Machines plc)

The puff adder, from Africa and western Arabia, grows up to 1.6 m/5 ft long. Puff adders often bask in the sun during the day and, if disturbed, make a loud hissing or puffing sound, hence their name.

---

addiction

state of dependence caused by frequent and regular use of drugs, alcohol, or other substances. It is characterized by uncontrolled craving, tolerance, and symptoms of withdrawal when access is denied. Habitual use produces changes in body chemistry and treatment must be geared to a gradual reduction in dosage.

The meaning of 'addiction' is complicated and depends partly on the drug to which is being referred. Typical addictive drugs are alcohol, nicotine (in cigarette smoke), cocaine (including crack), heroin, amphetamines, and barbiturates.

It is thought that there are three stages to an addiction. In the first stage the dose of the drug has to be continually increased in order to get the same effect. This is called tolerance. The second stage is when the person is dependent on the drug and feels depressed or ill if they do not take it. In the third stage, the person has a compulsion to seek out the drug and this drug-seeking becomes a dominant part of their lives.

'Britain's New Strategy for Tackling Drugs Misuse'

Go to site

Part of a collection of articles maintained by the *British Medical Journal*, this page features the full text of a 9 May 1998 editorial in praise of the UK government's new national drug strategy which is 'more seriously committed to evidence than to rhetoric'. In addition to the editorial, you will find a list of related articles from the extensive PubMed collection. You can also search the collections under which this article appears, search other articles written by the authors of this article, and submit or read responses to this article. There is a list of references at the bottom of the article.

Closing in on Addiction

Go to site

Part of a larger site maintained by *Scientific American*, this page includes facts and figures on drug and alcohol addiction, information about the effects of drugs on the brain, new discoveries related to abuse and addiction, and two special sections on new methods for treating smoking and alcohol addicts. The text includes hypertext links to further information, and there is also a list of related links at the bottom of the page.

Addison's disease

rare condition caused by destruction of the outer part of the adrenal glands, leading to reduced secretion of corticosteroid hormones; it is treated by replacement of these hormones. The condition, formerly fatal, is mostly caused by autoimmune disease or tuberculosis. Symptoms include weight loss, anaemia, weakness, low blood pressure, digestive upset, and brownish pigmentation of the skin.

Addison's disease is rare in children and in those over 60 years of age. It is commonest in the second and third decades. There is no cure, but patients can live normal lives when given regular treatment with adrenal hormones. It is named after Thomas Addison, the London physician who first described it 1849 and more fully 1855.

addition

in arithmetic, the operation of combining two numbers to form a sum; thus, 7 + 4 = 11. It is one of the four basic operations of arithmetic (the others are subtraction, multiplication, and division).

addition reaction

chemical reaction in which the atoms of an element or compound react with a double bond or triple bond in an organic compound by opening up one of the bonds and becoming attached to it, for example:

$CH_2{=}CH_2 + HCl \rightarrow CH_3CH_2Cl$

Another example is the addition of hydrogen atoms to unsaturated compounds in vegetable oils to produce margarine. Addition reactions are used to make polymers from alkenes.

adenoids

masses of lymphoid tissue, similar to tonsils, located in the upper part of the throat, behind the nose. They are part of a child's natural defences against the entry of germs but usually shrink and disappear by the age of ten.

Adenoids may swell and grow, particularly if infected, and block the breathing passages. If they become repeatedly infected, they may be removed surgically (**adenoidectomy**), usually along with the tonsils.

ADEOS

abbreviation for Advanced Earth-Observing Satellite.

ADH

abbreviation for antidiuretic hormone

in biology, part of the system maintaining a correct salt/water balance in vertebrates.

Its release is stimulated by the hypothalamus in the brain, which constantly receives information about salt concentration from receptors situated in the neck. In conditions of water shortage increased ADH secretion from the brain will cause more efficient conservation of water in the kidney, so that fluid is retained by the body. When an animal is able to take in plenty of water, decreased ADH secretion will cause the urine to become dilute and plentiful. The system allows the body to compensate for a varying fluid intake and maintain a correct balance.

adhesion

in medicine, the abnormal binding of two tissues as a result of inflammation or damage. The moving surfaces of joints or internal organs may merge together if they have been inflamed and tissue fluid has been present between the surfaces.

Adhesions sometimes occur after abdominal operations and may lead to colicky pains and intestinal obstruction.

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adhesive

substance that sticks two surfaces together. Natural adhesives (glues) include gelatin in its crude industrial form (made from bones, hide fragments, and fish offal) and vegetable gums. Synthetic adhesives include thermoplastic and thermosetting resins, which are often stronger than the substances they join; mixtures of epoxy resin and hardener that set by chemical reaction; and elastomeric (stretching) adhesives for flexible joints. Superglues are fast-setting adhesives used in very small quantities.

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adiabatic

in biology and physics, describing a process that occurs without loss or gain of heat, especially the expansion or contraction of a gas in which a change takes place in the pressure or volume, although no heat is allowed to enter or leave. Adiabatic processes can be both non-reversible and approximately reversible.

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adipose tissue

type of connective tissue of vertebrates that serves as an energy reserve, and also pads some organs. It is commonly called fat tissue, and consists of large spherical cells filled with fat. In mammals, major layers are in the inner layer of skin and around the kidneys and heart.

Fatty acids are transported to and from it via the blood system. An excessive amount of adipose tissue is developed in the course of some disorders, especially obesity.

Adler, Alfred (1870-1937)

Austrian psychologist. He saw the 'will to power' as more influential in accounting for human behaviour than the sexual drive. A dispute over this theory led to the dissolution of his ten-year collaboration with psychiatry's founder Sigmund Freud.

The concepts of inferiority complex and overcompensation originated with Adler.

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admiral butterfly

any of several species of butterfly in the same family (Nymphalidae) as the tortoiseshells. The best-known is the **red admiral** (*Vanessa atalanta*), found worldwide in the northern hemisphere. It has black wings crossed by scarlet bands and marked with white and blue spots, and spanning 6 cm/2.5 in. It either hibernates, or migrates south each year from northern areas to subtropical zones. The spiny black caterpillar feeds on nettles.

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adolescence

in the human life cycle, the period between the beginning of puberty and adulthood.

ADP

abbreviation for adenosine diphosphate, the chemical product formed in cells when ATP breaks down to release energy.

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adrenal gland

or suprarenal gland

triangular endocrine gland situated on top of the kidney. The adrenals are soft and yellow, and consist of two parts: the cortex and medulla. The **cortex** (outer part) secretes various steroid hormones and other hormones that control salt and water metabolism and regulate the use of carbohydrates, proteins, and fats. The **medulla** (inner part) secretes the hormones adrenaline and noradrenaline which, during times of stress, cause the heart to beat faster and harder, increase blood flow to the heart and muscle cells, and dilate airways in the lungs, thereby delivering more oxygen to cells throughout the body and in general preparing the body for 'fight or flight'.

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adrenaline

or epinephrine

hormone secreted by the medulla of the adrenal glands. Adrenaline is synthesized from a closely related substance, noradrenaline, and the two hormones are released into the bloodstream in situations of fear or stress.

Adrenaline's action on the liver raises blood-sugar levels by stimulating glucose production and its action on adipose tissue raises blood fatty-acid levels; it also increases the heart rate, increases blood flow to muscles, reduces blood flow to the skin with the production of sweat, widens the smaller breathing tubes (bronchioles) in the lungs, and dilates the pupils of the eyes.

ADSL

abbreviation for asymmetric digital subscriber line, loop, or link

standard for transmitting data through existing copper telephone wires. ADSL was developed by US telephone companies as a way of competing with cable television companies in delivering both TV and telephone services. ADSL is one of several types of digital subscriber loops (DSLs) in use and the most popular connection for home internet access.

ADSL technology allows for rates of data transfer faster than standard modem rates. A downstream rate (rate for receiving data) of up to 9 mbps (megabytes per second) is possible, and an upstream rate (rate for sending data) of up to 640 kbps (kilobytes per second). A special ADSL modem is required to use the technology. Downstream rates of up to 24 mbps are possible with newer versions of the standard, such as ADSL2+, but these can only be achieved over short distances (as of 2006).

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adsorption

taking up of a gas or liquid at the surface of another substance, most commonly a solid (for example, activated charcoal adsorbs gases). It involves molecular attraction at the surface, and should be distinguished from absorption (in which a uniform solution results from a gas or liquid being incorporated into the bulk structure of a liquid or solid).

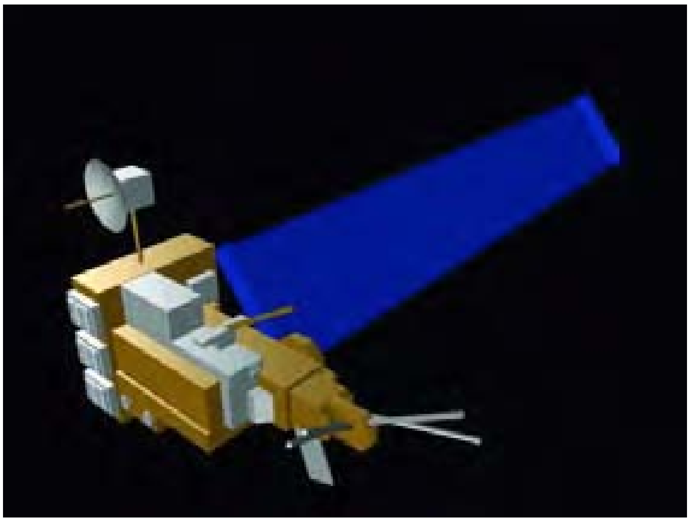
Advanced Earth-Observing Satellite

ADEOS

Japanese remote-sensing satellite launched on 17 August 1996. It gathered data on climate change, the environment, and land and ocean processes. On 30 June 1997, ADEOS suffered damage to its solar array that made it go out of control and led to its subsequent failure.

There were eight instruments on board ADEOS, including the ocean colour and temperature scanner (OCTS), the interferometric monitor for greenhouse gases (IMGG), and the total ozone mapping spectrometer (TOMS). A second satellite, ADEOS-II, was launched on 14 December 2002. Its two main instruments are the advanced microwave scanning radiometer (AMSR), to observe the Earth's water cycle, and the global imager (GLI), for precise observations of the land, oceans, and clouds.

Advanced Earth-Observing Satellite



(Image © Research Machines plc)

The Advanced Earth-Observing Satellite (ADEOS) is heavy for a satellite, with a mass of 3,500 kg/7,700 lb. It was launched from Tanegashima Space Centre into an orbit of 830 km/515 mi altitude in 1996.

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aerenchyma

plant tissue with numerous air-filled spaces between the cells. It occurs in the stems and roots of many aquatic plants where it aids buoyancy and facilitates transport of oxygen around the plant.

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aerial

or antenna

in radio and television broadcasting, a conducting device that radiates or receives electromagnetic waves. The design of an aerial depends principally on the wavelength of the signal. Long waves (hundreds of metres in wavelength) may employ long wire aerials; short waves (several centimetres in wavelength) may employ rods and dipoles; microwaves may also use dipoles – often with reflectors arranged like a toast rack – or highly directional parabolic dish aerials. Because microwaves travel in straight lines, requiring line-of-sight communication, microwave aerials are usually located at the tops of tall masts or towers.

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aerial oxidation

in chemistry, a reaction in which air is used to oxidize another substance, as in the contact process for the manufacture of sulphuric acid:

$2SO_2 + O_2 \leftrightarrow 2SO_3$

and in the souring of wine, where alcohol (ethanol) is oxidized by atmospheric oxygen to produce vinegar (ethanoic, or acetic, acid).

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aerobic

in biology, describing those organisms that require oxygen in order to survive. Aerobic organisms include all plants and animals and many micro-organisms. They use oxygen (usually dissolved in water) to release the energy contained in food molecules such as glucose in a process called aerobic respiration. Oxygen is used to break down carbohydrates into carbon dioxide and water, releasing energy, which is used to drive many processes within the cells.

Aerobic reactions occur inside every cell and lead to the formation of energy-rich ATP, which is used by the cell for driving its metabolic processes.

Most aerobic organisms die in the absence of oxygen, but certain organisms and cells, such as those found in muscle tissue, can function for short periods anaerobically (without oxygen). Some micro-organisms – certain bacteria, yeasts, and internal parasites – can live without oxygen and these are said to be anaerobic.

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aerobic respiration

in plant and animal cells, a complex process of chemical reactions in which oxygen is used to break glucose into carbon dioxide and water. Energy is released in this process. The starting and finishing points of this process would be the same if glucose was burned. During burning the energy that is released is all in the form of heat. In aerobic respiration, however, the energy is released in a controlled way and less is released as heat. Most of the released energy is used to drive various processes in the cell, such as growth or movement.

If insufficient oxygen reaches human muscles in severe exercise, such as a sprint, the muscles can carry on respiring using anaerobic respiration for a short time.

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aerodynamics

branch of fluid physics that studies the forces exerted by air or other gases in motion. Examples include the airflow around bodies moving at speed through the atmosphere (such as land vehicles, bullets, rockets, and aircraft), the behaviour of gas in engines and furnaces, air conditioning of buildings, the deposition of snow, the operation of air-cushion vehicles (hovercraft), wind loads on buildings and bridges, bird and insect flight, musical wind instruments, and meteorology. For maximum efficiency, the aim is usually to design the shape of an object to produce a streamlined flow, with a minimum of turbulence in the moving air. The behaviour of aerosols or the pollution of the atmosphere by foreign particles are other aspects of aerodynamics.

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aerogel

light, transparent, highly porous material composed of more than 90% air. Such materials are formed from silica, metal oxides, and organic chemicals, and are produced by drying gels – networks of linked molecules suspended in a liquid – so that air fills the spaces previously occupied by the liquid. They are excellent heat insulators and have unusual optical, electrical, and acoustic properties.

Aerogels were first produced by US scientist Samuel Kristler in the early 1930s by drying silica gels at high temperatures and pressures.

aeronautics

science of travel through the Earth's atmosphere, including aerodynamics, aircraft structures, jet and rocket propulsion, and aerial navigation. It is distinguished from astronautics, which is the science of travel through space.

In **subsonic aeronautics** (below the speed of sound), aerodynamic forces increase at the rate of the square of the speed.

Trans-sonic aeronautics covers the speed range from just below to just above the speed of sound and is crucial to aircraft design. Ordinary sound waves move at about 1,225 kph/760 mph at sea level, and air in front of an aircraft moving slower than this is 'warned' by the waves so that it can move aside. However, as the flying speed approaches that of the sound waves, the warning is too late for the air to escape, and the aircraft pushes the air aside, creating shock waves, which absorb much power and create design problems. On the ground the shock waves give rise to a sonic boom. It was once thought that the speed of sound was a speed limit to aircraft, and the term sound barrier came into use.

Supersonic aeronautics is concerned with speeds above that of sound and in one sense may be considered a much older study than aeronautics itself, since the study of the flight of bullets (ballistics) was undertaken soon after the introduction of firearms.
Hypersonics is the study of airflows and forces at speeds above five times that of sound (Mach 5); for example, for guided missiles, space rockets, and advanced concepts such as HOTOL (horizontal takeoff and landing). For all flight speeds, streamlining is necessary to reduce the effects of air resistance.

Astronavigation (navigation by reference to the stars) is used in aircraft as well as in ships and is a part of aeronautics.

American Institute of Aeronautics and Astronautics

Go to site

Access to the *AIAA Bulletin*. This site also includes details of the Institute's research departments, recent conferences, technical activities, and project updates. If the extensive front page doesn't have what you need, the site is also fully searchable.

Beginner's Guide to Aeronautics

Go to site

NASA's introduction to aeronautics. Tutorials, practical experiments (build your own wind tunnel!), and information about aerodynamics, rockets, and space flight. An index of aerodynamics makes browsing the documents very easy.

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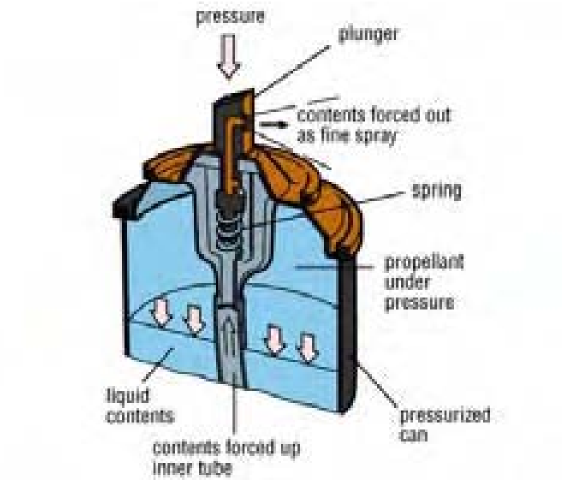
aerosol

particles of liquid or solid suspended in a gas. Fog is a common natural example. Aerosol cans contain material packed under pressure with a device for releasing it as a fine spray. Most aerosols used chlorofluorocarbons (CFCs) as propellants until these were found to cause destruction of the ozone layer in the stratosphere.

The international community agreed to phase out the use of CFCs. However, the early so-called 'ozone-friendly' replacement aerosols were found to also use ozone-depleting chemicals, although they are not as destructive as CFCs. Some of the products sprayed, such as pesticides, can be directly toxic to humans.

aerosol


pressure
plunger
contents forced out as fine spray
spring
propellant under pressure
liquid contents
pressurized can
contents forced up inner tube

(Image © Research Machines plc)

The aerosol can produces a fine spray of liquid particles, called an aerosol. When the top button is pressed, a valve is opened, allowing the pressurized propellant in the can to force out a spray of the liquid contents.

As the liquid sprays from the can, the small amount of propellant dissolved in the liquid vaporizes, producing a fine spray of small droplets.

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aestivation

in zoology, a state of inactivity and reduced metabolic activity, similar to hibernation, that occurs during the dry season in species such as lungfish and snails. In botany, the term is used to describe the way in which flower petals and sepals are folded in the buds. It is an important feature in plant classification.

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affinity

in chemistry, the force of attraction (see bond) between atoms that helps to keep them in combination in a molecule. The term is also applied to attraction between molecules, such as those of biochemical significance (for example, between enzymes and substrate molecules). This is the basis for affinity chromatography, by which biologically important compounds are separated.

The atoms of a given element may have a greater affinity for the atoms of one element than for another (for example, hydrogen has a great affinity for chlorine, with which it easily and rapidly combines to form hydrogen chloride, but has little or no affinity for argon).

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afforestation

planting of trees in areas that have not previously held forests. (**Reafforestation** is the planting of trees in deforested areas.) Trees may be planted (1) to provide timber and wood pulp; (2) to provide firewood in countries where this is an energy source; (3) to bind soil together and prevent soil erosion; and (4) to act as windbreaks.

Afforestation is a controversial issue because while many ancient woodlands of mixed trees are being lost, the new plantations consist almost exclusively of conifers. It is claimed that such plantations acidify the soil and conflict with the interests of biodiversity (they replace more ancient and ecologically valuable species and do not sustain wildlife).

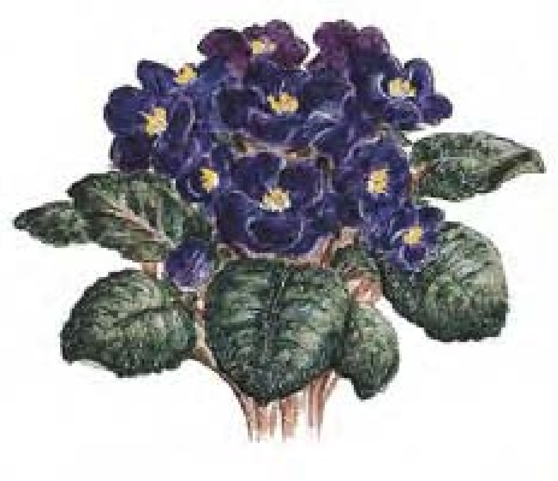
Afghan hound

breed of fast hunting dog resembling the saluki in build, though slightly smaller.

African violet

herbaceous plant from tropical central and East Africa, with velvety green leaves and scentless purple flowers. Different colours and double-flowered varieties have been bred. (*Saintpaulia ionantha*, family Gesneriaceae.)

African violet



(Image © Research Machines plc)

The deep-blue African violet *Saintpaulia ionatha* is a popular houseplant. It is named after Baron Walter von Saint Paul St Claire, who discovered it in the Usambara Mountains in South Africa in the late 19th century. It is unrelated to the common violet.

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afterbirth

in mammals, the placenta, umbilical cord, and ruptured membranes that become detached from the uterus and expelled soon after birth.

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afterburning

method of increasing the thrust of a gas turbine (jet) aeroplane engine by spraying additional fuel into the hot exhaust duct between the turbojet and the tailpipe where it ignites. Used for short-term increase of power during takeoff, or during combat in military aircraft.

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afterimage

persistence of the activity of the retina of the eye after the image producing it has been removed. This leads to persistence of vision, a necessary phenomenon for the illusion of continuous movement in films and television. The term is also used for the persistence of sensations other than vision.

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after-ripening

process undergone by the seeds of some plants before germination can occur. The length of the after-ripening period in different species may vary from a few weeks to many months.

It helps seeds to germinate at a time when conditions are most favourable for growth. In some cases the embryo is not fully mature at the time of dispersal and must develop further before germination can take place. Other seeds do not germinate even when the embryo is mature, probably owing to growth inhibitors within the seed that must be leached out or broken down before germination can begin.

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agamid

lizard in the family Agamidae, containing about 300 species.

Agamids include the common agama; the Australian frilled lizard *Chlamydosaurus*, which runs on its hind legs and has a frill on each side of its neck; the thorny devil *Moloch horridus*, whose body is covered with large spikes; and the Malaysia flying dragon *Draco volans*.

classification

Agamids are in family Agamidae, suborder Sauria, order Squamata, class Reptilia.

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agar

jellylike carbohydrate, obtained from seaweeds. It is used mainly in microbiological experiments as a culture medium for growing bacteria and other micro-organisms. The agar is resistant to breakdown by micro-organisms, remaining a solid jelly throughout the course of the experiment.

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agaric

any of a group of fungi (see fungus) of typical mushroom shape. Agarics include the field mushroom *Agaricus campestris* and the cultivated edible mushroom *A. brunnesiens*. Closely related is the often poisonous *Amanita*, which includes the fly agaric *A. muscaria*. (Genus *Agaricus*, family Agaricaceae.)

Agassiz, (Jean) Louis Rodolphe (1807–1873)

Swiss-born US palaeontologist and geologist who developed the idea of the ice age. He established his name through his work on the classification of fossil fishes. Unlike Charles Darwin, he did not believe that individual species themselves changed, but that new species were created from time to time.

Travelling in the Alps in 1836, Agassiz developed the novel idea that glaciers, far from being static, were in a constant state of almost imperceptible motion. Finding rocks that had been shifted or abraded, presumably by glaciers, he inferred that in earlier times much of northern Europe had been covered with ice sheets. *Etudes sur les glaciers/Studies on Glaciers* (1840) developed the original concept of the ice age, which he viewed as a cause of extinction, demarcating past flora and fauna from those of the present.

His book *Researches on Fossil Fish* (1833–44) described and classified over 1,700 species. He conducted many expeditions to the American West, and his *Contributions to the Natural History of the United States* (1857–62) is an exhaustive study of the American natural environment.

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agate

cryptocrystalline (with crystals too small to be seen with an optical microscope) silica, SiO_2, composed of cloudy and banded chalcedony, sometimes mixed with opal, that forms in rock cavities.

Agate stones, being hard, are also used to burnish and polish gold applied to glass and ceramics and as clean vessels for grinding rock samples in laboratories.

agave

any of several related plants with stiff, sword-shaped, spiny leaves arranged in a rosette. All species come from the warmer parts of the New World. They include *Agave sisalana*, whose fibres are used for rope making, and the Mexican century plant *A. americana*, which may take many years to mature (hence its common name). Alcoholic drinks such as tequila and pulque are made from the sap of agave plants. (Genus *Agave*, family Agavaceae.)

ageing

in common usage, the period of deterioration of the physical condition of a living organism that leads to death; in biological terms, the entire life process.

Three current theories attempt to account for ageing. The first suggests that the process is genetically determined, to remove individuals that can no longer reproduce. The second suggests that it is due to the accumulation of mistakes during the replication of DNA at cell division. The third suggests that it is actively induced by fragments of DNA that move between cells, or by cancer-causing viruses; these may become abundant in old cells and induce them to produce unwanted proteins or interfere with the control functions of their DNA.

Agent Orange

selective weedkiller, notorious for its use by US forces during the Vietnam War to eliminate ground cover that could protect enemy forces. It was subsequently discovered to contain highly poisonous dioxin.

Agent Orange, named after the distinctive orange stripe on its packaging, combines equal parts of 2,4-D (2,4-dichlorophenoxyacetic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), both now banned in the USA. Thousands of US troops who handled the chemical, along with many Vietnamese people who came into contact with it, later developed cancer. Agent Orange has also been linked to cases of diabetes in veterans and there is also a high incidence of leukaemia and deformity in the children of those exposed to it. Companies that manufactured Agent Orange faced an increasing number of lawsuits in the 1970s. All the suits were settled out of court in a single class action, resulting in the largest ever payment of its kind (US $180 million) to claimants.

agglutination

in biology, the clumping together of antigens, such as red blood cells or bacteria, to form larger, visible clumps, under the influence of antibodies. Because each antigen clumps only in response to its particular antibody, agglutination provides a way of determining blood groups and the identity of unknown bacteria.

aggression

in biology, behavior used to intimidate or injure another organism (of the same or of a different species), usually for the purposes of gaining a territory, a mate, or food. Aggression often involves an escalating series of threats aimed at intimidating an opponent without having to engage in potentially dangerous physical contact. Aggressive signals include roaring by wapiti (American elk), snarling by dogs, the fluffing up of feathers by birds, and the raising of fins by some species of fish.

agonist

in biology, a muscle that contracts and causes a movement. Contraction of an agonist is complemented by relaxation of its antagonist. For example, the biceps (in the front of the upper arm) bends the elbow while the triceps (lying behind the biceps) straightens the arm.

agoraphobia

phobia involving fear of open spaces and public places. The anxiety produced can be so severe that some sufferers are unable to leave their homes for many years.

Agoraphobia affects 1 person in 20 at some stage in their lives. The most common time of onset is between the ages of 18 and 28.

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agouti

small rodent of the genus *Dasyprocta*, family Dasyproctidae. It is found in the forests of Central and South America. The agouti is herbivorous, swift-running, and about the size of a rabbit.

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agrarian revolution

until the 1960s historians believed that there had been an 18th-century revolution in agriculture, similar to the revolution that occurred in industry. They claimed that there had been sweeping changes, possibly in response to the increased demand for food from a rapidly expanding population. Major events included the enclosure of open fields; the development of improved breeds of livestock; the introduction of four-course crop rotation; and the use of new crops such as turnips as animal fodder.

Recent research, however, has shown that these changes were only part of a much larger, slower, ongoing process of development: many were in fact underway before 1750, and other breakthroughs, such as farm mechanization, did not become common until after 1945.

causes of improvement

The main cause of change seems to have been the rapidly growing population (from around 6 million in 1700 to 11 million in 1801), particularly in the towns, which created an increased demand for food. This was particularly important during the Napoleonic Wars, since Napoleon's Continental System prevented all trade with Europe; Britain had to produce more food, or starve. Prices rose rapidly, increasing profitability and encouraging an expansion of production; the Corn Laws also played a part in this. Villages that had been happy to be merely self-sufficient now began to look to produce for the market – so the changes involved the adoption of a new capitalist business ethic by the farmers. Better transport also played a part, for it extended the hinterland of population areas, and allowed more farmers to produce for the market.

Enclosure was also crucially important. In 1700 about half the arable land of England was held in open-field strips. The open-field system had some advantages, mainly social, but limited production. Enclosure rationalized the system of land-holding, consolidated farmland, and gave farmers the opportunity to introduce the new methods. Agricultural propagandists such as Arthur Young and William Cobbett also helped the agrarian revolution, for they helped to create a climate of improvement.

To a degree, production was increased because of technical improvements – new crops, crop rotations, selective breeding, new buildings and drainage, the use of manure, and new implements. However, change was uneven from region to region, and even from farm to farm, and very gradual. The full technological revolution in farming did not occur until after World War II.

new crops

The introduction of new crops – such as potatoes, red clover, and turnips – into Britain in the 17th century improved farming practices, since farmers could use them to feed their livestock throughout the winter. This meant that is was no longer necessary for animals to be slaughtered in the autumn so that meat could be salted for storage through the winter. Also, clover returned certain nutrients to the soil, and the growing of turnips meant that the land was thoroughly weeded by hoeing.

four-course rotation

The 18th century saw the replacement of the three-field system of wheat-barley-fallow by the four-course crop rotation system (wheat-turnips-barley-clover), which was designed to ensure that no land would need to lie fallow between periods of cultivation because if crops are rotated correctly they absorb different kinds and quantities of nutrients from the soil. The four-course rotation system was subsequently popularized by enlightened landowners such as Viscount 'Turnip' Townshend and Thomas Coke, who used it to produce greatly increased crop yields on his farmland in Norfolk, and encouraged other farmers and landowners to use the same method. Because both Coke and Townshend lived in Norfolk the system also became known as the 'Norfolk System'.

livestock farming

Other pioneers of the new farming methods that were developed in Britain in the latter part of the 18th century included the livestock farmer Robert Bakewell, who improved the quality of horned stock and sheep by means of selective breeding (purposefully mating strong and healthy animals). His work resulted in a great reduction in the age at which bullocks and sheep were ready for the butcher. Other successful breeders included the Colling brothers of County Durham (Durham Shorthorns) and George Culley of Northumberland (Border Leicester sheep).

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agribusiness

commercial farming on an industrial scale, often financed by companies whose main interests lie outside agriculture, for example multinational corporations. Agribusiness farms are mechanized, large, highly structured, and reliant on chemicals.

Many farms now specialize in one particular crop, maximizing yields by extending field sizes and areas under cultivation.

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agricultural revolution

see agrarian revolution.

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agriculture

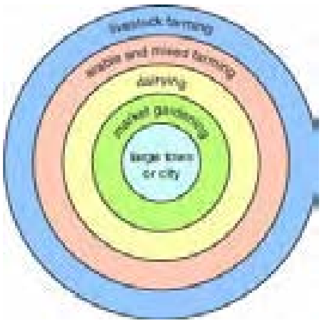
(Latin ager 'field', colere 'to cultivate')

the practice of farming, including the cultivation of the soil (for raising crops) and the raising of domesticated animals. The units for managing agricultural production vary from smallholdings and individually owned farms to corporate-run farms and collective farms run by entire communities or by the government.

Crops are cultivated for human or animal food, or as industrial crops such as cotton and sisal. For successful production, the land must be prepared (ploughed, cultivated, harrowed, and rolled), seed must be planted and the growing plants nurtured. This may involve fertilizers, irrigation, pest control by chemicals, and monitoring of acidity or nutrients. When the crop has grown, it must be harvested and, depending on the crop, processed in a variety of ways before it is stored or sold. Greenhouses allow cultivation of plants in cold climates. Hydroponics allows commercial cultivation of crops using nutrient-enriched water instead of soil. Special methods, such as terracing, may be adopted to allow cultivation in steep regions and to retain topsoil in mountainous areas with heavy rainfall.

Animals are raised for wool, milk, leather, dung (as fuel), or meat. They may be semidomesticated, such as reindeer, or fully domesticated but nomadic (where naturally growing or cultivated food supplies are sparse), or kept on a farm. Animal farming involves rearing, feeding, breeding, gathering the produce (eggs, milk, or wool), slaughtering, and further processing such as tanning.

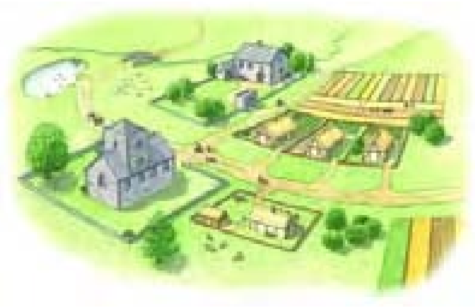
agriculture



(Image © Research Machines plc)

A pattern of agricultural land use. The large town or city represents the market. Land close to the centre will be more expensive and require more intensive farming. Market gardening and dairying need to be close to the market to be profitable, while arable and livestock farms can be placed at a greater distance. A farmer may choose what to produce on the basis of how far the farm is from the market.

agriculture



(Image © Research Machines plc)

Before the agrarian revolution, land was farmed in strips separated by ditches and livestock was grazed on common land.

agriculture

(Image © Research Machines plc)

Queen Elizabeth the Queen Mother visiting the Royal Cornwall Show. This annual event, held at Wadebridge, is among the largest livestock shows in the UK. In 2000, 113,000 people attended the show over three days. As well as livestock, there are also separate horse and dog shows, a flower show, and marquees showcasing Cornish produce.

agriculture

(Image © Research Machines plc)

Small fields and small holdings are typical of farming in the west of Ireland. The dry-stone walls are easily breached when the farmer needs to let his livestock roam from one field to another.

agriculture

(Image © Research Machines plc)

Fields in southern Mexico. Agriculture accounts for about one tenth of Mexico's gross domestic product (GDP). The country produces crops for both subsistence and local consumption, and for export. Crops include maize, squash, coffee, and cotton, as well as speciality crops such as henequen, used for its fibre, and maguey, from which tequila is derived.

Agriculture: key events

10 000-8000 BC	Holocene (post-glacial) period of hunters and gatherers. Harvesting and storage of wild grains in southwest Asia. Herding of reindeer in northern Eurasia. Domestic sheep in northern Iraq.
8000	Neolithic revolution with cultivation of domesticated wheats and barleys, sheep, and goats in southwest Asia. Domestication of pigs and cultivation of sugarcane in New Guinea. Wild maize (Indian corn) used as food in central America.
7000-6000	Domestic goats, sheep, and cattle in Anatolia, Greece, Persia, and the Caspian basin. Planting and harvesting techniques are transferred from Asia Minor to Europe.
5000	Beginning of Nile valley civilization. Millet is cultivated in China.
3400	Flax used for textiles in Egypt. Widespread corn production in the Americas.
3200	Records of ploughing, raking, and manuring by Egyptians.
c. 3100	River Nile dammed during the rule of King Menes.
3000	First record of asses used as beasts of burden in Egypt. Sumerian civilization uses barley as main crop with wheat, dates, flax, apples, plums, and grapes.
2900	Domestication of pigs in eastern Asia.
2640	Reputed start of Chinese silk industry.
2500	Domestic elephants in the Indus valley. Potatoes a staple crop in Peru.
2350	Wine-making in Egypt.
2250	First known irrigation dam.
1600	Important advances are made in the cultivation of vines and olives in Crete.
1500	*Shadoof* (mechanism for raising water) is used for irrigation in Egypt.
1400	Iron ploughshares are in use in India.
1300	Aqueducts and reservoirs are used for irrigation in Egypt.
1200	Domestic camels are in use in Arabia.
1000-500	Evidence of crop rotation, manuring, and irrigation in India.
600	First windmills are used for corn grinding in Persia.
350	Rice cultivation is well established in parts of western Africa. Hunting and gathering take place in the east, central, and south parts of the continent.
c. 200	Use of gears to create ox-driven water wheel for irrigation. Archimedes screw used for irrigation.
100	Cattle-drawn iron ploughs are in use in China.
AD 65	Publication of *De Re Rustica/On Rural Things*, Latin treatise on agriculture and irrigation by the Spanish-born writer Columella.
500	'Three fields in two years' rotation used in China.
630	Cotton is introduced into Arabia.
800	Origins of the 'open field' system in northern Europe.
900	Wheeled ploughs are in use in Western Europe. Horse collar, originating in China, allows horses to be used for ploughing as well as carrying.
1000	Frisians (northwest Netherlanders) begin to build dykes and reclaim land. Chinese begin to introduce Champa rice which crops much more quickly than other varieties.
11th century	Three-field system replaces the two-field system in Western Europe. Concentration on crop growing.
1126	First artesian wells, at Artois, France.
12th century	Increasing use of watermills and windmills. Horses replace oxen for pulling work in many areas.
12th-14th centuries	Expansion of European population brings more land into cultivation. Crop rotations, manuring, and new crops such as beans and peas help increase productivity. Feudal system at its height.
13th-14th centuries	Agricultural recession in Western Europe with a series of bad harvests, famines, and pestilence.
1347	Black Death (plague) kills about a third of the European population.
16th century	Decline of the feudal system in Western Europe. More specialist forms of production are now possible with urban markets. Manorial estates and serfdom remain in eastern Europe. Spaniards introduce maize from North, Central, and South America into Europe. Chinese begin cultivation of non-indigenous crops such as corn, sweet potatoes, potatoes, and peanuts.
17th century	The potato is introduced into Europe. Norfolk crop rotation becomes widespread in England, involving wheat, turnips, barley, and then ryegrass/clover.
1620	Native American peoples teach the first English colonists how to cultivate maize (Indian corn).
1700-1845	Agrarian revolution begins in England. Two million hectares of farmland in England enclosed. The removal of open fields in other parts of Europe follows.
c. 1701	Jethro Tull develops the seed drill and the horse-drawn hoe.
1747	First sugar is extracted from sugar beet in Prussia.
1762	First veterinary school founded in Lyon, France.
1783	First plough factory established in England.
1785	Cast-iron ploughshare patented.
1793	Invention of the cotton gin, a machine for separating cotton fibres from the seed boll (pod).
1800	Early threshing machines developed in England.
1820s	First nitrates for fertilizer imported from South America.
1830	Reaping machines developed in Scotland and the USA. Steel plough made by John Deere in Illinois, USA.
1840s	Extensive potato blight in Europe, failure of potato crop contributes to the Great Famine in Ireland.
1850s	Use of clay pipes for drainage well established throughout Europe.
1862	First steam plough used in the Netherlands.
1850s-90s	Major developments in transport and refrigeration technology alter the nature of agricultural markets with crops, dairy products, and wheat being shipped internationally.
1890s	Development of stationary engines for ploughing.

1892	First petrol-driven tractor used in the USA.
1921	First attempt at crop dusting with pesticides from an aeroplane near Dayton, Ohio, USA.
1938	First self-propelled grain combine harvester used in the USA.
1942–62	Huge increase in the use of pesticides, later curbed by disquiet about their effects and increasing resistance of pests to standard controls such as DDT.
1943	*The Living Soil* by Lady Eve Balfour, one of the most important figures in the development of organic farming in the UK, is published. She begins the 'Haughley Experiment' – a long-term (30 years) trial comparing the new intensive farming regime, reliant on chemicals, with the alternative organic methods championed by her and Howard.
1945 onwards	Increasing use of scientific techniques, crop specialization, and large-scale farm enterprises.
1985	First cases of bovine spongiform encephalopathy (BSE) recorded by UK vets.
1992	Number of cases of BSE in cattle in the UK is at its peak (700 cases per week).
1995	Increase in the use of genetic engineering with nearly 3,000 transgenic crops being field-tested.
1996	A global ban on UK beef exports follows the government announcement that BSE may have been transmitted to humans in the form of a variant strain of Creutzfeldt-Jakob disease (CJD) through the eating of contaminated beef.
1996	Organic farming is on the increase in EU countries. The rise is 11% per year in the UK, 50% in Germany, and 40% in Italy.
1997	The UK government bans the sale of beef on the bone because of fears it is more likely to be contaminated with BSE than other cuts.
1998	The official enquiry into BSE hears that 250,000 animals were needlessly infected because of government reluctance to release data 1989–91. According to the results of a survey by a team of UK psychiatrists, one in ten farmers regularly exposed to organophosphates will suffer irreversible physical and mental damage. Fears grow that genetically modified (GM) crops may have unpredictable harmful biological and environmental effects.
1999	The worldwide ban on UK beef is lifted, but France continues to prohibit beef imports from the UK. The sale of beef on the bone resumes after a UK government ban lasting two years.
2000	An outbreak of swine fever in East Anglia leads to the slaughter of thousands of pigs throughout the UK and depresses pig prices. A report states that farm incomes in the UK have fallen generally to 10% of what they were in 1995. Opposition to GM food grows: 28 protesters admit destroying a field of GM crops but are cleared of criminal damage by a UK court. A Dutch-based seed company compensates farmers for selling them GM-contaminated oilseed rape seeds. The official BSE enquiry publishes its 16-volume report on the crisis, blaming the government for unduly favouring the agriculture industry and failing to act in the interests of consumers. It also criticizes senior civil servants and government scientists for failing to release vital information. Cases of BSE increase in France, where beef production comes under investigation. The Food Standards Agency asks French authorities to ensure illegally sold beef does not find its way into Britain.
2001	In February 2001, an outbreak of foot-and-mouth disease spreads rapidly across the UK. By March, cases were discovered in France, Ireland, and the Netherlands. Severe restrictions on the movement of livestock were imposed across Europe; many countries banned imports of British and French meat, and some banned imports from all European Union countries. By the end of June 2001, over 5 million animals in the UK had been slaughtered due to the foot-and-mouth outbreak.
2002	The March for Liberty and Livelihood through Central London attracts around 400,000 people bringing the concerns of rural communities to the government.
2003	The first case of BSE is recorded in the US, leading many countries to ban imports of US beef.
2004	Fears begin of an avian flu pandemic, with human cases of the disease confined in South East Asia.
2005	The world trade talks are held in Hong Kong. It is agreed to reduce farm subsidies by 2013.
2006	The first avain flu cases of the lethal H5-n1 strain are recorded in Britain and other European countries; the European Commission lifts its ban on exports of British beef, imposed in 1996 following the BSE outbreak.

Consultative Group on International Agriculture Research

Go to site

Web site of the Consultative Group on International Agriculture Research (CGIAR), which is sponsored by the World Bank, the Food and Agricultural Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP) to promote sustainable agricultural use and development through environmentally sound management of natural resources.

Sustainable Agriculture Network

Go to site

US-government-funded organization dedicated to the global exchange of information on sustainable farming systems. This well-organized site highlights the issues through interesting profiles of individual farming families who have moved away from conventional cultivation techniques. Findings of research projects are presented and there are links to a number of US sustainable agriculture sites.

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agriculture, 19th-century British

after a period of depression following the Napoleonic Wars, agriculture developed rapidly during the 19th century. The landed interests countered the post-war slump in agriculture with protective legislation, although the implementation of the Corn Laws led to rural poverty and discontent in the first half of the 19th century and contributed to the distress in Ireland caused by the potato famine. Following the repeal of the Corn Laws in 1846, the expanding urban population and improvements in transport opened up a greater market and led to what has been called the 'golden age' in British farming (1850–70). This, however, was followed by a great depression in agriculture that lasted until 1914, as rising imports of cheap foodstuffs undercut the British farmer.

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agrimony

herbaceous plant belonging to the rose family, with small yellow flowers on a slender spike. It grows along hedges and in fields. (*Agrimonia eupatoria*, family Rosaceae.)

Agrimony

Go to site

Describes both the plant itself and its habitat in detail. There is also a description of the history of the plant, as well as detailed information on its constituents. It also includes notes on the medicinal uses of agrimony, including curing jaundice and treating skin complaints.

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agronomy

study of crops and soils, a branch of agricultural science. Agronomy includes such topics as selective breeding (of plants and animals), irrigation, pest control, and soil analysis and modification.

AI

abbreviation for artificial intelligence and artificial insemination.

AIDS

acronym for acquired immune deficiency syndrome

most serious of all the sexually transmitted diseases (STDs). It is caused by the retrovirus human immunodeficiency virus (HIV), and is transmitted in body fluids, such as blood, saliva, semen, and vaginal secretions. AIDS is the world's most deadly STD and the fourth leading global cause of death. Unlike other diseases, which typically claim most lives among young children and the elderly, AIDS particularly hits those of working age. This has resulted in huge demographic changes in the countries most severely affected by AIDS, causing widespread social and economic hardship.

diagnosis of AIDS

The HIV virus destroys the immune system, leaving the victim vulnerable to diseases that would not otherwise develop. Diagnosis of AIDS is based on the appearance of rare tumours or infections in people unexpected to suffer from such illness. *Pneumocystis carinii* pneumonia, for instance, normally seen only in the malnourished or those whose immune systems have been deliberately suppressed, is common among AIDS victims and is for them a leading cause of death.

treatment

In the West, the time-lag between infection with HIV and the development of AIDS seems to be about ten years. However, it is far more rapid in developing countries, where roughly 50% of AIDS victims die within three years. There is no cure for the disease. In 1995 it was discovered that using a recently developed AIDS drug called 3TC in conjunction with zidovudine (formerly AZT) reduced levels of virus in the blood by ten times. In the West, the use of a three-drug cocktail has had dramatic effects, suppressing levels of the virus to a point where infected people can lead normal lives, although the drugs can have unpleasant side effects. In Africa, triple therapy drug treatment is not widely used because it is so expensive. Drugs companies have reduced the cost of medication, but the price still takes into account the costs of research and development for new drugs. However, in April 2001 pharmaceutical companies dropped their court case against the South African government over the provision of cheaper generic drugs for AIDS.

Research has found that the HIV virus has begun to mutate to become resistant to the current drug cocktail. Studies in 1999 on 11,990 HIV patients in the USA found more than one-quarter to be resistant to all three classes of HIV drugs. Likewise, in the UK, 30% of new HIV infections in 2000 were found to be caused by viruses that are resistant to at least one of the currently available treatment drugs.

worldwide statistics

Estimates published by the World Health Organization (WHO) and the Joint United Nations programme on HIV/AIDS (UNAIDS) put the number of adults living with the HIV virus globally at the end of 2003 to be 37 million. A further 2.5 million children are also thought to be infected with the virus. During 2003, 3 million people died from HIV/AIDS and another 5 million are thought to have become infected with HIV. Around 95% of the people infected with HIV live in the developing world.

AIDS and HIV Information

Go to site

AIDS and HIV site offering safe sex and AIDS prevention advice, information about treatments and testing, and health and nutritional guidance for those with the disease.

AIDS Virtual Library

Go to site

This site is maintained by volunteers and deals with the social, political, and medical aspects of AIDS, HIV, and other related issues. The organizers welcome suggestions for new topics for the AIDS virtual library.

HIV Research Lab

Go to site

Interesting window into a vital area of scientific research, courtesy of an American laboratory investigating HIV and tuberculosis. The page tries to place its work in a socio-economic context and there is a lot here of interest to the general browser.

Aiken, Howard Hathaway (1900-1973)

US mathematician and computer pioneer. In 1939, in conjunction with engineers from IBM, he started work on the design of an automatic calculator using standard business-machine components. In 1944 the team completed one of the first computers, the Automatic Sequence Controlled Calculator (known as the Harvard Mark I), a programmable computer controlled by punched paper tape and using punched cards.

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ailanthus

any of several trees or shrubs with compound leaves made up of pointed leaflets and clusters of small greenish flowers with an unpleasant smell. The tree of heaven (*Ailanthus altissima*), native to East Asia, is grown worldwide as an ornamental; it can grow to 30 m/100 ft in height and the trunk can reach 1 m/3 ft in diameter. (Genus *Ailanthus*, family Simaroubaceae.)

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air

the mixture of gases making up the Earth's atmosphere.

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airbrush

small fine spray-gun used by artists, graphic designers, and photographic retouchers. Driven by air pressure from a compressor or pressurized can, it can apply a thin, very even layer of ink or paint, allowing for subtle gradations of tone.

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air conditioning

system that controls the state of the air inside a building or vehicle. A complete air-conditioning unit controls the temperature and humidity of the air, removes dust and odours from it, and circulates it by means of a fan. US inventor Willis Haviland Carrier (1876–1950) developed the first effective air-conditioning unit in 1902 for a New York printing plant. The first fully air-conditioned high-rise building, the Milam office building in San Antonio, Texas, USA, was built in the 1920s.

The air in an air conditioner is cooled by a type of refrigeration unit comprising a compressor and a condenser. The air is cleaned by means of filters and activated charcoal. Moisture is extracted by condensation on cool metal plates. The air can also be heated by electrical wires or, in large systems, pipes carrying hot water or steam; and cool, dry air may be humidified by circulating it over pans of water or through a water spray.

The first air conditioners were used in 19th century textile mills, where a fine water spray was used to cool and humidify the atmosphere.

A specialized air-conditioning system is installed in spacecraft as part of the life-support system. This includes the provision of oxygen to breathe and the removal of exhaled carbon dioxide.

Outdoor spaces may also be cooled using overhead cool air jets.

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aircraft

any aeronautical vehicle capable of flying through the air. It may be lighter than air (supported by buoyancy) or heavier than air (supported by the dynamic action of air on its surfaces). Balloons and airships are lighter-than-air craft. Heavier-than-air craft include the aeroplane, glider, autogiro, and helicopter.

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air-cushion vehicle

ACV

craft that is supported by a layer, or cushion, of high-pressure air. The hovercraft is one form of ACV.

Airedale terrier

breed of large terrier, about 60 cm/24 in tall, with a wiry red-brown coat and black saddle patch. It originated about 1850 in England, as a cross between the otterhound and Irish and Welsh terriers.

Airedale Terrier Club of America

Go to site

Absolute must for lovers of Airedale terriers. The site is filled with information about the history of the breed, the breed standard, shows, veterinary advice, and many tips for owners. There is a comprehensive listing of other Airedale terrier sites across the world and an extensive bibliography. Pages may be slow to load, but there is music and an Airedale to help while away the time.

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airglow

faint and variable light in the Earth's atmosphere produced by chemical reactions (the recombination of ionized particles) in the ionosphere.

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airlock

airtight chamber that allows people to pass between areas of different pressure; also an air bubble in a pipe that impedes fluid flow. An airlock may connect an environment at ordinary pressure and an environment that has high air pressure (such as a submerged caisson used for tunnelling or building dams or bridge foundations).

An airlock may also permit someone wearing breathing apparatus to pass into an airless environment (into water from a submerged submarine or into the vacuum of space from a spacecraft).

airlock

(Image © NASA)

Destined for the *International Space Station*, this airlock module is pictured during the final stages of its make-up in the space station manufacturing building at the Marshall Space Flight Center. The narrow section forms the airlock exit, while the wide part is the equipment lock, used to store spacesuits and equipment.

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air mass

large body of air with particular characteristics of temperature and humidity. An air mass forms when air rests over an area long enough to pick up the conditions of that area. When an air mass moves to another area it affects the weather of that area, but its own characteristics become modified in the process. For example, an air mass formed over the Sahara will be hot and dry, becoming cooler as it moves northwards. Air masses that meet form **fronts**.

There are four types of air mass.
Tropical continental (Tc) air masses form over warm land and **Tropical maritime** (Tm) masses form over warm seas. Air masses that form over cold land are called **Polar continental** (Pc) and those forming over cold seas are called **Polar** or **Arctic maritime** (Pm or Am).

The weather of the UK is affected by a number of air masses which, having different characteristics, bring different weather conditions. For example, an Arctic air mass brings cold conditions whereas a Tropical air mass brings hot conditions.

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air passages

in biology, the nose, pharynx, larynx, trachea, and bronchi. When a breath is taken, air passes through high narrow passages on each side of the nose where it is warmed and moistened and particles of dust are removed. Food and air passages meet and cross in the pharynx. The larynx lies in front of the lower part of the pharynx and it is the organ where the voice is produced using the vocal cords. The air passes the glottis (the opening between the vocal cords) and enters the trachea. The trachea leads into the chest and divides above the heart into two bronchi. The bronchi carry the air to the lungs and they subdivide to form a succession of fine tubes and, eventually, a network of capillaries that allow the exchange of gases between the inspired air and the blood.

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airplane

powered heavier-than-air craft supported in flight by fixed wings. Airplanes can be propelled by the thrust of a jet engine, a rocket engine, or airscrew (propeller), as well as combinations of these. They must be designed aerodynamically, as streamlining ensures maximum flight efficiency. The shape of a plane depends on its use and operating speed – aircraft operating at well below the speed of sound need not be as streamlined as supersonic aircraft. The Wright brothers flew the first powered plane (a biplane) in Kitty Hawk, North Carolina, USA, 1903. For the history of aircraft and aviation, see flight.

design

Efficient streamlining prevents the formation of shock waves over the body surface and wings, which would cause instability and power loss. The wing of an airplane has the cross-sectional shape of an aerofoil, being broad and curved at the front, flat underneath, curved on top, and tapered to a sharp point at the rear. It is so shaped that air passing above it is speeded up, reducing pressure below atmospheric pressure. This follows from Bernoulli's principle and results in a force acting vertically upwards, called lift, which counters the plane's weight. In level flight lift equals weight. The wings develop sufficient lift to support the plane when they move quickly through the air. The thrust that causes propulsion comes from the reaction to the air stream accelerated backwards by the propeller or the gases shooting backwards from the jet exhaust. In flight the engine thrust must overcome the air resistance, or drag. Drag depends on frontal area (for example, large, airliner; small, fighter plane) and shape (drag coefficient); in level flight at constant speed, drag equals thrust. The drag is reduced by streamlining the plane, resulting in higher speed and reduced fuel consumption for a given power. Less fuel need be carried for a given distance of travel, so a larger payload (cargo or passengers) can be carried.

The shape of a plane is dictated principally by the speed at which it will operate (see aeronautics). A low-speed plane operating at well below the speed of sound (about 965 kph/600 mph) need not be particularly well streamlined, and it can have its wings broad and projecting at right angles from the fuselage. An aircraft operating close to the speed of sound must be well streamlined and have swept-back wings. This prevents the formation of shock waves over the body surface and wings, which would result in instability and high power loss. Supersonic planes (faster than sound) need to be severely streamlined, and require a needle nose, extremely swept-back wings, and what is often termed a 'Coke-bottle' (narrow-waisted) fuselage, in order to pass through the sound barrier without suffering undue disturbance.

To give great flexibility of operation at low as well as high speeds, some supersonic planes are designed with variable geometry, or swing wings. For low-speed flight the wings are outstretched; for high-speed flight they are swung close to the fuselage to form an efficient delta wing configuration.

Aircraft designers experiment with different designs in wind tunnel tests, which indicate how their designs will behave in practice. Fighter jets are now deliberately designed to be aerodynamically unstable, to ensure greater agility. This is achieved by a main wing whose shape is of continuously modifiable shape, the airflow over which is controlled by a smaller tilting foreplane. New aircraft are being made lighter and faster (to Mach 3) by the use of heat-resistant materials, some of which are also radar-absorbing, making the aircraft 'invisible' to enemy defences.

construction

Planes are constructed using light but strong aluminium alloys such as duralumin (with copper, magnesium, and so on). For supersonic planes special stainless steel and titanium may be used in areas subjected to high heat loads. The structure of the plane, or the airframe (wings, fuselage, and so on) consists of a surface skin of alloy sheets supported at intervals by struts known as ribs and stringers. The structure is bonded together by riveting or by powerful adhesives such as epoxy resins. In certain critical areas, which have to withstand very high stresses (such as the wing roots), body panels are machined from solid metal for extra strength.

On the ground a plane rests on wheels, usually in a tricycle arrangement, with a nose wheel and two wheels behind, one under each wing. For all except some light planes the landing gear, or undercarriage, is retracted in flight to reduce drag.

Seaplanes, which take off and land on water, are fitted with nonretractable floats.

flight control

Wings by themselves are unstable in flight, and a plane requires a tail to provide stability. The tail comprises a horizontal tailplane and vertical tailfin, called the horizontal and vertical stabilizer respectively. The tail plane has hinged flaps at the rear called elevators to control pitch (attitude). Raising the elevators depresses the tail and inclines the wings upwards (increases the angle of attack). This speeds the airflow above the wings until lift exceeds weight and the plane climbs. However, the steeper attitude increases drag, so more power is needed to maintain speed and the engine throttle must be opened up. Moving the elevators in the opposite direction produces the reverse effect. The angle of attack is reduced, and the plane descends. Speed builds up rapidly if the engine is not throttled back. Turning (changing direction) is effected by moving the rudder hinged to the rear of the tailfin, and by banking (rolling) the plane. It is banked by moving the ailerons, interconnected flaps at the rear of the wings which move in opposite directions, one up, the other down.

In planes with a delta wing, the ailerons and elevators are combined. Other movable control surfaces, called flaps, are fitted at the rear of the wings closer to the fuselage. They are extended to increase the width and camber (curve) of the wings during takeoff and landing, thereby creating extra lift, while movable sections at the front, or leading edges, of the wing, called slats, are also extended at these times to improve the airflow. To land, the nose of the plane is brought up so that the angle of attack of the wings exceeds a critical point and the airflow around them breaks down; lift is lost (a condition known as stalling), and the plane drops to the runway. A few planes (for example, the Harrier) have a novel method of takeoff and landing, rising and dropping vertically by swivelling nozzles to direct the exhaust of their jet engines downwards. The helicopter and convertiplane use rotating propellers (rotors) to obtain lift to take off vertically.

operation

The control surfaces of a plane are operated by the pilot on the flight deck, by means of a control stick, or wheel, and by foot pedals (for the rudder). Traditionally, and still today in smaller planes, the controls are brought into action by hydraulic power systems. More sophisticated aircraft use computer-controlled systems. The pilot instructs the computer which manoeuvre the plane must perform, and the computer, informed by a series of sensors around the craft about the altitude, speed, and turning rate of the plane, sends signals to the control surface and throttle to enable the manoeuvre to be executed.

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air pollution

contamination of the atmosphere caused by the discharge, accidental or deliberate, of a wide range of toxic airborne substances. Often the amount of the released substance is relatively high in a certain locality, so the harmful effects become more noticeable. The cost of preventing any discharge of pollutants into the air is prohibitive, so attempts are more usually made to reduce the amount of discharge gradually and to disperse it as quickly as possible by using a very tall chimney, or by intermittent release.

One major air pollutant is sulphur dioxide (SO_2), produced from the burning of fossil fuels. It dissolves in atmospheric moisture to produce sulphurous acid (acid rain):

$SO_2 + H_2O = H_2SO_3$

Effect of air pollutants on selected materials

Air pollution is harmful not only to living creatures, but also to the materials around them. Acids are formed by the reaction of sulphur and nitrogen dioxides with atmospheric moisture. Damage to buildings in the USA from acid deposition alone is estimated at $5 billion annually.

Material	Effects	Pollutants responsible
ceramics and glass	surface erosion	particulates
leather	cracking, loss of strength	sulphur dioxide
metals	corrosion, tarnishing, loss of strength	sulphur dioxide, sulphuric acid, nitric acid, particulates
paints	surface erosion, discoloration, soiling	sulphur dioxide, ozone, particulates
paper	embrittlement, discoloration	sulphur dioxide
rubber	cracking, loss of strength	ozone
stone and concrete	surface erosion, discoloration, soiling	sulphur dioxide, sulphuric acid, nitric acid, particulates
textiles	deterioration, fading, soiling	sulphur dioxide, nitrogen dioxide, ozone, particulates
wood	discoloration, loss of strength, more prone to fungal diseases	sulphur dioxide, ozone

Major air pollutants

Air pollution is contamination of the atmosphere caused by the discharge, accidental or deliberate, of a wide range of toxic airborne substances. Often the amount of the released substance is relatively high in a certain locality, so the harmful effects become more noticeable. The cost of preventing any discharge of pollutants into the air is prohibitive, so attempts are more usually made to reduce the amount of discharge gradually and to disperse it as quickly as possible by using a very tall chimney, or by intermittent release.

Pollutant	Sources	Effects
Sulphur dioxide (SO_2)	oil, coal combustion in power stations	acid rain formed, which damages plants, trees, buildings, and lakes
Oxides of nitrogen (NO, NO_2)	high-temperature combustion in cars, and to some extent power stations	acid rain formed
Lead compounds	from leaded petrol used by cars	nerve poison
Carbon dioxide (CO_2)	oil, coal, petrol, diesel combustion	greenhouse effect
Carbon monoxide (CO)	incomplete combustion of oil, coal, petrol, diesel fuels	poisonous, leads to photochemical smog in some areas

Nuclear waste	nuclear power plants, nuclear weapon testing, war	radioactivity, contamination of locality, cancers, mutations, death
Ozone (O_3)	formed by the reaction between sunlight and NO_x compounds	greenhouse effect, acid rain by-product
Particulates (PM_{10}, 'smog')	vehicle exhausts, power generation, combustion processes	respiratory effects, acid rain
Volatile organic compounds (VOC)	industrial processes, vehicle emissions, petrol evaporation	greenhouse effect, ozone production

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air sac

in birds, a thin-walled extension of the lungs. There are nine of these and they extend into the abdomen and bones, effectively increasing lung capacity.

The sacs subdivide into further air spaces which partially replace the marrow in many of the bird's bones. The air space in these bones assists flight by making them lighter. In mammals, it is another name for the alveoli in the lungs, and in some insects, for widenings of the trachea.

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airship

or dirigible

any aircraft that is lighter than air and power-driven, consisting of an ellipsoidal balloon that forms the streamlined envelope or hull and has below it the propulsion system (propellers), steering mechanism, and space for crew, passengers, and/or cargo. The balloon section is filled with lighter-than-air gas, either the nonflammable helium or, before helium was industrially available in large enough quantities, the easily ignited and flammable hydrogen. The envelope's form is maintained by internal pressure in the nonrigid (blimp) and semirigid (in which the nose and tail sections have a metal framework connected by a rigid keel) types. The rigid type (zeppelin) maintains its form using an internal metal framework. Airships have been used for luxury travel, polar exploration, warfare, and advertising.

Rigid airships predominated from about 1900 until 1940. As the technology developed, the size of the envelope was increased from about 45 m/150 ft to more than 245 m/800 ft for the last two zeppelins built. In 1852 the first successful airship was designed and flown by Henri Giffard of France. In 1900 the first rigid type was designed by Count (*Graf*) Ferdinand von Zeppelin of Germany (though he did not produce a successful model till his L-24 in1908). Airships were used by both sides during World War I, but they were not seriously used for military purposes after that as they were largely replaced by aeroplanes. The British mainly used small machines for naval reconnaissance and patrolling the North Sea; Germany used Schutte-Lanz and Zeppelin machines for similar patrol work and also for long-range bombing attacks against English and French cities, mainly Paris and London.

Airship and Blimp Resources

Go to site

Information about airships - with the main focus on contemporary development. This site includes sections such as 'Hot news', 'Manufacturer database', 'Homebuilding', and 'Museums'.

German Zeppelin Offensive of 1916

Go to site

Details of the German airship attacks on England during World War I. This site provides descriptions of the offensives, information on what the Germans hoped these bombing runs would achieve, and the technology that the British devised to bring the zeppelins down. There are a number of photographs of downed airships, plus quotes from German airmen concerning the fear of going down in flames. A brief list of sources is included after the narrative.

Radio Broadcast of the Hindenburg Disaster

Go to site

Part of a larger site paying homage to the glory days of radio, this site features audio of the chilling, live news coverage of the Hindenburg disaster as the giant airship exploded into flames at Lakehurst, New Jersey, on 6 May 1937. In addition to a seven minute audio clip, there is a brief article that provides context and a photograph of the Hindenburg engulfed in flames.

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ajolote

Mexican reptile of the genus *Bipes*. It and several other tropical burrowing species are placed in the Amphisbaenia, a group separate from lizards and snakes among the Squamata. Unlike the others, however, which have no legs, it has a pair of short but well-developed front legs. In line with its burrowing habits, the skull is very solid, the eyes small, and external ears absent.

The scales are arranged in rings, giving the body a wormlike appearance.

alabaster

naturally occurring fine-grained white or light-coloured translucent form of gypsum, often streaked or mottled. A soft material, it is easily carved, but seldom used for outdoor sculpture.

Alaskan malamute

breed of dog. It is a type of husky.

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albacore

name loosely applied to several species of fishes found in warm regions of the Atlantic and Pacific oceans, in particular to a large tuna, *Thunnus alalunga*, and to several other species of the mackerel family.

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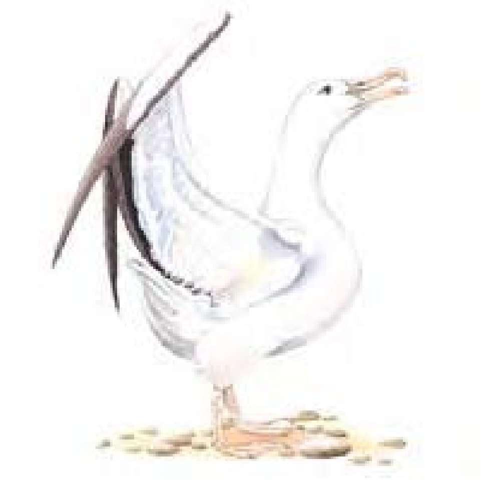
albatross

large seabird, genus *Diomedea*, with long narrow wings adapted for gliding and a wingspan of up to 3.4 m/11 ft, mainly found in the southern hemisphere. It belongs to the family Diomedeidae, order Procellariiformes, the same group as petrels and shearwaters. The nostrils of birds in this order are tubular, and the bills are hooked.

Albatrosses feed mainly on squid and fish, and nest on remote oceanic islands. They can cover enormous distances, flying as far as 16,100 km/10,000 mi in 33 days, or up to 640 km/600 mi in one day. They fly at speeds of up to 53.5 kph/50 mph, and continue flying even after dark, though they may stop for an hour's rest and to feed during the night. Albatrosses are becoming increasingly rare, and are in danger of extinction.

The Diomedeidae family contains 14 species of albatross found in the South Atlantic and the Pacific oceans. A single white egg is laid. The chick's full weight is 12 kg/26 lb, heavier than the parents, which typically weigh around 9 kg/20 lb. The chick needs this extra body weight to survive the Antarctic winter; the parents only return to the chick if and when they find food for it. The lack of readily available food means that 50% of the chicks will starve.

albatross



(Image © Research Machines plc)

The wandering albatross *Diomedea exulans*. The young are cared for by both parents for almost a year, so breeding takes place every two years. Courtship involves elaborate displays of dancing, bill-rubbing, and wing-spreading.

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albedo

fraction of the incoming light reflected by a body such as a planet. A body with a high albedo (near 1) is very bright, while a body with a low albedo (near 0) is dark. The Moon has an average albedo of 0.12, Venus 0.76, and Earth 0.37.

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albinism

rare hereditary condition in which the body lacks tyrosinase, one of the enzymes that form the pigment melanin, normally found in the skin, hair, and eyes. As a result, the hair is white and the skin and eyes are pink. The skin and eyes are abnormally sensitive to light, and vision is often impaired. The condition occurs among all human groups and across the animal kingdom.

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albumin

any of a group of water-soluble proteins found in body fluids. The best known is in the form of egg white (albumen); others occur in milk, and as a major component of serum. They can be coagulated by heat.

The presence of serum albumin in the urine, termed albuminuria or proteinuria, may be indicative of kidney or heart disease.

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alchemy

(Arabic al-Kimya)

supposed technique of transmuting base metals, such as lead and mercury, into silver and gold by the philosopher's stone, a hypothetical substance, to which was also attributed the power to give eternal life.

This aspect of alchemy constituted much of the chemistry of the Middle Ages. More broadly, however, alchemy was a system of philosophy that dealt both with the mystery of life and the formation of inanimate substances. Alchemy was a complex and indefinite conglomeration of chemistry, astrology, occultism, and magic, blended with obscure and abstruse ideas derived from various religious systems and other sources. It was practised in Europe from ancient times to the Middle Ages but later fell into disrepute when chemistry and physics developed.

Alchemical Substances

Go to site

Modern explanations of the lyrical names alchemists gave to their substances. Part of the huge Virtual Alchemy Library Web site this section is slightly disorganized, not being listed in alphabetical or any other particular order. Some of the exotic substances described include the bizarrely named 'Thion hudor' and the rather poetic 'Purple of Cassius'.

Alchemy Virtual Library

Go to site

Virtual library dedicated to alchemy in all its facets. There are 600 sections, more than 130 graphics, and - for subscribers - an e-mail discussion forum.

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alcohol

in chemistry, any member of a group of organic chemical compounds characterized by the presence of one or more aliphatic OH (hydroxyl) groups in the molecule, and which form esters with acids. The main uses of alcohols are as solvents for gums, resins, lacquers, and varnishes; in the making of dyes; for essential oils in perfumery; and for medical substances in pharmacy. The alcohol produced naturally in the fermentation process and consumed as part of alcoholic beverages is called ethanol. When consumed the effects of alcohol include poisoning at high concentrations, and changes in the functioning of human nerve cells.

Alcohols may be liquids or solids, according to the size and complexity of the molecule. A **monohydric alcohol** contains only one hydroxyl group in each molecule. The five simplest alcohols form a series in which the number of carbon and hydrogen atoms in the molecule increases progressively, each one having an extra CH_2 (methylene) group: methanol or wood spirit (methyl alcohol, CH_3OH); ethanol (ethyl alcohol, C_2H_5OH); propanol (propyl alcohol, C_3H_7OH); butanol (butyl alcohol, C_4H_9OH); and pentanol (amyl alcohol, $C_5H_{11}OH$). The lower alcohols are liquids that mix with water; the higher alcohols, such as pentanol, are oily liquids immiscible with water; and the highest are waxy solids - for example, hexadecanol (cetyl alcohol, $C_{16}H_{33}OH$) and melissyl alcohol ($C_{30}H_{61}OH$), which occur in sperm-whale oil and beeswax, respectively. Alcohols containing the CH_2OH group are primary; those containing CHOH are secondary; while those containing COH are tertiary.

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alcohol, effects

in biology, the effects of alcohol on cells. Alcohol differs from many other organic chemicals by affecting the way nerve cells operate when present in the body. At high concentrations it is poisonous and can kill all forms of life, including micro-organisms. In fact, alcohol can be used to preserve the remains of animals and plants for ever by preventing the micro-organisms of decay from breaking down the tissues.

Nerve cells in the brain are affected by the alcohol (ethanol) in alcoholic beverages. The result is that it reduces anxiety and makes people drowsy (sedative or depressant). It increases the effects of antihistamines and barbiturates and people can die as a result of taking these drugs with alcohol. However, in low doses the depressing effect is most marked on parts of the brain concerned with inhibiting extreme behaviour and making fine judgements. So people affected by alcohol are often uninhibited and unaware that they are not able to drive as safely as they should - in fact, one of the effects of alcohol is to give a sense of overconfidence in driving ability. Tests show that reaction time can be slowed by 10-30% because the brain is working inefficiently and messages to the muscles are delayed. Night vision may also be reduced by up to

25%. This makes alcohol quite dangerous.

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alcoholism

dependence on alcohol. It is characterized as an illness when consumption of alcohol interferes with normal physical or emotional health. Excessive alcohol consumption, whether through sustained ingestion or irregular drinking bouts or binges, may produce physical and psychological addiction and lead to nutritional and emotional disorders. Long-term heavy consumption of alcohol leads to diseases of the heart, liver, and peripheral nerves. Support groups such as Alcoholics Anonymous are helpful.

Alcohol: Problems and Solutions

Go to site

US-based Web site covering the topic of alcohol in many contexts. There are 24 sections that deal with most aspects of alcohol in society, from the law to alcohol facts and figures. The site is very colourful and attractively produced, and includes many activities to raise awareness of the problems associated with alcohol.

Mind, Body, and Soul

Go to site

Flash-based site which covers a wide range of PSHE-relevant subjects for GCSE students. The site aims to give 'The lowdown on health in a fun and interesting way' and has sections on a variety of topics such as: accidents, alcohol, drugs, healthy eating, mental health, physical activity, sexual health, smoking, and sun safety. Each section contains subsections, which all explain different aspects in the form of Flash-based animations.

Aldebaran

or Alpha Tauri

brightest star in the constellation Taurus and the 14th-brightest star in the night sky; it marks the eye of the 'bull'. Aldebaran is a red giant 65 light years away from the Sun, shining with a true luminosity of about 100 times that of the Sun.

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aldehyde

any of a group of organic chemical compounds prepared by oxidation of primary alcohols, so that both the OH (hydroxyl) group and the adjacent carbon lose a hydrogen to give an oxygen joined by a double bond to a carbon atom (the aldehyde group, with the formula CHO).

Higher aldehydes are commonly used in perfumes.

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alder

any of a group of trees or shrubs belonging to the birch family, found mainly in cooler parts of the northern hemisphere and characterized by toothed leaves and catkins. (Genus *Alnus*, family Betulaceae.)

Alder, Common

Go to site

Contains much detailed information on the common alder, or *Alnus glutinose*. The plant itself is described, as is its habitat. There is also a detailed description of the constituents of the plant, and there are even notes on its uses as a dye and as a cure for rheumatism.

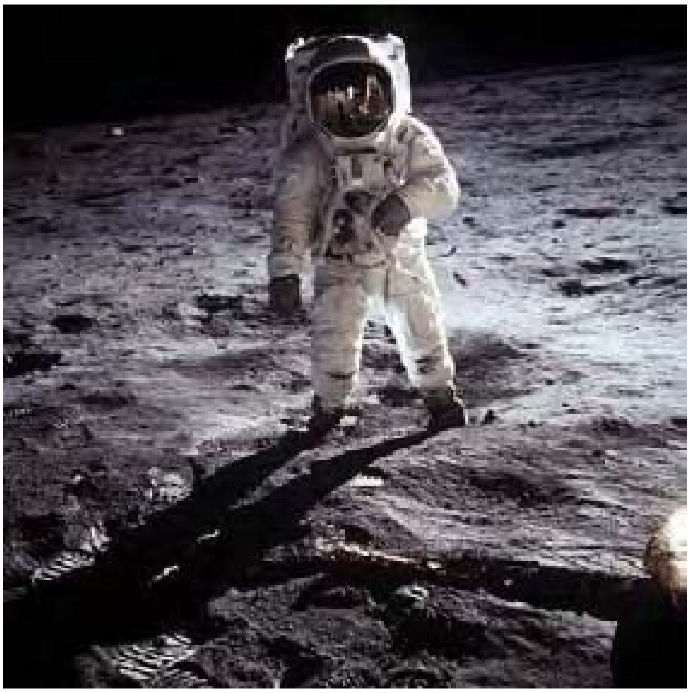
Aldrin, Buzz (1930-)

born Edwin Eugene Aldrin

US astronaut who, with Neil Armstrong, landed on the Moon on 20 July 1969 during the *Apollo 11* mission, becoming the second person to set foot on the Moon.

During the *Gemini 12* flight with James Lovell in 1966, Aldrin spent 5.5 hours in outer space without any ill effects. His 'walk' in space set a record for extravehicular activity and proved that people could work outside an orbiting vehicle. He resigned from NASA in 1971, having spent 289 hours and 53 minutes in space.

Aldrin



(Image © NASA)

Buzz Aldrin photographed by Neil Armstrong during the historic *Apollo 11* Moon walk. Visible to the lower right of the picture is the foot of the *Eagle* lunar module. The astronaut's crisp footprints reveal the fine-grained, talclike nature of the topmost lunar soil.

Aldrin

(Image © NASA)

Buzz Aldrin stands near the US flag erected by the crew of the *Apollo 11* lunar module. A bar holds the flag unfurled, as it would otherwise hang limp on the airless and windless surface of the Moon.

Alembert, Jean Le Rond d' (1717-1783)

French mathematician, encyclopedist, and theoretical physicist. In association with Denis Diderot, he helped plan the great *Encyclopédie*, for which he also wrote the 'Discours préliminaire' (1751). He framed several theorems and principles - notably **d'Alembert's principle** - in dynamics and celestial mechanics, and devised the theory of partial differential equations.

The principle that now bears his name was first published in his *Traité de dynamique* (1743), and was an extension of the third of Isaac Newton's laws of motion. D'Alembert maintained that the law was valid not merely for a static body, but also for mobile bodies. Within a year he had found a means of applying the principle to the theory of equilibrium and the motion of fluids. Using also the theory of partial differential equations, he studied the properties of sound, and air compression, and also managed to relate his principle to an investigation of the motion of any body in a given figure.

D'Alembert, Jean Le Rond

Go to site

Biography and portrait of the French physicist and mathematician famous for his works on the use of differential equations in physics. In addition to a brief history of d'Alembert's work there are links to lengthy descriptions of his fields of expertise, and also a short publications list for use as a reference.

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alexanders

strong-smelling tall herbaceous plant belonging to the carrot family. It is found along hedgerows and on cliffs throughout southern Europe. Its yellow flowers appear in spring and early summer. (*Smyrnium olusatrum*, family Umbelliferae.)

Alexander technique

in alternative medicine, a method of correcting bad habits of posture, breathing, and muscular tension, which Australian therapist F M Alexander maintained cause many ailments. The technique is also used to promote general health and relaxation and enhance vitality.

Back troubles, migraine, asthma, hypertension, and some gastric and gynaecological disorders are among the conditions said to be alleviated by the technique, which is also said to be effective in the prevention of disorders, particularly those of later life.

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alfalfa

or lucerne

perennial tall herbaceous plant belonging to the pea family. It is native to Europe and Asia and has spikes of small purple flowers in late summer. It is now a major fodder crop, commonly processed into hay, meal, or silage. Alfalfa sprouts, the sprouted seeds, have become a popular salad ingredient. (*Medicago sativa*, family Leguminosae.)

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algae

singular alga

highly varied group of plants, ranging from single-celled forms to large and complex seaweeds. They live in both fresh and salt water, and in damp soil. Algae do not have true roots, stems, or leaves.

Marine algae help combat global warming by removing carbon dioxide from the atmosphere during photosynthesis.

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algebra

branch of mathematics in which the general properties of numbers are studied by using symbols, usually letters, to represent variables and unknown quantities. For example, the algebraic statement:

$$(x + y)^2 = x^2 + 2xy + y^2$$

is true for all values of x and y. For instance, the substitution $x = 7$ and $y = 3$ gives:

$$(7 + 3)^2 = 7^2 + 2(7 \times 3) + 3^2 = 100$$

An algebraic expression that has one or more variables (denoted by letters) is a polynomial equation. A polynomial equation has the form:

$$f(x) = a_n x^n + a_{n-1} x^{n-1} + \rangle + a_2 x^2 + a_1 x + a_0$$

where a_n, a_{n-1}, $\rangle$, a_0 are all constants, n is a positive integer, and $a_n \neq 0$. Examples of polynomials are:

$$f(x) = 3x^4 + 2x^2 + 1$$

or

$$f(x) = x^5 - 18x + 71$$

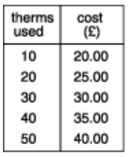
or

$$f(x) = 2x + 3$$

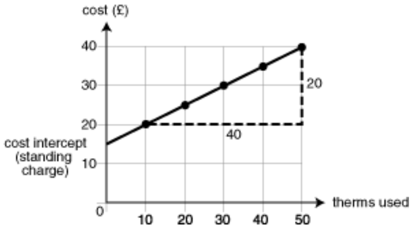
Algebra is used in many areas of mathematics - for example, arithmetic progressions, or number sequences, and Boolean algebra (the latter is used in working out the logic for computers).

In ordinary algebra the same operations are carried on as in arithmetic, but, as the symbols are capable of a more generalized and extended meaning than the figures used in arithmetic, it facilitates calculation where the numerical values are not known, or are inconveniently large or small, or where it is desirable to keep them in an analysed form.

For example, the following table shows the cost of gas for heating:



therms used	cost (£)
10	20.00
20	25.00
30	30.00
40	35.00
50	40.00



There is a connecting rule between the cost and the number of therms used. Gradient = change in cost/ change in therms:

= 40 - 20/50 - 10 = 20/40 = £0.5 per therm

Cost intercept = £15 (the intercept is the standing charge).

Since this is a straight line graph, a linear equation connecting the cost and therms used can be created:

cost = 0.5 therms + 15 or c = 0.5 t + 15

A straight line graph can be represented by the general formula:

$y = mx + c$

where c is the y-intercept, m is the gradient, and (x,y) are the points on the line.

order of calculation

The simplification of an algebraic equation or expression must be completed in a set order. The procedure follows the rules of BODMAS - any elements in **b**rackets should always be calculated first, followed by power **o**f (or index), **d**ivision, **m**ultiplication, **a**ddition, and **s**ubtraction.

For example, to solve the equation:

$3(2x - x - 1) = 2(x + 3 + 4)$

collect the like terms and work out the brackets:

$3(x - 1) = 2(x + 7)$

multiply out the brackets:

$3x - 3 = 2x + 14$

collect the xs on the left-hand side of the equation:

$3x - 3 - 2x = 14$

then solve for x:

$x - 3 = 14$ $x = 14 + 3$ $x = 17$

Inequations or inequalities may be solved using similar rules. When multiplying or dividing by a negative value, however, the direction of the inequality must be reversed, for example: $-x > 5$ is equivalent to $x < -5$.

quadratic equation

A quadratic equation is a polynomial equation of second degree (that is, an equation containing as its highest power the square of a variable, such as x^2). The general formula of such equations is:

$ax^2 + bx + c = 0$

in which the coefficients$a$, b, and c are real numbers, and only the coefficient a cannot equal 0.

Some quadratic equations can be solved by factorization (see factor (algebra)), or the values of x can be found by using the formula for the general solution.

$x = [-b + \surd(b^2 - 4ac)]/2a$ or

$x = [-b - \surd(b^2 - 4ac)]/2a$

Depending on the value of the discriminant $b^2 - 4ac$, a quadratic equation has two real, two equal, or two complex roots (solutions).

When $b^2 - 4ac > 0$, there are two distinct real roots.

When $b^2 - 4ac = 0$, there are two equal real roots.

When $b^2 - 4ac < 0$, there are two distinct complex roots.

simultaneous equations

If there are two or more algebraic equations that contain two or more unknown quantities that may have a unique solution, they can be solved simultaneously as simultaneous equations. For example, in the case of two linear equations with two unknown variables, such as:

(i) $3y + x = 6$ and

(ii) $3y - 2x = 6$

the solution will be those unique values of x and y that are valid for both equations. Linear simultaneous equations can be solved by using algebraic manipulation to eliminate one of the variables. For example, subtracting equation (ii) from equation (i) gives:

$3y - 3y + x + 2x = 6 - 6$

So $x = 0$, and substituting this value into (ii) gives:

$3y = 6$

So $y = 2$.

Another method is to rearrange (i) to give:

$x = 6 - 3y$

Substituting this into (ii) gives:

$3y - 2(6 - 3y) = 6$

Multiplying out the brackets gives:

$3y - 12 + 6y = 6$

So $9y = 18$, and $y = 2$.

'Algebra' was originally the name given to the study of equations. In the 9th century, the Arab mathematician Muhammad ibn-Musa al-Khwarizmi used the term *al-jabr* for the process of adding equal quantities to both sides of an equation. When his treatise was later translated into Latin, *al-jabr* became 'algebra' and the word was adopted as the name for the whole subject.

algebra

To remember the order of operations in complex algebraic or numerical expressions:

Bless **m**y **d**ear **A**unt **S**ally!

Brackets, **m**ultiply, **d**ivide, **a**dd, **s**ubtract

Algebra Help

Go to site

Great resource containing algebra lessons, beginning with the basics, then moving on to the more complex issue of simplifying equations. There are numerous worksheets that demonstrate the workings as well as giving the answers. In addition, there are some excellent online calculators that will solve equations, complete the square, and simplify or factorize equations for you.

Fundamental Theorem of Algebra

Go to site

Web site run by St Andrews University, Scotland, chronicling the history of the theorem of algebra. The site also provides biographical details on many of the main characters involved in its development.

PurpleMath

Go to site

Lots of algebra lessons! The site starts off with simple lessons and moves on to more complicated topics. The lessons are detailed, with lots of examples; some are cross-referenced to other lessons and some contain 'Quizlets' to test understanding. There are also links to other maths sites.

SOS Mathematics: Algebra

Go to site

Useful site covering algebra and numbers. It contains lessons with examples, and online questions, with solutions against which to mark work. However, some of the lessons do go beyond the GCSE syllabus.

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algebraic fraction

in mathematics, fraction in which letters are used to represent numbers – for example, a/b, xy/z^2, and $1/(x + y)$. Like numerical fractions, algebraic fractions may be simplified or factorized. Two equivalent algebraic fractions can be cross-multiplied; for example, if

$a/b = c/d$

then $ad = bc$

(In the same way, the two equivalent numerical fractions 2/3 and 4/6 can be cross-multiplied to give cross-products that are both 12.)

factorization

Algebraic fractions can be simplified by factorization, that is by taking out those factors that are common to both the numerator and denominator. For example, the algebraic fraction:

$(x^2 - 2x - 8)(x^2 + 5x + 4)/(x^2 - 16)(x + 1)$

can be simplified as follows:

$(x^2 - 2x - 8)$ factorizes as $(x - 4)(x + 2)$

$(x^2 + 5x + 4)$ factorizes as $(x + 4)(x + 1)$

$(x^2 - 16)$ factorizes as $(x - 4)(x + 4)$

so the $(x - 4)$, $(x + 4)$, and $(x + 1)$ from the denominator cancel out those in the numerator, leaving only $(x + 2)$.

addition and subtraction

As with numerical fractions, to add or subtract algebraic fractions a common denominator must be found. The easiest way to do this is to multiply the denominators together. For example:

$3/x - 4/x + 2 = 3(x + 2)/ x(x + 2) - 4x/x(x + 2)$

which can be simplified to:

$3x +6 - 4x/x(x + 2) = 6 - x/x^2 + 2x$

---

alginate

in chemistry, salt of alginic acid, $(C_6H_8O_6)_n$, obtained from brown seaweeds and used in textiles, paper, food products, and pharmaceuticals.

Algol

or Beta Persei

eclipsing binary, a pair of orbiting stars in the constellation Perseus, the fainter one of which eclipses the brighter one every 69 hours, causing the apparent brightness of the pair to drop by two-thirds.

The brightness changes were first explained in 1782 by English amateur astronomer John Goodricke. He pointed out that the changes between magnitudes 2.2 and 3.5 repeated themselves exactly after an interval of 2.867 days and supposed this to be due to two stars orbiting round and eclipsing each other.

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algorithm

procedure or series of steps that can be used to solve a problem.

In computer science, it describes the logical sequence of operations to be performed by a program. A flow chart is a visual representation of an algorithm.

The word derives from the name of 9th-century Arab mathematician Muhammad bin Musa al-Khwarizmi.

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alimentary canal

tube through which food passes in animals – it extends from the mouth to the anus and forms a large part of the digestive system. In human adults, it is about 9 m/30 ft long, consisting of the mouth cavity, pharynx, oesophagus, stomach, and the small and large intestines. It is also known as the gut. It is a complex organ, specifically adapted for digestion and the absorption of food. Enzymes from the wall of the canal and from other associated organs, such as the pancreas, speed up the digestive process.

The muscles in the wall of the alimentary canal contract, mixing food with the enzymes and slowly pushing it along in the direction of the anus in a process known as peristalsis. Dietary fibre encourages this movement. The constant stream of enzymes from the canal wall and from the pancreas assists the breakdown of food molecules into smaller, soluble nutrient molecules, which are absorbed through the canal wall into the bloodstream and carried to individual cells. The wall of the canal receives an excellent supply of blood and is folded so as to increase its surface area. These two adaptations ensure efficient absorption of nutrient molecules.

aliphatic compound

any organic chemical compound in which the carbon atoms are joined in straight chains, as in hexane (C_6H_{14}), or in branched chains, as in 2-methylpentane ($CH_3CH(CH_3)CH_2CH_2CH_3$).

Aliphatic compounds have bonding electrons localized within the vicinity of the bonded atoms. Cyclic compounds that do not have delocalized electrons are also aliphatic, as in the alicyclic compound cyclohexane (C_6H_{12}) or the heterocyclic piperidine ($C_5H_{11}N$). Compare aromatic compound.

alkali

in chemistry, a base that is soluble in water. Alkalis neutralize acids, and solutions of alkalis are soapy to the touch. The strength of an alkali is measured by its hydrogen-ion concentration, indicated by the pH value. They may be divided into strong and weak alkalis: a strong alkali (for example, potassium hydroxide, KOH) ionizes completely when dissolved in water, whereas a weak alkali (for example, ammonium hydroxide, NH_4OH) exists in a partially ionized state in solution. All alkalis have a pH above 7.0.

The hydroxides of metals are alkalis. Those of sodium and potassium are corrosive; both were historically derived from the ashes of plants.

The four main alkalis are sodium hydroxide (caustic soda, NaOH); potassium hydroxide (caustic potash, KOH); calcium hydroxide (slaked lime or limewater, $Ca(OH)_2$); and aqueous ammonia ($NH_{3(aq)}$). Their solutions all contain the hydroxide ion OH^-, which gives them a characteristic set of properties.

alkali metal

any of a group of six metallic elements with similar chemical properties: lithium, sodium, potassium, rubidium, caesium, and francium. They form a linked group (Group 1) in the periodic table of the elements. They each have a valency of one and have very low densities (lithium, sodium, and potassium float on water); in general they are reactive, soft, low-melting-point metals. Because of their reactivity they are only found as compounds in nature.

alkaline-earth metal

any of a group of six metallic elements with similar bonding properties: beryllium, magnesium, calcium, strontium, barium, and radium. They form a linked group in the periodic table of the elements. They are strongly basic, bivalent (have a valency of two), and occur in nature only in compounds. Calcium and magnesium are abundant on Earth and essential for all organisms, while the other three elements are relatively rare.

alkaloid

any of a number of physiologically active and frequently poisonous substances contained in some plants. They are usually organic bases and contain nitrogen. They form salts with acids and, when soluble, give alkaline solutions.

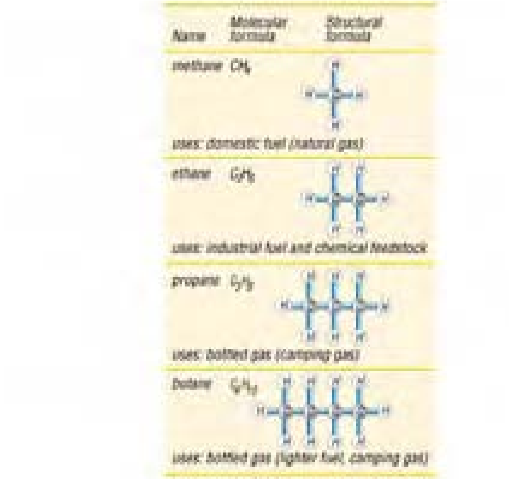
Substances in this group are included by custom rather than by scientific rules. Examples include morphine, cocaine, quinine, caffeine, strychnine, nicotine, and atropine.

In 1992, epibatidine, a chemical extracted from the skin of an Ecuadorean frog, was identified as a member of an entirely new class of alkaloid. It is an organochlorine compound, which is rarely found in animals, and a powerful painkiller, about 200 times as effective as morphine.

alkane

member of a group of hydrocarbons having the general formula C_nH_{2n+2}, commonly known as **paraffins**. As they contain only single covalent bonds, alkanes are said to be saturated. Lighter alkanes, such as methane, ethane, propane, and butane, are colourless gases; heavier ones are liquids or solids. In nature they are found in natural gas and petroleum.

alkane


Name
Molecular formula
Structural formula
methane CH_4
uses: domestic fuel (natural gas)
ethane C_2H_6
uses: industrial fuel and chemical feedstock
propane C_3H_8
uses: bottled gas (camping gas)
butane C_4H_{10}
uses: bottled gas (lighter fuel, camping gas)

(Image © Research Machines plc)

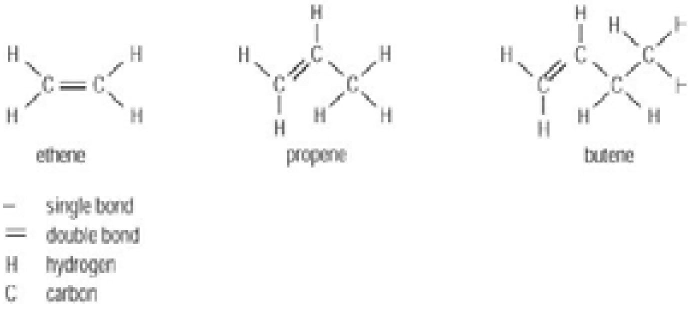
The lighter alkanes methane, ethane, propane, and butane, showing the aliphatic chains, where a hydrogen atom bonds to a carbon atom at all available sites.

---

alkene

member of the group of hydrocarbons having the general formula C_nH_{2n}, formerly known as **olefins**. Alkenes are unsaturated compounds, characterized by one or more double bonds between adjacent carbon atoms. Lighter alkenes, such as ethene and propene, are gases, obtained from the cracking of oil fractions. Alkenes react by addition, and many useful compounds, such as polythene and bromoethane, are made from them.

alkene


ethene
propene
butene
single bond
double bond
H hydrogen
C carbon

(Image © Research Machines plc)

The alkenes ethene (C_2H_4), propene ($CH_3CH{=}CH_2$), and butene (C_4H_8). Alkenes all have the general formula C_nH_{2n}.

---

alkyne

member of the group of hydrocarbons with the general formula C_nH_{2n-2}, formerly known as the **acetylenes**. They are unsaturated compounds, characterized by one or more triple bonds between adjacent carbon atoms. Lighter alkynes, such as ethyne, are gases; heavier ones are liquids or solids.

---

allele

one of two or more alternative forms of a gene at a given position (locus) on a chromosome, caused by a difference in the sequence of DNA. This is best explained with examples. A gene which controls eye colour in humans may have two alternative forms – an allele that can produce blue eyes, and an allele that produces brown eyes. In a plant that occurs in tall and short forms, there may be an allele that tends to produce tall plants and an alternative allele that produces short plants.

The individual genes that form a pair of alleles are located at exactly the same point along a chromosome. Organisms with two sets of chromosomes (diploids), such as animals and plants, have chromosomes that are found as matching pairs in the nucleus of each cell. This means that there will always be two genes for a characteristic in a cell. If the same allele is present twice, the organism is said to be homozygous for this characteristic. If, however, one chromosome contains one allele and the other chromosome a contrasting allele, the organism is said to be heterozygous.

In a heterozygous organism the appearance of the organism (phenotype) may be determined by one allele and not the other. The allele that determines the phenotype is said to be dominantly expressed; it shows dominance over other alleles. The expression of the other allele is described as being recessive.

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allergy

special sensitivity of the body that makes it react with an exaggerated response of the natural immune defence mechanism to the introduction of an otherwise harmless foreign substance (**allergen**).

Common allergies

Allergy is extremely widespread and now affects 1 in 4 of the UK population at some time during their lifetime. Each year the numbers are increasing by 5%. The most common allergy in the UK is hay fever which can occur at any age.

This table is meant as a guide only. Always consult a doctor if you have any concerns or doubts.

Allergy	Cause	Symptoms/comments
Pollen allergy (hay fever)	mainly grass and tree pollen	allergic rhinitis (running eyes and nose, sneezing, nasal congestion), eczema, urticaria (nettlerash or hives), and asthma; asthma symptoms range from mild to moderate or severe and can be life-threatening; people with the disease suffer 'attacks', or acute episodes, when the air passages in their lungs narrow and breathing becomes difficult; affects more than 3 million people in the UK, including one in every seven school children and one in every 25 adults
Dust-mite allergy	enzymes in the faeces of mites in house dust, feathers, pillows, and mattresses	symptoms as above, though they tend to be primarily respiratory in nature; affects about 5% of the UK population (1999)
Pet allergy	allergens in the pet's saliva, urine, or skin flakes, carried on its fur	symptoms as above
Mould allergy	spores from moulds growing in damp living spaces and on hay and cereal grain	symptoms as above, though they tend to be primarily respiratory in nature; moulds can be found both indoors and outdoors and allergies are often associated with pollen allergies
Insect bite or sting allergy	proteins in the venom	severe and prolonged swelling at the site of the sting, pain, and - in extreme cases - anaphylactic shock (respiratory difficulties, a rapid fall in blood pressure, and collapse, followed by loss of consciousness and even death); sufferers may also experience abdominal pain, vomiting, and diarrhoea
Food allergy	most commonly proteins in dairy foods, eggs, peanuts, true nuts, wheat and soya products, and shellfish, or to chemicals such as monosodium glutamate, tartrazine, sulphur dioxide, and sodium benzoate in food additives	eczema, urticaria, asthma, itching around the mouth, vomiting, diarrhoea, and - in extreme cases - anaphylactic shock (see above); the most visible signs of the onset of anaphylactic shock resulting from food allergies are often swelling and rashes on the lips and tongue; food allergy is often confused with food intolerance, which is not caused by the body's immune response but by its inability to digest a particular food (for example, lactose intolerance) or by adverse reactions to drug-like chemicals such as caffeine in coffee and amines in chocolate and cheese; peanut allergies affect about 0.5% of the UK population
Drug allergy	most commonly the antibiotics penicillin and tetracycline, sulfonamides, streptomycin, and local anaesthetics such as novocaine and lidocaine	signs of an allergic reaction include fever, urticaria, itchy nose, throat, or ears, and flushed skin; symptoms of a stronger reaction may include coughing, swelling - especially of the eyes or tongue, and cyanosis, a bluish tint of the skin; anaphylactic shock can be triggered by drugs like morphine or the dye injected prior to X-raying; the horse serum used in the makeup of some vaccines can also cause anaphylactic shock
Latex allergy	latex, the processed form of the milky sap derived from natural rubber trees, used mainly in gloves and many other medical products such as IV tubing and catheters, as well as in condoms, shoe soles, and swimming goggles	early symptoms include eczema, urticaria, and flushing, often followed by itching, congestion, eye irritation, wheezing, asthma, and progression into anaphylaxis; while direct skin contact is a problem, the allergen can also be inhaled - this occurs primarily when the gloves are removed and the protein which has combined with the powder inside the glove becomes airborne; those allergic to the following foods may also be sensitive to latex: avocados, bananas, potatoes, tomatoes, hazelnuts, chestnuts, kiwi, and papayas

Allergy Facts

Go to site

Extended fact sheet about allergies. It provides basic information about the causes, symptoms, and treatment of allergy attacks, and helps clarify typical misunderstandings about allergy sufferers. It also provides tips for the everyday life of an allergy sufferer and an extended list of allergy symptoms.

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alligator

(Spanish el lagarto 'the lizard')

reptile of the genus *Alligator*, related to the crocodile. There are only two living species: *A. mississipiensis*, the Mississippi alligator of the southern states of the USA, and *A. sinensis* from the swamps of the lower Chang Jiang River in China. The former grows to about 4 m/12 ft, but the latter only to 1.5 m/5 ft. Alligators lay their eggs in waterside nests of mud and vegetation and are good mothers. They swim well with lashing movements of the tail and feed on fish and mammals but seldom attack people.

Alligator skin is of value for fancy leather, and according to estimates released in December 2001, there are fewer than 130 Chinese alligators remaining in the wild. Numbers have been decreasing by 4-6% a year and alligator farms have been established in the USA.

Closely related are the caymans of South America; these belong to the genus *Caiman*. Alligators ranged across northern Europe from the Upper Cretaceous to the Pliocene period.

American Alligator

Go to site

Illustrated guide to the American alligator including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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allium

any of a group of plants of the lily family, usually strong-smelling with a sharp taste; they form bulbs in which sugar is stored. Cultivated species include onion, garlic, chive, and leek. Some species are grown in gardens for their decorative globular heads of white, pink, or purple flowers. (Genus *Allium*, family Liliaceae.)

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allometry

in biology, a regular relationship between a given feature (for example, the size of an organ) and the size of the body as a whole, when this relationship is not a simple proportion of body size. Thus, an organ may increase in size proportionately faster, or slower, than body size does. For example, a human baby's head is much larger in relation to its body than is an adult's.

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allopathy

(Greek allos 'other', pathos 'suffering')

in homeopathy, a term used for orthodox medicine, using therapies designed to counteract the manifestations of the disease. In strict usage, allopathy is the opposite of homeopathy.

---

allotropy

property whereby an element can exist in two or more forms (allotropes), each possessing different physical properties but the same state of matter (gas, liquid, or solid). The allotropes of carbon are diamond, fullerene, and graphite. Sulphur has several allotropes (flowers of sulphur, plastic, rhombic, and monoclinic). These solids have different crystal structures, as do the white and grey forms of tin and the black, red, and white forms of phosphorus.

Oxygen exists as two gaseous allotropes: the O_2 molecule which makes up 21% of the air we breathe, and the highly reactive ozone, O_3, which occurs in trace amounts as a pollutant and in the stratosphere.

---

alloy

metal blended with some other metallic or non-metallic substance to give it special qualities, such as resistance to corrosion, greater hardness, or tensile strength. The atoms in a metal are held together by the metallic bond. In a pure metal the atoms are all the same size and can slip over each other if a force is applied. In an alloy, the presence of different sized atoms prevents such dislocations from weakening the metal. Useful alloys include bronze, brass, cupronickel, duralumin, German silver, gunmetal, pewter, solder, steel, and stainless steel.

Among the oldest alloys is bronze (mainly an alloy of copper and tin), the widespread use of which ushered in the Bronze Age. Complex alloys are now common; for example, in dentistry, where a cheaper alternative to gold is made of chromium, cobalt, molybdenum, and titanium. Among the most recent alloys are superplastics: alloys that can stretch to double their length at specific temperatures, permitting, for example, their injection into moulds as easily as plastic.

Common alloys

Name	Approximate composition	Uses
brass	35-10% zinc, 65-90% copper	decorative metalwork, plumbing fittings, industrial tubing
bronze - common	2% zinc, 6% tin, 92% copper	machinery, decorative work
bronze - aluminium	10% aluminium, 90% copper	machinery castings
bronze - coinage	1% zinc, 4% tin, 95% copper	coins
cast iron	2-4% carbon, 96-98% iron	decorative metalwork, engine blocks, industrial machinery
dentist's amalgam	30% copper, 70% mercury	dental fillings
duralumin	0.5% magnesium, 0.5% manganese, 5% copper, 94% aluminium	framework of aircraft
gold - coinage	10% copper, 90% gold	coins
gold - dental	14-28% silver, 14-28% copper, 58% gold	dental fillings
lead battery plate	6% antimony, 94% lead	car batteries
manganin	1.5% nickel, 16% manganese, 82.5% copper	resistance wire
nichrome	20% chromium, 80% nickel	heating elements
pewter	20% lead, 80% tin	utensils
silver - coinage	10% copper, 90% silver	coins
solder	50% tin, 50% lead	joining metals
steel - stainless	8-20% nickel, 10-20% chromium, 60-80% iron	kitchen utensils
steel - armour	1-4% nickel, 0.5-2% chromium, 95-98% iron	armour plating
steel - tool	2-4% chromium, 6-7% molybdenum, 90-95% iron	tools

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allspice

spice prepared from the dried berries of the evergreen pimento tree, also known as the West Indian pepper tree, (*Pimenta dioica*) of the myrtle family, cultivated chiefly in Jamaica. It has an aroma similar to that of a mixture of cinnamon, cloves, and nutmeg.

Allspice

Go to site

Detailed information about allspice, including notes on the tree *Pimento officinalis* and its habitat. There are notes on the constituents of the tree and on its uses and preparations in medicine.

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alluvial deposit

layer of broken rocky matter, or sediment, formed from material that has been carried in suspension by a river or stream and dropped as the velocity of the current decreases. River plains and deltas are made entirely of alluvial deposits, but smaller pockets can be found in the beds of upland torrents.

Alluvial deposits can consist of a whole range of particle sizes, from boulders down through cobbles, pebbles, gravel, sand, silt, and clay. The raw materials are the rocks and soils of upland areas that are loosened by erosion and washed away by mountain streams. Much of the world's richest farmland lies on alluvial deposits. These deposits can also provide an economic source of minerals. River currents produce a sorting action, with particles of heavy material deposited first while lighter materials are washed downstream.

Hence heavy minerals such as gold and tin, present in the original rocks in small amounts, can be concentrated and deposited on stream beds in commercial quantities. Such deposits are called 'placer ores'.

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alluvial fan

roughly triangular sedimentary formation found at the base of slopes. An alluvial fan results when a sediment-laden stream or river rapidly deposits its load of gravel and silt as its speed is reduced on entering a plain.

The surface of such a fan slopes outward in a wide arc from an apex at the mouth of the steep valley. A small stream carrying a load of coarse particles builds a shorter, steeper fan than a large stream carrying a load of fine particles. Over time, the fan tends to become destroyed piecemeal by the continuing headward and downward erosion levelling the slope.

alluvial fan

(Image © Garret Nagle)

Alluvial fans are cone-shaped landforms that form at the base of slopes, near the mouth of a mountain canyon. Material is deposited by a river as it emerges from the gorge. There is a reduction in the velocity of the river, and it drops some of its load. The heavy, coarse material is deposited first, and the finest material is deposited later, further from the mountain face, helping to produce the conical slope.

Almagest

(Arabic al 'the' and a corruption of the Greek megiste 'greatest')

book compiled by the Egyptian astronomer Ptolemy during the 2nd century, which included the idea of an Earth-centred universe; it was translated into Arabic in the 9th century. Some medieval books on astronomy, astrology, and alchemy were given the same title.

Each of the 13 sections of the book deals with a different branch of astronomy. The introduction describes the universe as spherical and contains arguments for the Earth being stationary at the centre. From this mistaken assumption, it goes on to describe the motions of the Sun, Moon, and planets; eclipses; and the positions, brightness, and precession of the 'fixed stars'. The book drew on the work of earlier astronomers such as Hipparchus.

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almond

tree related to the peach and apricot. Dessert almonds, which can be eaten whole, are the kernels of the fruit of the sweet variety *Prunus amygdalus dulcis*, which is also used to produce a low-cholesterol cooking oil. Oil of bitter almonds, from the variety *P. amygdalus amara*, is used in flavouring. Bitter almonds contain hydrocyanic acid, which is poisonous and must be extracted before the oil can be processed. Almond oil is also used for cosmetics, perfumes, and fine lubricants. (*Prunus amygdalus*, family Rosaceae.)

Almonds

Go to site

Detailed information about the almond tree and its habitat. The place of the almond tree in history and mythology is discussed in detail, as is the tree itself. There are notes on its cultivation and even a selection of recipes in which it is used. It also features information about sweet and bitter almonds, including details of their constituents and, where relevant, uses in medicine.

---

aloe

one of a group of plants native to southern Africa, with long, fleshy, spiny-edged leaves. The drug usually referred to as 'bitter aloes' is a powerful purgative (agent that causes the body to expel impurities) prepared from the juice of the leaves of several of the species. (Genus *Aloe*, family Liliaceae.)

Aloes

Go to site

Contains a detailed text-only description of a number of types of aloes and their habitat. Their constituents are also described in detail, as are their medicinal uses. There are even notes on the preparation of the tincture made from the plant.

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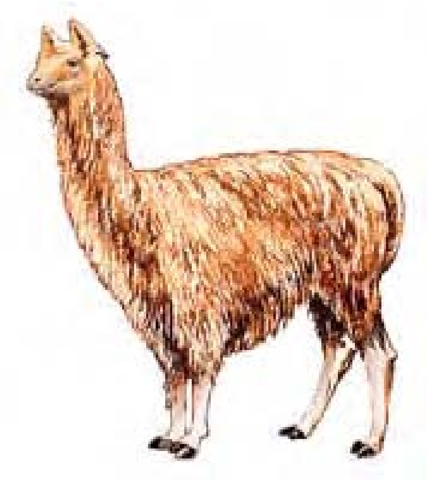
alpaca

domesticated South American hoofed mammal *Lama pacos* of the camel family, found in Chile, Peru, and Bolivia, and herded at high elevations in the Andes. It is bred mainly for its long, fine, silky wool, and stands about 1 m/3 ft tall at the shoulder with neck and head another 60 cm/2 ft.

The alpaca is also used for food at the end of its fleece-producing years. Like the llama, it was probably bred from the wild guanaco and is a close relative of the vicuna.

alpaca



(Image © Research Machines plc)

The alpaca is related to the llama, and has been known since 200 BC. The main breeding centre is around Lake Titicaca on the borders of Peru and Bolivia. It is sheared every two years and may provide up to 5 kg/11 lb of fine wool.

Alpha Centauri

brightest star in the constellation Centaurus; see Rigil Kent.

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alpha decay

spontaneous alteration of the nucleus of a radioactive atom, which transmutes the atom from one atomic number to another through the emission of a helium nucleus (known as an alpha particle). As a result, the atomic number decreases by two and the atomic weight decreases by four. See also radioactivity.

---

alpha particle

or alpha ray

positively charged (2+), high-energy particle emitted from the nucleus of a radioactive atom. It is one of the products of the spontaneous disintegration of radioactive elements (see radioactivity) such as radium and thorium, and is identical to the nucleus of a helium atom (^{4}He) - that is, it consists of two protons and two neutrons. The process of emission, **alpha decay**, transforms one element into another, decreasing the atomic number by two and the atomic mass by four. Plutonium-239 (^{239}Pu) is an example of a material that emits alpha particles.

Because of their large mass, alpha particles have a short range of only a few centimetres in air. They have a low penetrating power and can be stopped by a sheet of paper or aluminium. They have a strongly ionizing effect (see ionizing radiation) on the molecules that they strike, and are therefore capable of damaging living cells. Alpha particles travelling in a vacuum are deflected slightly by magnetic and electric fields.

Alps, Lunar

see Lunar Alps.

Alsatian

another name for the German shepherd dog.

Altair

or Alpha Aquilae

brightest star in the constellation Aquila and the 13th-brightest star in the night sky. It is a white star about 16 light years away from the Sun and forms the Summer Triangle with the stars Deneb (in the constellation Cygnus) and Vega (in Lyra).

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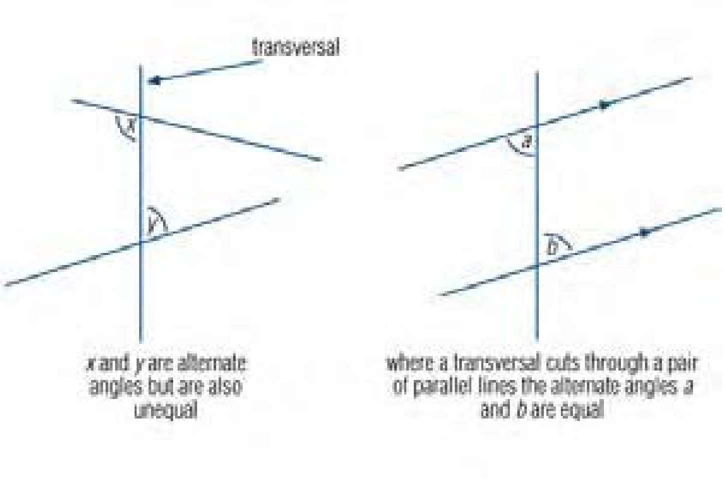
alternate angles

pair of angles that lie on opposite sides and at opposite ends of a transversal (a line that cuts two or more lines in the same plane). The alternate angles formed by a transversal of two parallel lines are equal.

alternate angles


transversal
x
y
a
b
x and y are alternate angles but are also unequal
where a transversal cuts through a pair of parallel lines the alternate angles a and b are equal

(Image © Research Machines plc)

Where a transversal (a line that cuts two or more lines in the same plane) cuts through a pair of parallel lines, the alternate angles *a* and *b* are equal.

---

alternating current

AC

electric current that flows for an interval of time in one direction and then in the opposite direction; that is, a current that flows in alternately reversed directions through or around a circuit. Electric energy is usually generated as alternating current in a power station, and alternating currents may be used for both power and lighting.

If half an amp moves in one direction past a point in half a second and in the next half a second half an amp reverses and moves past the same point in the opposite direction, then in total one coulomb of electrons or one amp has passed the point in one second. The current flow is 1 amp AC.

The advantage of alternating current over direct current (DC), as from a battery, is that its voltage can be raised or lowered economically by a transformer; high voltage for generation and transmission, and low voltage for safe utilization. Railways, factories, and domestic appliances, for example, use alternating current.

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alternation of generations

typical life cycle of terrestrial plants and some seaweeds, in which there are two distinct forms occurring alternately: **diploid** (having two sets of chromosomes) and **haploid** (one set of chromosomes). The diploid generation produces haploid spores by meiosis, and is called the sporophyte, while the haploid generation produces gametes (sex cells), and is called the gametophyte. The gametes fuse to form a diploid zygote which develops into a new sporophyte; thus the sporophyte and gametophyte alternate.

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alternative medicine

see medicine, alternative.

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alternator

electricity generator that produces an alternating current.

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altimeter

instrument used in aircraft that measures altitude, or height above sea level. The common type is a form of aneroid barometer, which works by sensing the differences in air pressure at different altitudes. This must continually be recalibrated because of the change in air pressure with changing weather conditions. The radar altimeter measures the height of the aircraft above the ground, measuring the time it takes for radio pulses emitted by the aircraft to be reflected. Radar altimeters are essential features of automatic and blind-landing systems.

altitude

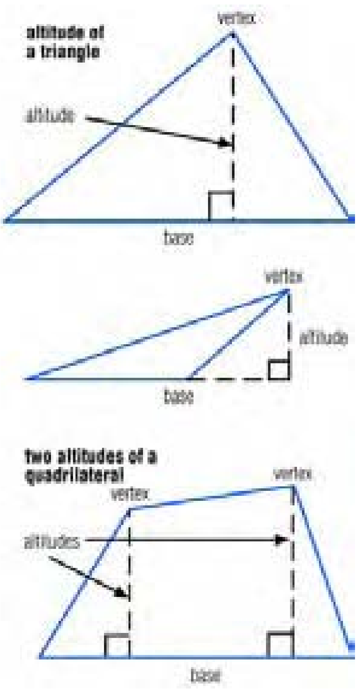
or elevation

in astronomy, angular distance of an object above the horizon, ranging from 0° on the horizon to 90° at the zenith. Together with the azimuth, it forms a system of horizontal coordinates for specifying the positions of celestial bodies.

altitude

in geometry, the perpendicular distance from a vertex (corner) of a figure, such as a triangle, to the base (the side opposite the vertex).

altitude



(Image © Research Machines plc)

The altitude of a figure is the perpendicular distance from a vertex (corner) to the base (the side opposite the vertex).

altitude

measurement of height, usually given in metres (or feet) above sea level.

altruism

in biology, helping another individual of the same species to reproduce more effectively, as a direct result of which the altruist may leave fewer offspring itself. Female honey bees (workers) behave altruistically by rearing sisters in order to help their mother, the queen bee, reproduce, and forgo any possibility of reproducing themselves.

ALU

abbreviation for arithmetic and logic unit.

alum

any double sulphate of a monovalent metal or radical (such as sodium, potassium, or ammonium) and a trivalent metal (such as aluminium, chromium, or iron). The commonest alum is the double sulphate of potassium and aluminium, $K_2Al_2(SO_4)_4.24H_2O$, a white crystalline powder that is readily soluble in water. It is used in curing animal skins. Other alums are used in papermaking and to fix dyes in the textile industry.

alumina

or corundum; Al_2O_3

oxide of aluminium, widely distributed in clays, slates, and shales. It is formed by the decomposition of the feldspars in granite and used as an abrasive. Typically it is a white powder, soluble in most strong acids or caustic alkalis but not in water. Impure alumina is called 'emery'. Rubies, sapphires, and topaz are corundum gemstones. It is the chief component of bauxite.

aluminium

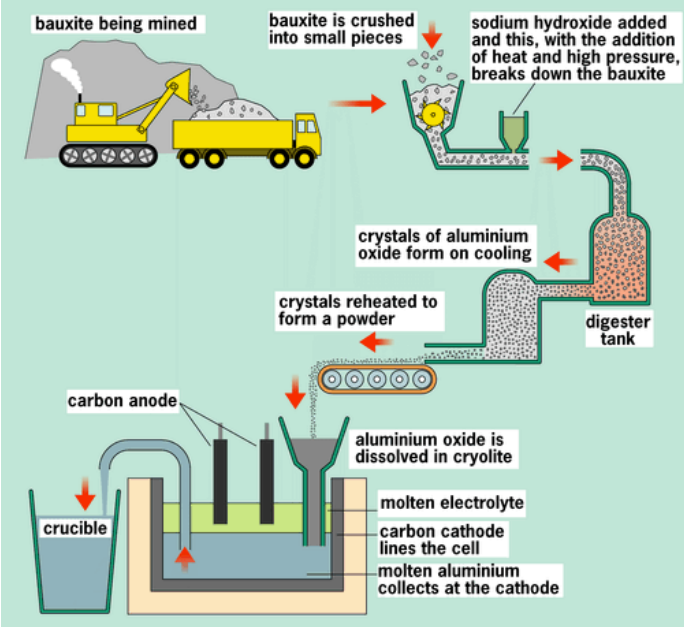
chemical symbol Al

lightweight, silver-white, ductile and malleable, metallic element, atomic number 13, relative atomic mass 26.9815, melting point 658°C/1,216°F. It is the third most abundant element (and the most abundant metal) in the Earth's crust, of which it makes up about 8.1% by mass. It is non-magnetic, an excellent conductor of electricity, and oxidizes easily, the layer of oxide on its surface making it highly resistant to tarnish.

pure aluminium

Aluminium is a reactive element which forms stable compounds, so a great deal of energy is needed in order to separate aluminium from its ores, and the pure metal was not readily obtainable until the middle of the 19th century. Commercially, it is prepared by the electrolysis of alumina (aluminium oxide), which is obtained from the ore bauxite. In its pure state aluminium is a weak metal, but when combined with elements such as copper, silicon, or magnesium it forms alloys of great strength.

aluminium


bauxite being mined
bauxite is crushed into small pieces
sodium hydroxide added and this, with the addition of heat and high pressure, breaks down the bauxite
crystals of aluminium oxide form on cooling
crystals reheated to form a powder
digester tank
carbon anode
aluminium oxide is dissolved in cryolite
molten electrolyte
crucible
carbon cathode lines the cell
molten aluminium collects at the cathode

(Image © Research Machines plc)

The extraction of aluminium is a two-stage process. In the first stage bauxite is crushed to extract aluminium oxide (alumina). In the second stage pure aluminium is extracted from the alumina by electrolysis.

aluminium ore

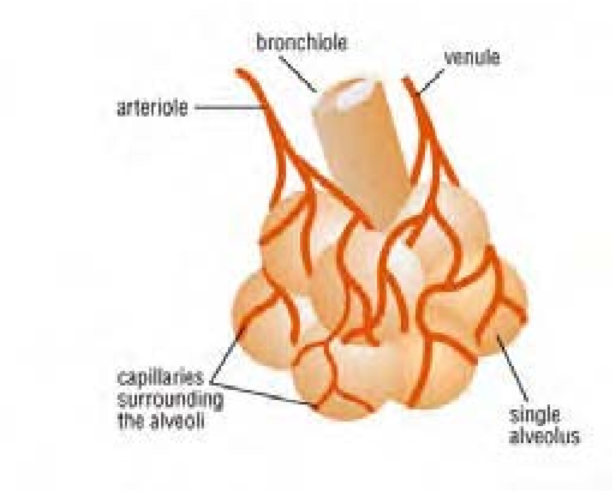
raw material from which aluminium is extracted. The main ore is bauxite, a mixture of minerals, found in economic quantities in Australia, Guinea, the West Indies, and several other countries.

alveolus

plural alveoli

one of the many thousands of tiny air sacs in the lungs. By the process of diffusion oxygen is transported from air in the alveoli into the blood, while carbon dioxide diffuses out of the blood and into the air in the alveoli. This process is called gas exchange. To aid this process, the alveoli have very thin walls, which are folded in order to increase their surface area and allow rapid gas exchange, and are surrounded by blood capillaries. The air in the alveoli is replenished as a result of breathing or ventilation. Smoking and exposure to other pollutants can cause the loss of the folds in the alveoli, which causes difficulties in breathing and the condition called emphysema.

alveolus



(Image © Research Machines plc)

The tiny air sacs, called alveoli, in the lungs are covered with a network of blood capillaries, allowing oxygen to enter the blood. The alveoli of an adult have a total surface area of 70 sq m/750 sq ft.

Alzheimer's disease

common manifestation of dementia, thought to afflict 1 in 20 people over 65. After heart disease, cancer, and strokes it is the most common cause of death in the Western world. Attacking the brain's 'grey matter', it is a disease of mental processes rather than physical function, characterized by memory loss and progressive intellectual impairment. It was first described by Alois Alzheimer in 1906. Dementia affects nearly 18 million people worldwide, 66% of whom live in developed countries; this includes some 4 million people in the USA, and over 750,000 in Britain (2001). Numbers are expected to rise with the world's ageing population, reaching an estimated 34 million worldwide by 2025.

causes

Various factors have been implicated in causing Alzheimer's disease including high levels of aluminium in drinking water and the presence in the brain of an abnormal protein, known as beta-amyloid.

In 1993 the gene coding for apolipoprotein (APOE) was implicated. US researchers established that people who carry a particular version of this gene (APOE-E4) are at greatly increased risk of developing the disease. It is estimated that one person in thirty carries this protein mutation; in the USA the figure is as high as 15%. The suspect gene can be detected with a test, so it is technically possible to identify those most at risk. As no cure is available such testing is unlikely to be widespread.

A second Alzheimer's gene was identified in 1997. The gene, HLA-A2, increases the speed at which the disease begins. The *Neurology* report stated that if a person has both HLA-A2 and APOE-E4, he or she may reach dementia a decade earlier than those with only one of the genes.

In December 1999, after successful animal trials, a US trial was approved to ascertain whether gene therapy can be used to slow the development of Alzheimer's disease.

In 1999 researchers in Boston, Massachusetts, discovered an enzyme, presenilin, that produces protein plaques associated with the disease. Presenilin opens up the amyloid parent protein (APP) that then releases beta-amyloid, or A-beta.

diagnosis

US researchers began trialling a simple eye test in 1994 that could be used to diagnose sufferers. The drug tropicamide causes marked pupil dilation in those with the disease, and only slight dilation in healthy individuals.

treatment

Some researchers are convinced that, whatever its cause, Alzheimer's disease is essentially an inflammatory condition, similar to rheumatoid arthritis. Although there is no cure, trials of anti-inflammatory drugs have shown promising results. Also under development are drugs which block the toxic effects of beta-amyloid. A 1996 study by US neuroscientists found that oestrogen skin patches were also beneficial in the treatment of female Alzheimer's patients, improving concentration and memory.

Alzheimer's Disease

Go to site

Fact sheet provided by the US National Institute of Neurological Disorders and Strokes. An overview of the disease is presented, along with comments about research into a cure, and links to other useful resources for those interested in learning more.

'Science, Medicine, and the Future: Alzheimer's Disease'

Go to site

Part of a collection of articles maintained by the British Medical Journal, this page features the full text of a 7 February 1998 clinical review regarding the causes of Alzheimer's disease and recent advances in the understanding and care, as well as the future treatment, of the disease. The text includes diagrams. In addition to the clinical review, you will find a list of related articles from the extensive PubMed collection. You can also search the collections under which this article appears, search other articles written by the authors of this article, and submit or read responses to this article. There is a list of references at the bottom of the article.

AM

in physics, abbreviation for amplitude modulation.

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amalgam

any alloy of mercury with other metals. Most metals will form amalgams, except iron and platinum. Amalgam is used in dentistry for filling teeth, and usually contains copper, silver, and zinc as the main alloying ingredients. This amalgam is pliable when first mixed and then sets hard, but the mercury leaches out and may cause a type of heavy-metal poisoning.

Amalgamation, the process of forming an amalgam, is a technique sometimes used to extract gold and silver from their ores. The ores are ground to a fine sand and brought into contact with mercury, which dissolves the gold and silver particles. The amalgam is then heated to distil off the mercury, leaving a residue of silver and gold. The mercury is recovered and reused.

Amalgamation to extract gold from its ore has been in use since Roman times.

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amanita

any of a group of fungi (see fungus) distinguished by a ring (or volva) around the base of the stalk, warty patches on the cap, and the clear white colour of the gills. Many of the species are brightly coloured and highly poisonous. (Genus *Amanita*, family Agaricaceae.)

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amber

fossilized resin from coniferous trees of the Middle Tertiary period. It is often washed ashore on the Baltic coast with plant and animal specimens preserved in it; many extinct species have been found preserved in this way. It ranges in colour from red to yellow, and is used to make jewellery.

When amber is rubbed with cloth, it attracts light objects, such as feathers. The effect, first noticed by the ancient Greeks, is due to acquisition of negative electric charge, hence the adaptation of the Greek word for amber, *elektron*, for electricity (see static electricity).

Amber has been coveted for its supposed special properties since prehistoric times. Archaeologists have found amulets made of amber dating back as far as 35000 BC.

Amber's preservative properties were demonstrated 1992 when DNA was extracted from insects estimated to be around 30 million years old which were found fossilized in amber, and in 1995 US scientists succeeded in extracting bacterial spores from a bee in amber that was 40 million years old. Despite their lengthy dormancy, the bacterial spores were successfully germinated.

World of Amber

Go to site

Everything you need to know about amber is here. There is information on its physical properties, uses, and geological and geographical occurrences, plus fossils in amber, recovery methods, amber myths, museums, and a quiz.

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ambergris

fatty substance, resembling wax, found in the stomach and intestines of the sperm whale. It is found floating in warm seas, and is used in perfumery as a fixative.

Basically intestinal matter, ambergris is not the result of disease, but the product of an otherwise normal intestine. The name derives from the French *ambre gris* (grey amber).

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amblyopia

dimness of vision without apparent eye disorder.

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ameba

any of a number of one-celled organisms, especially of the genus *Amoeba*, that move and feed by extensions of their colorless gelatinous protoplasm. They reproduce by binary fission. Some members of the genus *Entamoeba* are harmful parasites.

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americium

chemical symbol Am

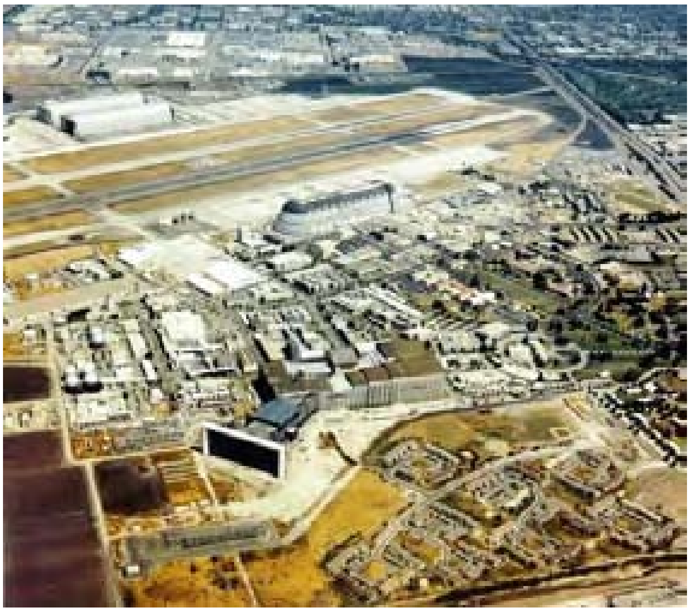
radioactive metallic element of the actinide series, atomic number 95, relative atomic mass 243.13; it was first synthesized in 1944. It occurs in nature in minute quantities in pitchblende and other uranium ores, where it is produced from the decay of neutron-bombarded plutonium, and is the element with the highest atomic number that occurs in nature. It is synthesized in quantity only in nuclear reactors by the bombardment of plutonium with neutrons. Its longest-lived isotope is Am-243, with a half-life of 7,650 years.

The element was named by US nuclear chemist Glenn Seaborg, one of the team who first synthesized it, by analogy with europium, the corresponding lanthanide. Ten isotopes are known.

Ames Research Center

NASA space-research field centre at Moffett Field, California, for the study of aeronautics and life sciences. It was established in 1939 as the Ames Aeronautical Laboratory, part of the National Advisory Committee for Aeronautics, and became part of NASA in 1958. Ames managed the Pioneer probe series, designed the Galileo probe, and is involved in the search for extraterrestrial life. Its passive dosimeter system (PDS) monitors radiation on the *International Space Station*. A research park houses facilities of collaborating universities.

Ames Research Center



(Image © NASA)

Aerial view of NASA's Ames Research Center. The large building just below the centre of the photograph is the facility's wind tunnel; beyond, at the edge of the Ames-operated Moffett Federal Airfield, is the vast airship or 'blimp' hangar.

Ames Research Center

Go to site

Latest news of Ames's space-technology and astrobiology research. These pages outline the purpose of astrobiology, future missions, and techniques. The 'Ask an Astrobiologist' feature allows registered users to put questions to top astrobiologists and participate in online discussions. The site is also a useful gateway to other astrobiology resources.

amethyst

variety of quartz, SiO_2, coloured violet by the presence of small quantities of impurities such as manganese or iron; used as a semi-precious stone. Amethysts are found chiefly in the Ural Mountains, India, the USA, Uruguay, and Brazil.

amide

any organic chemical derived from a carboxylic acid by the replacement of the hydroxyl group ($—OH$) by an amino group ($—NH_2$).

One of the simplest amides is ethanamide (acetamide, CH_3CONH_2), which has a strong odour.

amine

any of a class of organic chemical compounds in which one or more of the hydrogen atoms of ammonia (NH_3) have been replaced by other groups of atoms.

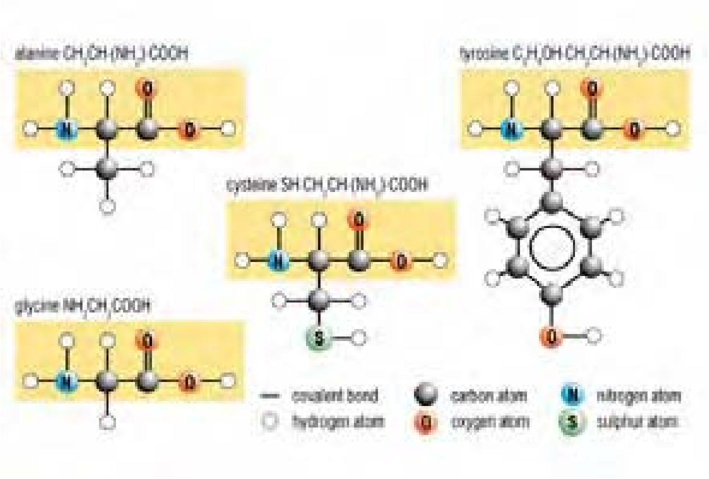
Depending on the number of hydrogens replaced by an organic molecule, one distinguishes between primary, secondary, and tertiary amines. All three types tend to be stronger bases than ammonia, with secondary amines the strongest. The NH_2 functionality of a primary amine is called an amino group, while the NH of secondary amines is known as an imino group.

amino acid

water-soluble organic molecule, mainly composed of carbon, oxygen, hydrogen, and nitrogen, containing both a basic amino group (NH_2) and an acidic carboxyl (COOH) group. They are small molecules able to pass through membranes. When two or more amino acids are joined together, they are known as peptides; proteins are made up of peptide chains folded or twisted in characteristic shapes.

Many different proteins are found in the cells of living organisms, but they are all made up of the same 20 amino acids, joined together in varying combinations (although other types of amino acid do occur infrequently in nature). Eight of these, the **essential amino acids**, cannot be synthesized by humans and must be obtained from the diet. Children need a further two amino acids that are not essential for adults. Other animals also need some preformed amino acids in their diet, but green plants can manufacture all the amino acids they need from simpler molecules, relying on energy from the Sun and minerals (including nitrates) from the soil.

amino acid



(Image © Research Machines plc)

Amino acids are natural organic compounds that make up proteins and can thus be considered the basic molecules of life. There are 20 different common amino acids. They consist mainly of carbon, oxygen, hydrogen, and nitrogen. Each amino acid has a common core structure (consisting of two carbon atoms, two oxygen atoms, a nitrogen atom, and four hydrogen atoms) to which is attached a variable group, known as the R group. In glycine, the R group is a single hydrogen atom; in alanine, the R group consists of a carbon and three hydrogen atoms (methyl group).

amino acid: essential

To remember the ten essential amino acids:

These **t**en **v**aluable **a**mino acids **h**ave **l**ong **p**reserved **l**ife **i**n **m**an

Threonine, **t**ryptophan, **v**aline, **a**rgenine, **h**istidine, **l**ysine, **p**henylalanine, **l**eucine, **i**soleucine, **m**ethionine

amino acid: properties

To remember the properties of amino acids:

(1) **H**ot **n**ews: **g**irls **a**re **v**ery **l**oving **if** **m**en **c**an **p**repare **p**erfect **t**ea (2) **P**olka - **a** **g**reat **s**tep **t**o **t**ry (3) **N**ails **l**eave **a** **h**ole (4) **N**ever **a**nger **g**orillas

(1) **H**ydrophilic **n**eutral - **g**lycine, **a**lanine, **v**aline, **l**eucine, **i**soleucine, **m**ethionine, **c**ysteine, **p**roline, **p**henylalanine, **t**ryptophan (2) **P**ositive - **a**sparagine, **g**lutamine, **s**erine, **t**hreonine, **t**yrosine (3) **N**eutral - **l**ysine, **a**rginine, **h**istidine (4) **N**egative - **a**spartate, **g**lutamate

Amino Acids

Go to site

Small but interesting site giving the names and chemical structures of all the common amino acids. The information is available in both English and German.

Molecular Expressions: The Amino Acid Collection

Go to site

Fascinating collection of images showing what all the known amino acids look like when photographed through a microscope. There is also a detailed article about the different amino acids.

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ammeter

instrument that measures electric current (flow of charge per unit time), usually in amperes, through a conductor. It should not to be confused with a voltmeter, which measures potential difference between two points in a circuit. The ammeter is placed in series (see series circuit) with the component through which current is to be measured, and is constructed with a low internal resistance in order to prevent the reduction of that current as it flows through the instrument itself. A common type is the moving-coil meter, which measures direct current (DC), but can, in the presence of a rectifier (a device which converts alternating current to direct current), measure alternating current (AC) also. Hot-wire, moving-iron, and dynamometer ammeters can be used for both DC and AC.

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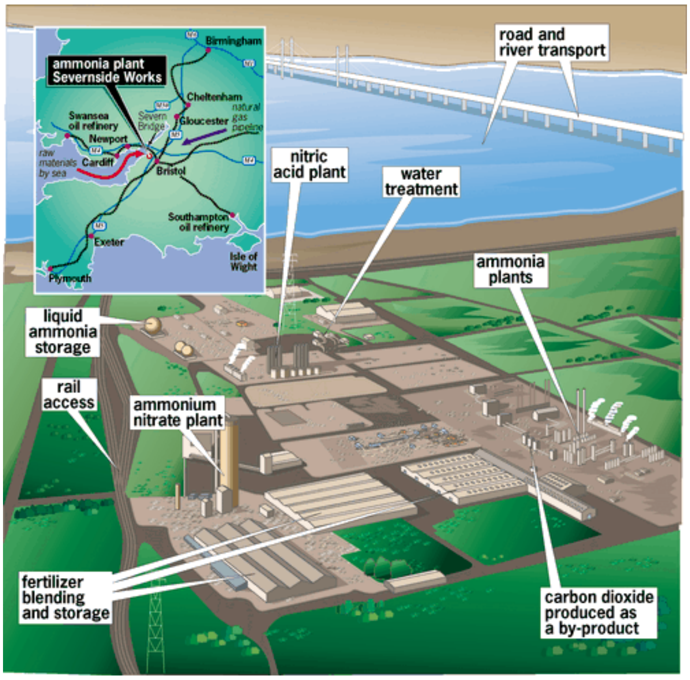
ammonia

NH_3

colourless pungent-smelling gas, lighter than air and very soluble in water. It is made on an industrial scale by the Haber (or Haber-Bosch) process, and used mainly to produce nitrogenous fertilizers, nitric acid, and some explosives.

In aquatic organisms and some insects, nitrogenous waste (from the breakdown of amino acids) is excreted in the form of ammonia, rather than as urea in mammals.

ammonia


road and river transport
ammonia plant Severnside Works
Birmingham
M6
M5
Cheltenham
M50
natural gas pipeline
Swansea oil refinery
Severn Bridge
Gloucester
M5
Newport
M4
raw materials by sea
Cardiff
Bristol
M4
Southampton oil refinery
M5
Exeter
Isle of Wight
Plymouth
nitric acid plant
water treatment
ammonia plants
liquid ammonia storage
rail access
ammonium nitrate plant
fertilizer blending and storage
carbon dioxide produced as a by-product

(Image © Research Machines plc)

The Severnside Works on the banks of the Bristol Channel is a plant for the manufacture of ammonia and ammonia products. Its location was chosen as it is accessible by road, river, and rail, so raw materials and finished products can be easily transported.

ammonite

extinct marine cephalopod mollusc of the order Ammonoidea, related to the modern nautilus. The shell was curled in a plane spiral and made up of numerous gas-filled chambers, the outermost containing the body of the animal. Many species flourished between 200 million and 65 million years ago, ranging in size from that of a small coin to 2 m/6 ft across.

amnesia

loss or impairment of memory. As a clinical condition it may be caused by disease or injury to the brain, by some drugs, or by shock; in some cases it may be a symptom of an emotional disorder.

amniocentesis

sampling the amniotic fluid surrounding a fetus in the womb for diagnostic purposes. It is used to detect Down's syndrome and other genetic abnormalities. The procedure carries a 1 in 200 risk of miscarriage.

amniotic fluid

in mammals, fluid consisting mainly of water that is produced by the amnion, a fibrous membrane that lines the cavity of the uterus during pregnancy, in which the fetus floats and is protected from external pressure. It is swallowed by the fetus and excreted by the kidneys back into the amniotic sac. In humans, there is about 0.5-1 l/0.8-1.75 pt of amniotic fluid. The amniotic sac normally ruptures in early labour to release the fluid (the 'waters').

ampere

symbol A

SI unit of electrical current. Electrical current (a flow of negative charge) is measured in a similar way to water current, in terms of an amount per unit time; one ampere (amp) represents a flow of one coulomb per second, which is about 6.28×10^{18} electrons per second.

When a charge (Q) of one coulomb is flowing at a given point in a material in a time (t) of one second, a current (I) of one ampere is flowing. This can be represented as a formula: $Q = I \times t$. The instrument used to measure the flow of current through a conductor is called an ammeter.

The ampere is defined as the current that produces a specific magnetic force (2×10^{-7} newtons per metre) between two long, straight, parallel conductors placed 1 m/3.3 ft apart in a vacuum. It is named after the French scientist André Ampère.

Ampère, André-Marie (1775-1836)

French physicist and mathematician who made many discoveries in electromagnetism and electrodynamics. He followed up the work of Hans Oersted on the interaction between magnets and electric currents, developing a rule for determining the direction of the magnetic field associated with an electric current. The unit of electric current, the ampere, is named after him.

Ampère's law is an equation that relates the magnetic force produced by two parallel current-carrying conductors to the product of their currents and the distance between the conductors. Today Ampère's law is usually stated in the form of calculus: the line integral of the magnetic field around an arbitrarily chosen path is proportional to the net electric current enclosed by the path.

Ampère, André

Go to site

Biography and portrait of the famous French physicist and mathematician. This Web site also contains a brief history of Ampère's work and a list of 24 publications that may be used as a reference source.

Ampère's rule

rule developed by French physicist André-Marie Ampère connecting the direction of an electric current and its associated magnetic currents. It states that around a wire carrying a current towards the observer, the magnetic field curls in the anticlockwise direction. This assumes the conventional direction of current flow (from the positive to the negative terminal of a battery).

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amphetamine

or speed

powerful synthetic stimulant. Benzedrine was the earliest amphetamine marketed, used as a 'pep pill' in World War II to help soldiers to overcome fatigue, and until the 1970s amphetamines were prescribed by doctors as an appetite suppressant for weight loss; as an antidepressant, to induce euphoria; and as a stimulant, to increase alertness.

Indications for its use today are very restricted because of severe side effects, including addiction. It is a sulphate or phosphate form of $C_9H_{13}N$.

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amphibian

(Greek 'double life')

member of the vertebrate class Amphibia, which generally spend their larval (tadpole) stage in fresh water, transferring to land at maturity (after metamorphosis) and generally returning to water to breed. Like fish and reptiles, they continue to grow throughout life, and cannot maintain a temperature greatly differing from that of their environment. The class contains about 4,500 known species, 4,000 of which are frogs and toads, 390 salamanders, and 160 caecilians (wormlike in appearance).

According to analysis of statistics from over 900 amphibian populations taken 1950-97, by Canadian and Swiss researchers, and published in 2000, amphibian populations have been declining at a rate of about 4% per year. US biologists concluded that the marked worldwide decline in amphibian populations is unlikely to have a single cause. Possible causes have been cited as increased ultraviolet radiation exposure, pollution, global climate change, and infection.

amphibian

Frogs and toads never eat with their eyes open. When eating, they have to push down with the back of the eyeball in order to force food into the stomach.

Classification of amphibians

Order	Number of species	Examples
Apoda	170	caecilians
Anura	4,000	frogs, toads
Urodela	390	axolotl, mudpuppies, newts, salamanders

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amphibole

any one of a large group of rock-forming silicate minerals with an internal structure based on double chains of silicon and oxygen, and with a general formula $X_2Y_5Si_8O_{22}(OH)_2$; closely related to pyroxene.

Amphiboles form orthorhombic, monoclinic, and triclinic crystals.

Amphiboles occur in a wide range of igneous and metamorphic rocks. Common examples are hornblende (*X* = Ca, *Y* = Mg, Fe, Al) and tremolite (*X* = Ca, *Y* = Mg).

amphoteric

of a chemical compound, being able to behave either as an acid or as a base depending on their environment. For example, the metals aluminium and zinc, and the oxides and hydroxides, act as bases in acidic solutions and as acids in alkaline solutions.

Amino acids and proteins are also amphoteric, as they contain both a basic (amino, $—NH_2$) and an acidic (carboxyl, —COOH) group.

amplifier

electronic device that increases the strength of a signal, such as a radio signal. The ratio of output signal strength to input signal strength is called the gain of the amplifier. As well as achieving high gain, an amplifier should be free from distortion and able to operate over a range of frequencies. Practical amplifiers are usually complex circuits, although simple amplifiers can be built from single transistors or valves.

amplitude

or argument

in mathematics, the angle in an Argand diagram between the line that represents the complex number and the real (positive horizontal) axis. If the complex number is written in the form $r(\cos\theta + i \sin\theta)$, where r is radius and $i = \sqrt{(-1)}$, the amplitude is the angle θ (theta).

The amplitude is also the peak value of an oscillation.

amplitude

in physics, maximum displacement of an oscillation from the equilibrium position. For a transverse wave motion, as in electromagnetic waves, it is the height of a crest (or the depth of a trough). For a longitudinal wave, such as a sound wave, amplitude is the maximum distance a particle is pushed (due to compression) or pulled (due to rarefaction) from its resting position. A quiet sound has a lower amplitude and a loud sound has a higher amplitude. For a louder sound, more sound energy enters the ear every second. Amplitude is generally denoted by a.

AM (amplitude modulation) radio broadcasting is a method of transmitting audio-frequency signals that would otherwise travel not very far in space on their own and would have to be transmitted one at a time. The amplitude of the low-frequency audio signal is made to modulate (vary slightly) the amplitude of a continuously transmitted radio **carrier wave** of a higher frequency. In this way the **modulating signal** is imprinted on the carrier wave.

amplitude modulation

AM

method by which radio waves carry information. AM waves are constant in frequency, but the amplitude of the transmitting wave continually varies in accordance with the signal being broadcast.

amyl alcohol

former name for pentanol.

amylase

enzyme that breaks down starch into a complex sugar that can be used in the body. It occurs widely in both plants and animals. In humans it is found in saliva and in the pancreatic digestive juices that drain into the alimentary canal.

Starch is an important food for humans and is found in plants such as potatoes and in wheat grains. It is made of large and insoluble molecules, but under the action of amylase produces sugars that are soluble – these can be absorbed by the body.

Human amylase has an optimum pH of 7.2–7.4. Like most enzymes amylase is denatured by temperatures above 60°C.

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anabolic steroid

any hormone of the steroid group that stimulates muscular tissue growth. Its use in medicine is limited to the treatment of some anaemias and breast cancers; it may help to break up blood clots. Side effects include aggressive behaviour, masculinization in women, and, in children, reduced height.

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anabolism

process of building up body tissue, promoted by the influence of certain hormones. It is the constructive side of metabolism, as opposed to catabolism.

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anaconda

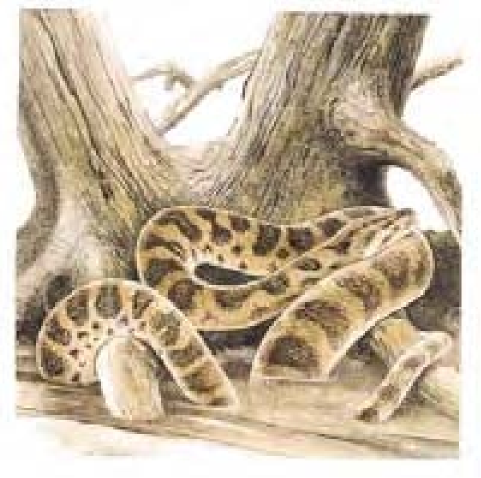
South American snake *Eunectes murinus*, a member of the python and boa family, the Boidae. One of the largest snakes, growing to 9 m/30 ft or more, it is found in and near water, where it lies in wait for the birds and animals on which it feeds. The anaconda is not venomous, but kills its prey by coiling round it and squeezing until the creature suffocates.

Females are up to 5 times larger than males. They have litters of up to 80 young, born live, and each weighing only 250-300 g. The gestation period last six to eight months, during which time the female will not eat at all.

anaconda

When anacondas mate, up to 12 males form a breeding ball around the female. They may stay entangled for up to 4 weeks.

anaconda



(Image © Research Machines plc)

The anaconda is a climber as well as a swimmer, and may be found in trees along river banks. Males attract mates by making booming noises. The young develop in thin-shelled eggs inside the mother, hatching as she lays them and emerging as live young.

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anaemia

condition caused by a shortage of haemoglobin, the oxygen-carrying component of red blood cells. The main symptoms are fatigue, pallor, breathlessness, palpitations, and poor resistance to infection. Treatment depends on the cause.

Anaemia arises either from abnormal loss or defective production of haemoglobin. Excessive loss occurs, for instance, with chronic slow bleeding or with accelerated destruction (haemolysis) of red blood cells. Defective production may be due to iron deficiency, vitamin B_{12} deficiency (pernicious anaemia), certain blood diseases (sickle-cell anaemia and thalassaemia), chronic infection, kidney disease, or certain kinds of poisoning. Untreated anaemia taxes the heart and may prove fatal.

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anaerobic

not requiring oxygen for the release of energy from food molecules such as glucose. An organism is described as anaerobic if it does not require oxygen in order to survive. Instead, anaerobic organisms use anaerobic respiration to obtain energy from food. Most anaerobic organisms are micro-organisms such as bacteria, yeasts, and internal parasites that live in places where there is never much oxygen, such as in the mud at the bottom of a lake or pond, or in the alimentary canal. Anaerobic organisms release much less of the available energy from their food than do aerobic organisms.

Obligate anaerobes, such as certain primitive bacteria, cannot function in the presence of oxygen, but **facultative anaerobes**, such as the fermenting yeasts and most bacteria, can function with or without oxygen.

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anaesthetic

drug that produces loss of sensation or consciousness; the resulting state is **anaesthesia**, in which the patient is insensitive to stimuli. Anaesthesia may also happen as a result of nerve disorder.

Ever since the first successful operation in 1846, on a patient rendered unconscious by ether, advances have been aimed at increasing safety and control. Sedatives may be given before the anaesthetic to make the process easier. The level and duration of unconsciousness are managed precisely. Where general anaesthesia may be inappropriate (for example, in childbirth, for a small procedure, or in the elderly), many other techniques are available. A topical substance may be applied to the skin or tissue surface; a local agent may be injected into the tissues under the skin in the area to be treated; or a regional block of sensation may be achieved by injection into a nerve. Spinal anaesthetic, such as epidural, is injected into the tissues surrounding the spinal cord, producing loss of feeling in the lower part of the body.

anaesthetic

Although the science of anaesthetics is 150 years old, it is only comparatively recently that safe doses have begun to be calculated correctly. It is said that when the Japanese bombed Pearl Harbor in 1941, more US servicemen were killed by anaesthetists than by bombs.

Virtual Anaesthesia Textbook

Go to site

Huge source of information on all aspects of anaesthesia. Though primarily designed for anaesthetists, a non-medical reader wishing to learn about the history and practice of modern anaesthetics would find a lot of interest on this massive site. A search engine facilitates navigation. There are also links to anaesthesia sites around the world.

---

analgesic

agent for relieving pain. Opiates alter the perception or appreciation of pain and are effective in controlling 'deep' visceral (internal) pain. Non-opiates, such as aspirin, paracetamol, and NSAIDs (nonsteroidal anti-inflammatory drugs), relieve musculoskeletal pain and reduce inflammation in soft tissues.

Pain is felt when electrical stimuli travel along a nerve pathway, from peripheral nerve fibres to the brain via the spinal cord. An anaesthetic agent acts either by preventing stimuli from being sent (local), or by removing awareness of them (general). Analgesic drugs act on both.

Temporary or permanent analgesia may be achieved by injection of an anaesthetic agent into, or the severing of, a nerve. Implanted devices enable patients to deliver controlled electrical stimulation to block pain impulses. Production of the body's natural opiates, endorphins, can be manipulated by techniques such as relaxation and biofeedback. However, for the severe pain of, for example, terminal cancer, opiate analgesics are required.

---

analogous

in biology, term describing a structure that has a similar function to a structure in another organism, but not a similar evolutionary path. For example, the wings of bees and of birds have the same purpose – to give powered flight – but have different origins. Compare homologous.

---

analogue

(of a quantity or device) changing continuously; by contrast, a digital quantity or device varies in series of distinct steps. For example, an analogue clock measures time by means of a continuous movement of hands around a dial, whereas a digital clock measures time with a numerical display that changes in a series of discrete steps.

Most computers are digital devices. Therefore, any signals and data from an analogue device must be passed through a suitable analogue-to-digital converter before they can be received and processed by computer. Similarly, output signals from digital computers must be passed through a digital-to-analogue converter before they can be received by an analogue device.

---

analogue computer

computing device that performs calculations through the interaction of continuously varying physical quantities, such as voltages (as distinct from the more common digital computer, which works with discrete quantities). An analogue computer is said to operate in real time (corresponding to time in the real world), and can therefore be used to monitor and control other events as they happen.

Although common in engineering since the 1920s, analogue computers are not general-purpose computers, but specialize in solving differential calculus and similar mathematical problems. The earliest analogue computing device is thought to be the flat, or planispheric, astrolabe, which originated in about the 8th century.

---

analogue signal

in electronics, current or voltage that conveys or stores information, and varies continuously in the same way as the information it represents (compare digital signal). Analogue signals are prone to interference and distortion.

The bumps in the grooves of a vinyl record form a mechanical analogue of the sound information stored, which is then converted into an electrical analogue signal by the record player's pick-up device.

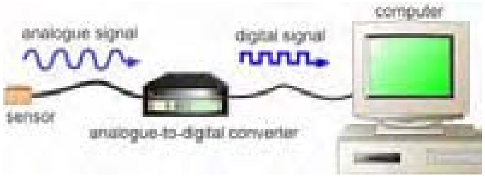
---

analogue-to-digital converter

ADC

electronic circuit that converts an analogue signal into a digital one. Such a circuit is needed to convert the signal from an analogue device into a digital signal for input into a computer. For example, many sensors designed to measure physical quantities, such as temperature and pressure, produce an analogue signal in the form of voltage and this must be passed through an ADC before a computer can process the information. A digital-to-analogue converter performs the opposite process.

analogue-to-digital converter



(Image © Research Machines plc)

An analogue-to-digital converter, or ADC, converts a continuous analogue signal produced by a sensor to a digital ('off and on') signal for computer processing.

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analysis

branch of mathematics concerned with limiting processes on axiomatic number systems; calculus of variations and infinitesimal calculus is now called analysis.

---

analytical chemistry

branch of chemistry that deals with the determination of the chemical composition of substances. **Qualitative analysis** determines the identities of the substances in a given sample; **quantitative analysis** determines how much of a particular substance is present.

Simple qualitative techniques exploit the specific, easily observable properties of elements or compounds – for example, the flame test makes use of the different flame colours produced by metal cations when their compounds are held in a hot flame. More sophisticated methods, such as those of spectroscopy, are required where substances are present in very low concentrations or where several substances have similar properties.

Most quantitative analyses involve initial stages in which the substance to be measured is extracted from the test sample, and purified. The final analytical stages (or 'finishes') may involve measurement of the substance's mass (gravimetry) or volume (volumetry, titrimetry), or a number of techniques initially developed for qualitative analysis, such as fluorescence and absorption spectroscopy, chromatography, electrophoresis, and polarography. Many modern methods enable quantification by means of a detecting device that is integrated into the extraction procedure (as in gas-liquid chromatography).

Analytical Chemistry Basics

Go to site

Detailed online course, designed for those at undergraduate level, that provides the user with an introduction to some of the fundamental concepts and methods of analytical chemistry. Some of the sections included are gravimetric analysis, titration, and spectroscopy.

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analytical geometry

another name for coordinate geometry.

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anaphylaxis

in medicine, a severe allergic response. Typically, the air passages become constricted, the blood pressure falls rapidly, and the victim collapses. A rare condition, anaphylaxis most often occurs following wasp or bee stings, or treatment with some drugs.

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anatomy

study of the structure of the body and its component parts, especially the human body, as distinguished from physiology, which is the study of bodily functions.

Herophilus of Chalcedon (*c.* 330–*c.* 260 BC) is regarded as the founder of anatomy. In the 2nd century AD, the Graeco-Roman physician Galen produced an account of anatomy that was the only source of anatomical knowledge until *On the Working of the Human Body* (1543) by Belgian physician Andreas Vesalius. Throughout the Middle Ages and well into modern times, the Catholic Church enforced a complete ban on dissecting human bodies, thus severely limiting any progress in anatomy. Only after the Reformation did Protestant rulers gradually allow dissection, for example of criminals who had been executed. In 1565, the Royal College of Physicians in London was granted permission to dissect human cadavers.

In 1628, English physician William Harvey published his demonstration of the circulation of the blood. With the invention of the microscope, Italian physiologist Marcello Malpighi and Dutch microscopist Anton van Leeuwenhoek were able to found the study of histology. In 1747, Albinus, with the help of the artist Wandelaar, produced the most exact account of the bones and muscles, and in 1757–65 Swiss biologist Albrecht von Haller gave the most complete and exact description of the organs that had yet appeared. Among the anatomical writers of the early 19th century are the surgeon Charles Bell, Jonas Quain, and Henry Gray. Radiographic anatomy (using X-rays; see radiography) was a great achievement of the 20th century, which was also marked by immense activity in embryological research.

anatomy

(Image © Billie Love)

The medieval notion of anatomy, *c.*1508. The findings of the Ancient Greek physician Galen, whose studies were based on the dissection of animals, were the only source of anatomical knowledge until 1543. Andreas Vesalius then published his classic work *De humani corporis fabrica* which was based on his own observation of human corpses.

Human Anatomy Online

Go to site

Interactive guide to the human body. Choose from ten body 'systems' to learn more about them. For each system there is a large diagram with 'hotspots', each of which can be clicked on to open up a description in the right-hand frame.

Visible Human Project

Go to site

Sample images from a long-term US project to collect a complete set of anatomically detailed, three-dimensional representations of the human body.

Anaximander (c. 610-c. 546 BC)

Greek astronomer and philosopher. He claimed that the Earth was a cylinder three times wider than it is deep, motionless at the centre of the universe, and that the celestial bodies were fire seen through holes in the hollow rims of wheels encircling the Earth. According to Anaximander, the first animals came into being from moisture and the first humans grew inside fish, emerging once fully developed.

---

anchovy

small fish *Engraulis encrasicholus* of the herring family. It is fished extensively, being abundant in the Mediterranean, and is also found on the Atlantic coast of Europe and in the Black Sea. It grows to 20 cm/8 in.

Pungently flavoured, it is processed into fish pastes and essences, and used as a garnish, rather than eaten fresh.

---

andalusite

aluminium silicate, Al_2SiO_5, a white to pinkish mineral crystallizing as square- or rhombus-based prisms. It is common in metamorphic rocks formed from clay sediments under low-pressure conditions. Andalusite, kyanite, and sillimanite are all polymorphs of Al_2SiO_5.

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andesite

volcanic igneous rock, intermediate in silica content between rhyolite and basalt. It is characterized by a large quantity of feldspar minerals, giving it a light colour. Andesite erupts from volcanoes at destructive plate margins (where one plate of the Earth's surface moves beneath another; see plate tectonics), including the Andes, from which it gets its name.

AND gate

in electronics, a type of logic gate.

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androecium

male part of a flower, comprising a number of stamens.

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androgen

general name for any male sex hormone, of which testosterone is the most important.

They are all steroids and are principally involved in the production of male secondary sexual characteristics (such as beard growth).

Andromeda

major constellation of the northern hemisphere, visible in autumn. Its main feature is the Andromeda galaxy. The star Alpha Andromedae forms one corner of the Square of Pegasus. It is named after the princess of Greek mythology.

Andromeda galaxy

galaxy 2.2 million light years away from Earth in the constellation Andromeda, and the most distant object visible to the naked eye. It is the largest member of the Local Group of galaxies.

Like the Milky Way, it is a spiral orbited by several companion galaxies but contains about twice as many stars as the Milky Way. It is about 200,000 light years across.

AND rule

rule used for finding the combined probability of two or more independent events both occurring. If two events E_1 and E_2 are independent (have no effect on each other) and the probabilities of their taking place are p_1 and p_2, respectively, then the combined probability p that both E_1 and E_2 will happen is given by:

$$p = p_1 \times p_2$$

For example, if a blue die and a red die are thrown together, the probability of a blue six is 1/6, and the probability of a red six is 1/6. Therefore, the probability of both a red six and a blue six being thrown is 1/6 × 1/6 = 1/36.

By contrast, the **OR rule** is used for finding the probability of either one event or another taking place.

---

anechoic chamber

room designed to be of high sound absorbency. All surfaces inside the chamber are covered by sound-absorbent materials such as rubber. The walls are often covered with inward-facing pyramids of rubber, to minimize reflections back into the interior of the chamber. It is used for experiments in acoustics and for testing audio equipment.

---

anemometer

device for measuring wind speed and liquid flow. The most basic form, the **cup-type anemometer**, consists of cups at the ends of arms, which rotate when the wind blows. The speed of rotation indicates the wind speed.

Vane-type anemometers have vanes, like a small windmill or propeller, that rotate when the wind blows.
Pressure-tube anemometers use the pressure generated by the wind to indicate speed. The wind blowing into or across a tube develops a pressure, proportional to the wind speed, that is measured by a manometer or pressure gauge.
Hot-wire anemometers work on the principle that the rate at which heat is transferred from a hot wire to the surrounding air is a measure of the air speed. Wind speed is determined by measuring either the electric current required to maintain a hot wire at a constant temperature, or the variation of resistance while a constant current is maintained.

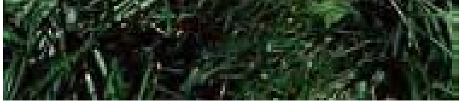
---

anemone

flowering plant belonging to the buttercup family, found in northern temperate regions, mainly in woodland. It has sepals which are coloured to attract insects. (Genus *Anemone*, family Ranunculaceae.)

The garden anemone (*Anemone coronaria*) is blue, purple, red, or white. The European and Asian white wood anemone (*A. nemorosa*), or windflower, grows in shady woods, flowering in spring. *Hepatica nobilis*, once included within the genus *Anemone*, is common in the Alps. The pasqueflower is now placed in a separate genus.

anemone



(Image © Research Machines plc)

Anemone blanda (common name windflower) is a low-growing perennial with a daisylike flower. It flowers in spring, and is found in partially-shaded conditions such as woodland. The windflower should not be confused with the wood anemone, *Anemone nemerosa*, whose star-shaped flower is rarely found in the UK,

mountain anemone

(Image © Corel)

The mountain anemone *Hepatica nobilis* is common in the Alps. This flower is growing wild in Austria.

Anemones

Go to site

Contains detailed information about this plant, including an informative description of the plant itself as well as of its habitat. There are also extensive notes on the cultivation of anemones, including tips on the soil, propagation, and planting.

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anemophily

type of pollination in which the pollen is carried on the wind. Anemophilous flowers are usually unscented, have either very reduced petals and sepals or lack them altogether, and do not produce nectar. In some species they are borne in catkins. Male and female reproductive structures are commonly found in separate flowers. The male flowers have numerous exposed stamens, often on long filaments; the female flowers have long, often branched, feathery stigmas.

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aneroid barometer

kind of barometer.

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aneurysm

weakening in the wall of an artery, causing it to balloon outwards with the risk of rupture and serious, often fatal, blood loss. If detected in time, some accessible aneurysms can be repaired by bypass surgery, but such major surgery carries a high risk for patients in poor health.

---

angel dust

popular name for the anaesthetic **phencyclidine**, a depressant drug.

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angelfish

any of a number of unrelated fishes. The freshwater angelfish, genus *Pterophyllum*, of South America, is a tall, side-to-side flattened fish with a striped body, up to 26 cm/10 in long, but usually smaller in captivity. The angelfish or monkfish of the genus *Squatina* is a bottom-living shark up to 1.8 m/6 ft long with a body flattened from top to bottom. The marine angelfishes, *Pomacanthus* and others, are long narrow-bodied fish with spiny fins, often brilliantly coloured, up to 60 cm/2 ft long, living around coral reefs in the tropics.

Angelfish

Go to site

This site includes details of angelfish breeds, feeding, keeping in an aquarium, and possible diseases. Images and multimedia clips are also downloadable from this site.

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angelica

any of a group of tall, perennial herbs with divided leaves and clusters of white or greenish flowers, belonging to the carrot family. Most are found in Europe and Asia. The roots and fruits have long been used in cooking and in medicine. (Genus *Angelica*, family Umbelliferae.)

Angelica

Go to site

Large resource of information about this herb. There is a description of the plant's place in history, as well as an in-depth look at the plant itself and its habitat. There are detailed notes on the cultivation and propagation of angelica, and on its constituents and numerous uses: in cooking and medicine.

---

angina

or angina pectoris

severe pain in the chest due to impaired blood supply to the heart muscle because a coronary artery is narrowed. Faintness and difficulty in breathing accompany the pain. Treatment is by drugs such as nitroglycerin and amyl nitrate or bypass surgery.

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angiosperm

flowering plant in which the seeds are enclosed within an ovary, which ripens into a fruit. Angiosperms are divided into monocotyledons (single seed leaf in the embryo) and dicotyledons (two seed leaves in the embryo). They include the majority of flowers, herbs, grasses, and trees except conifers.

There are over 250,000 different species of angiosperm, found in a wide range of habitats. Like gymnosperms, they are seed plants, but differ in that ovules and seeds are protected within the carpel. Fertilization occurs by male gametes passing into the ovary from a pollen tube. After fertilization the ovule develops into the seed while the ovary wall develops into the fruit.

Angkor

site of the ancient capital of the Khmer Empire in northwestern Cambodia, north of Tonle Sap. The remains date mainly from the 10th to 12th centuries, and comprise temples originally dedicated to the Hindu gods, shrines associated with Theravada Buddhism, and royal palaces. Many are grouped within the enclosure called Angkor Thom, but the great temple of Angkor Wat (early 12th century) lies outside.

Angkor was abandoned in the 15th century, and the ruins were overgrown by jungle and not adequately described until 1863. Buildings on the site suffered damage during the civil war 1970–75; restoration work is in progress.

Cambodia Mega Attraction - Angkor

Go to site

Guide to Cambodia's most impressive attraction. Good photographs accompany a history of the vast complex and details of Angkor Thom, Angkor Wat, and other sites.

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angle

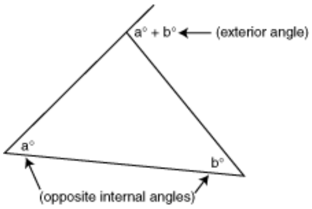
in mathematics, the amount of turn or rotation; it may be defined by a pair of rays (half-lines) that share a common endpoint (vertex) but do not lie on the same line. Angles are measured in degrees (°) or radians (rads or ^{c}) - a complete turn or circle being 360° or 2π rads.

All angles around a point on a straight line add up to 180°. All angles around a point add up to 360°.

Angles are classified generally by their degree measures: **acute angles** are less than 90°; **right angles** are exactly 90° (a quarter turn) and are created by two perpendicular lines crossing; **obtuse angles** are greater than 90° but less than 180° (a straight line); **reflex angles** are greater than 180° but less than 360°; **supplementary angles** add up to 180°.

angles in triangles

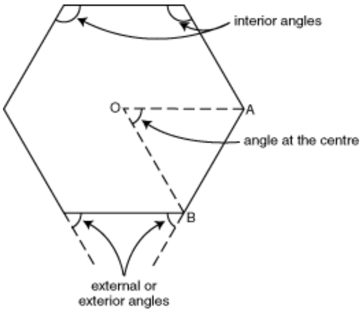
A triangle has three interior angles that together add up to 180°. In an equilateral triangle these angles are equal (60°). The exterior angles of a triangle (those produced if one side is extended beyond the triangle) are equal to the sum of the opposite internal angles.


a° + b°
(exterior angle)
a°
b°
(opposite internal angles)

Unknown angles in a right-angled triangle can be worked out using trigonometry.

angles in polygons

Regular polygons have three types of angle:


interior angles
O
A
angle at the centre
B
external or
exterior angles

The angle at the centre is equal to the exterior angle and it is found by dividing 360° by the number of sides in the polygon.

For example, the angle at the centre of a hexagon is 60°:

360 ÷ 6 = 60°

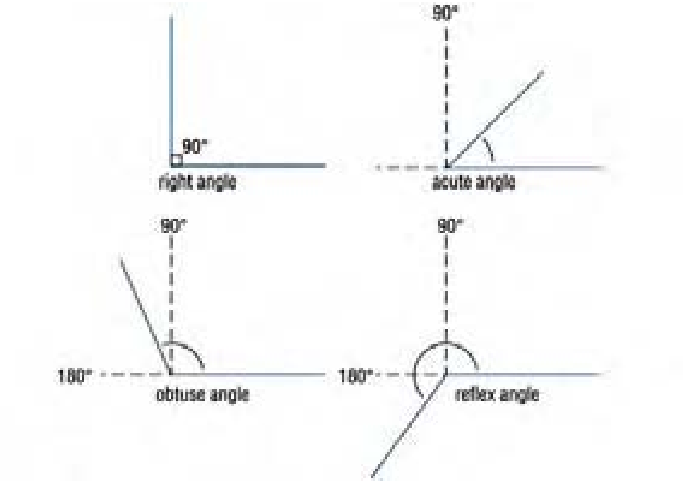
angles at parallel lines

Angles created by a line crossing two parallel lines are known as opposite angles, corresponding angles, or alternate angles.

angles in circles

Angles within a circle can be calculated using circle theorems.

angle


90°
right angle
90°
acute angle
90°
180°
obtuse angle
90°
180°
reflex angle

(Image © Research Machines plc)

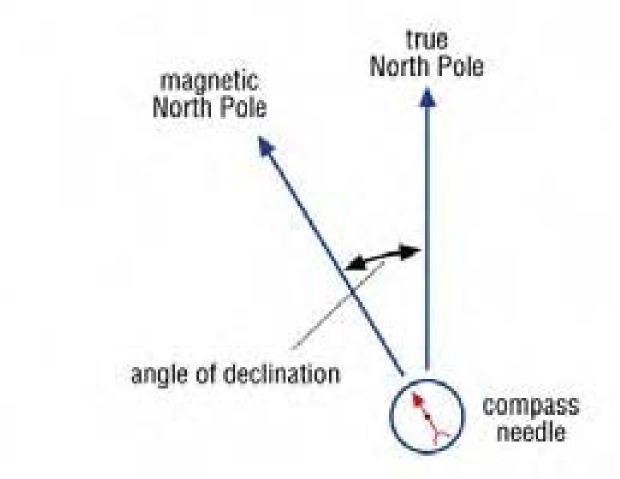
The four types of angle, as classified by their degree measures. No angle is classified as having a measure of 180°, as by definition such an 'angle' is actually a straight line.

---

angle of declination

angle at a particular point on the Earth's surface between the direction of the true or geographic North Pole and the magnetic north pole. The angle of declination has varied over time because of the slow drift in the position of the magnetic north pole.

angle of declination



(Image © Research Machines plc)

The angle of declination is the angle at a particular point on the Earth's surface between the direction of the true or geographic North Pole and the magnetic north pole. The angle of declination has varied over time because of the slow drift in the position of the magnetic north pole.

---

angle of dip

or angle of inclination

angle at a particular point on the Earth's surface between the direction of the Earth's magnetic field and the horizontal; see magnetic dip.

---

angler

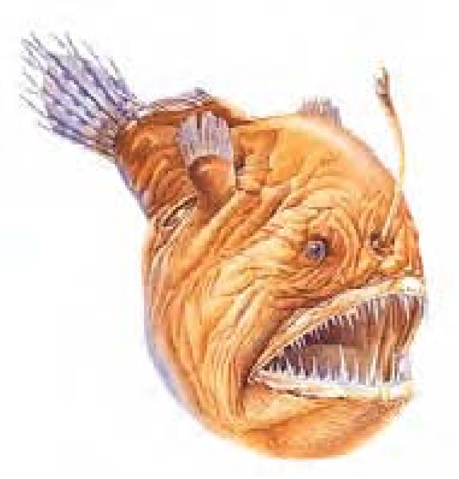
any of an order of fishes Lophiiformes, with flattened body and broad head and jaws. Many species have small, plantlike tufts on their skin. These act as camouflage for the fish as it waits, either floating among seaweed or lying on the sea bottom, twitching the enlarged tip of the threadlike first ray of its dorsal fin to entice prey.

There are over 200 species of angler fish, living in both deep and shallow water in temperate and tropical seas. The males of some species have become so small that they live as parasites on the females.

angler

The parasitic male anglerfish stays with his partner for life – literally. Once the tiny male is attached to the much larger female, his tissues fuse with hers, he loses his senses of sight and smell, and receives his nourishment from her bloodstream.

angler fish



(Image © Research Machines plc)

Angler fish entice their prey into their large mouths by means of a fishing rod – a modified dorsal ray with a fleshy lure at its tip. The female of this species (13 cm/5 in long) is very much larger than the male (4 cm/1.75 in long).

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angst

(German 'anxiety')

emotional state of anxiety without a specific cause. In existentialism, the term refers to general human anxiety at having free will, that is, of being responsible for one's actions.

---

angstrom

symbol Å

unit of length equal to 10^{-10} metres or one-ten-millionth of a millimetre, used for atomic measurements and the wavelengths of electromagnetic radiation. It is named after the Swedish scientist Anders Ångström.

Ångström, Anders Jonas (1814-1874)

Swedish astrophysicist who worked in spectroscopy and solar physics. In 1861 he identified the presence of hydrogen in the Sun. His outstanding *Recherches sur le spectre solaire* (1868) presented an atlas of the solar spectrum with measurements of 1,000 spectral lines expressed in units of one-ten-millionth of a millimetre, the unit which later became the angstrom.

---

anhydride

chemical compound obtained by the removal of water from another compound; usually a dehydrated acid. For example, sulphur(VI) oxide (sulphur trioxide, SO_3) is the anhydride of sulphuric acid (H_2SO_4).

For monobasic acids, such as carboxylic acids, the formation of an anhydride involves the loss of a molecule of water from two molecules of acid or from two carboxylic groups within one molecule, the latter resulting in a ring closure.

---

anhydrous

of a chemical compound, containing no water. If the water of crystallization is removed from blue crystals of copper(II) sulphate, a white powder (anhydrous copper sulphate) results. Liquids from which all traces of water have been removed are also described as being anhydrous.

---

aniline

or phenylamine; $C_6H_5NH_2$

(Portuguese anil 'indigo')

one of the simplest aromatic chemicals (a substance related to benzene, with its carbon atoms joined in a ring). When pure, it is a colourless oily liquid; it has a characteristic odour, and turns brown on contact with air. It occurs in coal tar, and is used in the rubber industry and to make drugs and dyes. It is highly poisonous.

Aniline was discovered in 1826, and was originally prepared by the dry distillation of indigo, hence its name. In the 19th century, the production of aniline-based dyes was a key industry.

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animal

or metazoan

(Latin anima 'breath', 'life')

member of the kingdom Animalia, one of the major categories of living things, the science of which is **zoology**. Animals are all multicellular heterotrophs (they obtain their energy from organic substances produced by other organisms); they have eukaryotic cells (the genetic material is contained within a distinct nucleus) which are bounded by a thin cell membrane rather than the thick cell wall of plants. Most animals are capable of moving around for at least part of their life cycle.

In the past, it was common to include the single-celled protozoa with the animals, but these are now classified as protists, together with single-celled plants. Thus all animals are multicellular. The oldest land animals known date back 440 million years. Their remains were found 1990 in a sandstone deposit near Ludlow, Shropshire, UK, and included fragments of two centipedes a few centimetres long and a primitive spider measuring about one millimetre.

Animal lifespans

(N/A = not available.)

Animal	Average longevity (years)	Maximum longevity (years)[1]
Ass	12	35.8
Baboon	20	35.5
Bear (black)	18	36.8
Bear (grizzly)	25	47
Bear (polar)	20	34.7
Beaver	10	20.5
Buffalo (American)	15	N/A
Camel (Bactrian)	12	N/A
Cat (domestic)	12	28
Chimpanzee	40	44.5
Chipmunk	6	8
Cow	15	30
Deer (white-tailed)	8	N/A
Dog (domestic)	12	20
Elephant (African)	60	80
Elephant (Asian)	60	80
Elk	15	26.5
Fox (red)	7	14
Giraffe	25	33.5
Goat (domestic)	8	18
Gorilla	35	50
Guinea pig	4	7.5
Hippopotamus	45	49
Horse	20	46
Kangaroo	12	28
Leopard	12	19.3
Lion	15	25
Monkey (rhesus)	15	N/A
Moose	12	N/A
Mouse (domestic white)	1	3.5
Mouse (meadow)	3	N/A
Opossum (American)	2	8
Pig (domestic)	10	27
Puma	12	19
Rabbit (domestic)	5	13
Rhinoceros (black)	15	N/A
Rhinoceros (white)	20	N/A
Sea lion (California)	12	28
Sheep (domestic)	12	20
Squirrel (grey)	10	N/A
Tiger	16	26.3
Wolf (grey)	12	20
Zebra (Grant's)	15	35

[1] Maximum longevity figures refer to animals in captivity; an animal's potential lifespan is rarely attained in the wild.

Average animal gestation periods and incubation times

Animal	Gestation[1]/incubation[2] (days)
Mammals	
Ass	365
Baboon	187
Bear (black)	210
Bear (grizzly)	225
Bear (polar)	240
Beaver	122
Buffalo (American)	270
Camel (Bactrian)	410
Cat (domestic)	58-65
Chimpanzee	230
Chinchilla	110-120
Chipmunk	31
Cow	279-292

Deer (white-tailed)	201
Dog (domestic)	58-70
Elephant (Asian)	645
Elk (Wapiti)	240-250
Fox (red)	52
Giraffe	420-450
Goat (domestic)	145-155
Gorilla	257
Guinea pig	68
Hippopotamus	225-250
Horse	330-342
Kangaroo	42
Leopard	92-95
Lion	108
Llama	330
Mink	40-75
Monkey (rhesus)	164
Moose	240-250
Mouse (domestic white)	19
Mouse (meadow)	21
Muskrat	28-30
Opossum (American)	12-13
Otter	270-300
Pig (domestic)	112-115
Porcupine	112
Puma	90
Rabbit (domestic)	30-35
Raccoon	63
Rhinoceros (black)	450
Seal	330
Sea lion (California)	350
Sheep (domestic)	144-151
Squirrel (grey)	30-40
Tiger	105-113
Whale (sperm)	480-500
Wolf	60-68
Zebra (Grant's)	365
Birds	
Chicken	20-22
Duck	26-28
Finch	11-14
Goose	25-28
Parrot	17-31
Pheasant	24
Pigeon	10-18
Quail	21-23
Swan	33-36
Turkey	28

[1] Mammals.

[2] Birds.

Collective names for animals

Animal	Collective name
Antelopes	troop
Ants	colony, nest, swarm
Apes	shrewdness
Asses	pace
Baboons	troop
Badgers	cete
Bears	sleuth, sloth
Bees	colony, drift, grist, hive, nest, swarm
Birds	flight, flock, volery
Bitterns	sedge, siege
Boars	singular, sounder

Bucks	leash
Camels	caravan, string
Cats	clowder, clutter, litter
Cattle	drove, herd
Chicks	brood, clutch
Choughs	chattering
Clams	bed
Colts	rag
Coots	covert, raft
Cubs	litter
Cranes	sedge, siege
Crows	hover, murder
Deer	bevy, herd, parcel
Dogs	litter, kennel, pack (wild)
Dolphins	school
Donkeys	pace
Doves	dole, dule, flight, pitying
Ducks	badling, brace, flock, paddling, team (in flight)
Eagles	convocation
Eels	swarm
Elephants	herd
Elk	gang
Falcons	cast
Ferrets	busyness, fesnying
Finches	charm
Fish	draught, school, shoal
Flies	swarm
Foxes	lead, leash, skulk
Frogs	army
Geese	flock, gaggle, nide, skein (in flight), wedge (in flight)
Gnats	cloud, horde, swarm
Goats	herd, tribe, trip
Goldfinches	charm, chirm
Gorillas	band
Greyhounds	leash
Grouse	covey
Gulls	colony
Hares	down, husk
Hawks	cast
Herons	sedge, siege
Horses	drove, herd, pair, team, stable, string
Hounds	cry, mute, pack
Jays	band
Kangaroos	herd, mob, troop
Kittens	kindle, litter
Lapwings	desert
Larks	bevy, exaltation
Leopards	leap, lepe
Lions	pride
Mallards	flush, sord (on land), sute
Martens	richesse
Mice	nest
Moles	labour
Monkeys	band, troop
Mules	span
Nightingales	charm, watch
Oxen	drove, herd, yoke
Oysters	bed
Partridges	covey
Peafowl	muster, ostentation, pride
Penguins	parcel, rookery
Pheasants	bevy, nest, nide, nye
Pigs	litter
Piglets	farrow, litter
Plovers	congregation, wing

Pochards	knob, rush
Polecats	chine
Porpoises	school
Puppies	litter
Quails	bevy, covey
Rabbits	nest
Ravens	unkindness
Rhinoceroses	crash
Rooks	clamour, parliament, rookery
Seals	bob, harem, herd, pod, rookery
Sheep	drove, flock, trip
Sheldrakes	dopping
Skunks	busyness
Snipe	wisp
Sparrows	host
Starlings	chattering, murmuration
Storks	mustering
Swallows	flight
Swans	bevy, wedge
Swine	drift, sounder
Teal	knob, spring, raft
Termites	colony, nest, swarm
Thrushes	mutation
Toads	army, knob, knot
Tortoises	bale
Turtles	bale, dole, dule, rafter
Vipers	nest
Walruses	pod
Waterfowl	plump
Whales	gam, herd, pod, school
Whiting	pod
Wigeons	company, knob
Wildfowl	sute
Wolves	pack, rout
Woodcocks	fall, plump

Names for animal young

Animal	Name for young
Antelope	calf
Bear	cub
Beaver	pup, kit, kitten
Bird	nestling, fledgling
Bobcat	kitten, cub
Buffalo	calf, yearling, spike-bull
Camel	calf, colt
Canary	chick
Cat	kitten
Cattle	calf
Chicken	chick
Chimpanzee	infant
Cod	codling, scrod, sprag
Condor	chick
Deer	fawn
Dog	pup, puppy, whelp
Duck	duckling
Elephant	calf
Fish	fry
Fox	cub
Frog	polliwog, tadpole
Giraffe	calf
Goat	kid
Goose	gosling
Hare	leveret
Hen	pullet
Hippopotamus	calf

Horse	foal, yearling, colt (male), filly (female)
Kangaroo	joey
Lion	cub
Louse	nit
Owl	owlet
Partridge	cheeper, chick
Penguin	fledgling, chick
Pig	piglet
Rabbit	bunny, kitten
Rhinoceros	calf
Seal	pup, whelp, cub
Sea lion	pup
Shark	cub
Sheep	lamb, lambkin
Squirrel	pup
Swan	cygnet
Tiger	cub, whelp
Turkey	chick, poult
Turtle	chicken
Walrus	calf
Whale	calf
Wolf	cub, pup
Zebra	colt, foal

Electronic Zoo

Go to site

Vast collection of links to animal Web sites and images (there is even a section devoted to fictional animals, from Animaniacs to Wile E Coyote), plus NetVet - animal welfare information and links to veterinary sites.

Virtual Library: Zoos

Go to site

Comprehensive collection of links to zoo sites, with many links to related Web sites, such as specific animal pages, images, and sounds.

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animal cell

cell in an animal, which, like all cells, has a cell membrane, cytoplasm, and a nucleus, but in which the surface consists of the cell surface membrane only - it does not have a cell wall. The cell surface membrane keeps the cell together by being strong, even though it is very thin and flexible. The membrane also controls what enters and leaves the cell. For example, nutrients need to be able to enter and waste materials to leave. The cell contains cytoplasm, in which is located a nucleus. This controls the activities of the cell.

An animal is made up of many thousands of cells, which are used as building blocks. However, as with a house, different types of building blocks are used in different places. Groups of similar cells form a tissue. An example of this is the tissue forming the brain. One of the specialized cells found in this tissue is the neurone or nerve cell. The brain is an organ made up of a number of different tissues.

The blood is a tissue consisting mainly of another type of specialized cell - the red blood cell. Other specialized cells include the epithelium and sperm cell.

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animism

in anthropology, the belief that everything, whether animate or inanimate, possesses a soul or spirit. It is a fundamental system of belief in certain religions, particularly those of some pre-industrial societies. Linked with this is the worship of natural objects such as stones and trees, thought to harbour spirits (naturism); fetishism; and ancestor worship.

In psychology and physiology, animism is the view of human personality that attributes human life and behaviour to a force distinct from matter. In developmental psychology, an animistic stage in the early thought and speech of the child has been described, notably by Swiss psychologist Jean Piaget.

In philosophy, the view that in all things consciousness or something mindlike exists.

In religious theory, the conception of a spiritual reality behind the material one: for example, beliefs in the soul as a shadowy duplicate of the body capable of independent activity, both in life and death.

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anion

ion carrying a negative charge. An anion is formed from an atom by the gain of electrons, a process known as **ionic bonding**. Non-metallic elements form anions. During electrolysis, anions in the electrolyte move towards the anode (positive electrode).

An electrolyte, such as the salt zinc chloride ($ZnCl_2$), is dissociated in aqueous solution or in the molten state into doubly charged Zn^{2+} cations and singly-charged Cl^- anions. During electrolysis, the zinc cations flow to the cathode (to become discharged and liberate zinc metal) and the chloride anions flow to the anode (to become discharged and form chlorine gas).

anise

Mediterranean plant belonging to the carrot family, with small creamy-white flowers in clusters; its fragrant seeds, similar to liquorice in taste, are used to flavour foods. Aniseed oil is used in cough medicines. (*Pimpinella anisum*, family Umbelliferae.)

annealing

controlled cooling of a material to increase ductility and strength. The process involves first heating a material (usually glass or metal) for a given time at a given temperature, followed by slow cooling. It is a common form of heat treatment.

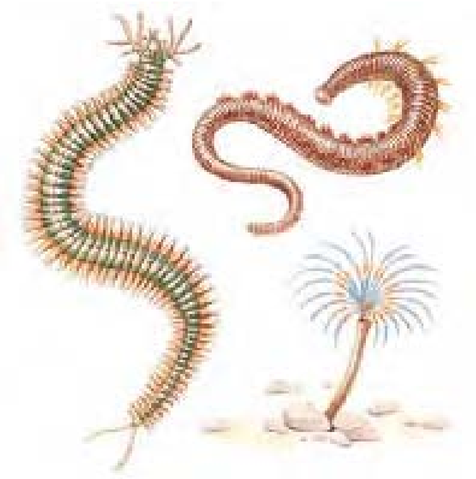
Normalizing is a type of annealing where a metal is heated to a point above its critical temperature before being cooled. This helps to refine the grain.

annelid

any segmented worm of the phylum Annelida. Annelids include earthworms, leeches, and marine worms such as lugworms.

They have a distinct head and soft body, which is divided into a number of similar segments shut off from one another internally by membranous partitions, but there are no jointed appendages. Annelids are noted for their ability to regenerate missing parts of their bodies.

annelid



(Image © Research Machines plc)

The ragworm, lugworm, and peacock worm shown here are all marine species of annelids (segmented worms). Ragworms commonly live in mucous-lined burrows on muddy shores or under stones, and lugworms occupy U-shaped burrows. The peacock worm, however, builds a smooth, round tube from fine particles of mud.

annihilation

in nuclear physics, a process in which a particle and its 'mirror image' particle called an antiparticle collide and disappear, with the creation of a burst of energy. The energy created is equivalent to the mass of the colliding particles in accordance with the mass-energy equation. For example, an electron and a positron annihilate to produce a burst of high-energy X-rays. See antimatter.

annual plant

plant that completes its life cycle within one year, during which time it germinates, grows to maturity, bears flowers, produces seed, and then dies.

annual plant

(Image © Research Machines plc)

Giant senecio, Shira Plateau, Tanzania. The *Senecio* genus comprises shrubs, trees, herbs, and climbers - including groundsel and ragwort - and can be found throughout the world. The plants pictured grow in the Afro-Alpine zone of the East African mountains, at around 3,660 m/12,000 ft.

annual rings

or growth rings

concentric rings visible on the wood of a cut tree trunk or other woody stem. Each ring represents a period of growth when new xylem is laid down to replace tissue being converted into wood (secondary xylem).

The wood formed from xylem produced in the spring and early summer has larger and more numerous vessels than the wood formed from xylem produced in autumn when growth is slowing down. The result is a clear boundary between the pale spring wood and the denser, darker autumn wood. Annual rings may be used to estimate the age of the plant (see dendrochronology), although occasionally more than one growth ring is produced in a given year.

annulus

(Latin 'ring')

in geometry, the plane area between two concentric circles, making a flat ring.

anode

the positive electrode in an electrolytic cell (see electrolysis), thermionic valve, cathode ray tube, or similar device, towards which negative particles are attracted. The negative particles originate from the cathode.

In these cases the flow of electrons is **out of** the device at the anode. The term is also inconsistently applied in some other cases to electrodes at which the flow of electrons is **into** the device - for example, to the positive terminal of a battery.

anodizing

process that increases the resistance to corrosion of a metal, such as aluminium, by building up a protective oxide layer on the surface. The natural corrosion resistance of aluminium is provided by a thin film of aluminium oxide; anodizing increases the thickness of this film and thus the corrosion protection.

It is so called because the metal becomes the anode in an electrolytic bath containing a solution of, for example, sulphuric or chromic acid as the electrolyte. During electrolysis oxygen is produced at the anode, where it combines with the metal to form an oxide film.

anorexia

lack of desire to eat, or refusal to eat, especially the pathological condition of **anorexia nervosa**, most often found in adolescent girls and young women. Compulsive eating, or bulimia, distortions of body image, and depression often accompany anorexia.

The causes of anorexia nervosa are not known. It is characterized by severe self-imposed restriction of food intake. The consequent weight loss may lead, in women, to absence of menstruation. Anorexia nervosa is often associated with increased physical activity and symptoms of mental disorders. Suicidal tendencies may occur among those suffering from anorexia. Psychotherapy is an important part of the treatment.

anoxaemia

or hypoxaemia

shortage of oxygen in the blood; insufficient supply of oxygen to the tissues. It may be due to breathing air deficient in oxygen (for instance, at high altitude or where there are noxious fumes), a disease of the lungs, or some disorder in which the oxygen-carrying capacity of the blood is impaired.

anoxia

or hypoxia

in biology, deprivation of oxygen, a condition that rapidly leads to collapse or death, unless immediately reversed.

ant

insect belonging to the family Formicidae, and to the same order (Hymenoptera) as bees and wasps. Ants are characterized by a conspicuous waist and elbowed antennae. About 10,000 different species are known; all are social in habit, and all construct nests of various kinds. Ants are found in all parts of the world, except the polar regions. It is estimated that there are about 10 million billion ants.

Ant behaviour is complex, and serves the colony rather than the individual. Ants find their way by light patterns, gravity (special sense organs are located in the joints of their legs), and chemical trails between food areas and the nest.

specialized roles

Communities include **workers**, sterile, wingless females, often all alike, although in some species large-headed 'soldiers' are differentiated; **fertile females**, fewer in number and usually winged; and **males**, also winged and smaller than their consorts, with whom they leave the nest on a nuptial flight at certain times of the year. After aerial mating, the males die, and the fertilized queens lose their wings when they settle, laying eggs to found their own new colonies. The eggs hatch into wormlike larvae, which then pupate in silk cocoons before emerging as adults.

remarkable species

Some species conduct warfare. Others are pastoralists, tending herds of aphids and collecting a sweet secretion ('honeydew') from them. Army (South American) and driver (African) ants march nomadically in huge columns, devouring even tethered animals in their path. Leaf-cutter ants, genus *Atta*, use pieces of leaf to grow edible fungus in underground 'gardens' which can be up to 5 m/16 ft deep and cover hundreds of square metres. Weaver ants, genus *Oecophylla*, use their silk-producing larvae as living shuttles to bind the edges of leaves together to form the nest. Eurasian robber ants *Formica sanguinea* raid the nests of another ant species, *Formica fusca*, for pupae, then use the adults as 'slaves' when they hatch. Among honey ants, some workers serve as distended honey stores.

ants and defence

Ants leap for safety from branches when birds are around. Research by a Swedish biologist showed that Northern wood ants *Formica aquilonia* will break into a run and then jump from the branch by springing outwards.

ants and fungus

Leaf-cutter ants feed their larvae on a fungus that they cultivate themselves in underground gardens. The ants depend on the fungus for food, and the fungus cannot reproduce without the ants. When a new queen takes flight to establish another colony, she takes some of the fungus with her in a special mouth pouch.

antacid

any substance that neutralizes stomach acid, such as sodium hydrogencarbonate (sodium bicarbonate) or magnesium hydroxide ('milk of magnesia'). Antacids are weak bases, swallowed as solids or emulsions. They may be taken between meals to relieve symptoms of hyperacidity, such as pain, bloating, nausea, and 'heartburn'. Excessive or prolonged need for antacids should be investigated medically.

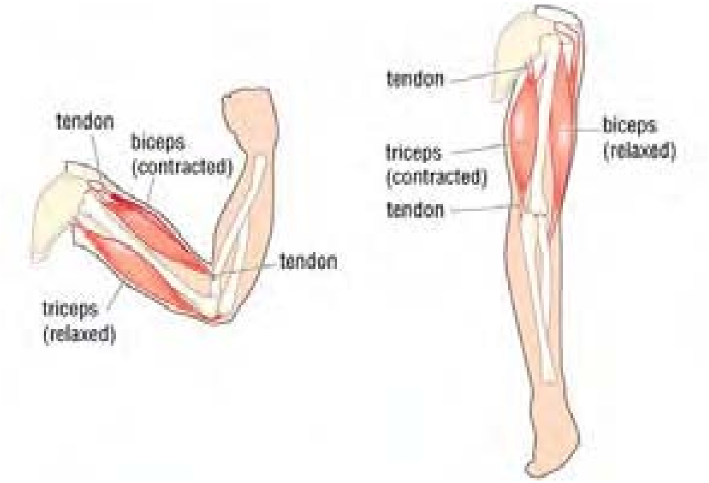
antagonist

in biology, a muscle that relaxes in response to the contraction of its agonist muscle. See antagonistic muscles.

antagonistic muscles

in the body, a pair of muscles working together to allow coordinated movement of the skeletal joints. Muscles can only exert a force and do work by contracting. An example is the antagonistic pair of muscles used in bending and straightening the arm. To bend the arm requires one set of muscles – the biceps – to contract, while another set – the triceps – relaxes. If the arm is to be straightened, the reverse happens. The individual components of antagonistic pairs can be classified into extensors (muscles that straighten a limb) and flexors (muscles that bend a limb).

antagonistic muscle



(Image © Research Machines plc)

Even simple movements such as bending and straightening the arm require muscle pairs to contract and relax synchronously.

Antarctic Circle

imaginary line that encircles the South Pole at latitude 66° 32' S. The line encompasses the continent of Antarctica and the Antarctic Ocean.

The region south of this line experiences at least one night in the southern summer during which the Sun never sets, and at least one day in the southern winter during which the Sun never rises.

Antares

or Alpha Scorpii

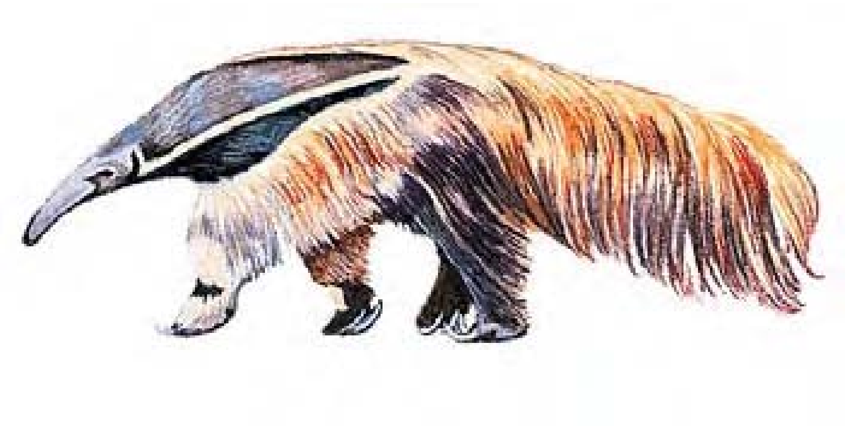
brightest star in the constellation Scorpius and the 15th-brightest star in the night sky. It is a red supergiant several hundred times larger than the Sun and perhaps 10,000 times as luminous. It lies about 420 light years away from the Sun, and varies in brightness.

anteater

mammal of the family Myrmecophagidae, order Edentata, native to Mexico, Central America, and tropical South America. The anteater lives almost entirely on ants and termites. It has toothless jaws, an extensile tongue, and claws for breaking into the nests of its prey.

Species include the giant anteater *Myrmecophaga tridactyla*, about 1.8 m/6 ft long including the tail, the tamandua or collared anteater *Tamandua tetradactyla*, about 90 cm/3.5 ft long, and the silky anteater *Cyclopes didactyla*, about 35 cm/14 in long. The name is also incorrectly applied to the aardvark, the echidna, and the pangolin.

anteater



(Image © Research Machines plc)

The anteater is a relative of the sloths, armadillos, and pangolins. There are four species, native to South and Central America. The giant anteater *Myrmecophaga tridactyla* is 1.8 m/6 ft long with an elongated face, hairy coat, and bushy tail. It lives in forests and in savannah regions.

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antelope

any of numerous kinds of even-toed, hoofed mammals belonging to the cow family, Bovidae. Most antelopes are lightly built and good runners. They are grazers or browsers, and chew the cud. They range in size from the dik-diks and duikers, only 30 cm/1 ft high, to the eland, which can be 1.8 m/6 ft at the shoulder.

The majority of antelopes are African, including the eland, wildebeest, kudu, springbok, and waterbuck, although other species live in parts of Asia, including the deserts of Arabia and the Middle East. The pronghorn antelope *Antilocapra americana* of North America belongs to a different family, the Antilocapridae.

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antenatal

in medicine, before birth. Antenatal care refers to health services provided to ensure the health of pregnant women and their babies.

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antenna

in radio and television, another name for aerial.

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antenna

in zoology, an appendage ('feeler') on the head. Insects, centipedes, and millipedes each have one pair of antennae but there are two pairs in crustaceans, such as shrimps. In insects, the antennae are involved with the senses of smell and touch; they are frequently complex structures with large surface areas that increase the ability to detect scents.

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anther

in a flower, the terminal part of a stamen in which the pollen grains are produced. It is usually borne on a slender stalk or filament, and has two lobes, each containing two chambers, or pollen sacs, within which the pollen is formed.

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antheridium

organ producing the male gametes, antherozoids, in algae, bryophytes (mosses and liverworts), and pteridophytes (ferns, club mosses, and horsetails). It may be either single-celled, as in most algae, or multicellular, as in bryophytes and pteridophytes.

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antherozoid

motile (or independently moving) male gamete produced by algae, bryophytes (mosses and liverworts), pteridophytes (ferns, club mosses, and horsetails), and some gymnosperms (notably the cycads). Antherozoids are formed in an antheridium and, after being released, swim by means of one or more flagella, to the female gametes. Higher plants have nonmotile male gametes contained within pollen grains.

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anthracene

white, glistening, crystalline, tricyclic, aromatic hydrocarbon with a faint blue fluorescence when pure. Its melting point is about 216°C/421°F and its boiling point 351°C/664°F. It occurs in the high-boiling-point fractions of coal tar, where it was discovered in 1832 by the French chemists Auguste Laurent (1808-1853) and Jean Dumas (1800-1884).

---

anthracite

(from Greek anthrax 'coal')

hard, dense, shiny variety of coal, containing over 90% carbon and a low percentage of ash and impurities, which causes it to burn without flame, smoke, or smell. Because of its purity, anthracite gives off relatively little sulphur dioxide when burnt.

Anthracite gives intense heat, but is slow-burning and slow to light; it is therefore unsuitable for use in open fires. Its characteristic composition is thought to be due to the action of bacteria in disintegrating the coal-forming material when it was laid down during the Carboniferous period.

Among the chief sources of anthracite coal are Pennsylvania in the USA; South Wales, UK; the Donbas, Ukraine and Russia; and Shanxi province, China.

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anthrax

disease of livestock, occasionally transmitted to humans, usually via infected hides and fleeces. It may also be used as a weapon in biological warfare. It develops as black skin pustules or severe pneumonia. Treatment is possible with antibiotics, and vaccination is effective.

Anthrax is caused by a bacillus (*Bacillus anthracis*). In the 17th century, some 60,000 cattle died in a European pandemic known as the Black Bane, thought to have been anthrax. The disease is described by the Roman poet Virgil and may have been the cause of the biblical fifth plague of Egypt.

anthrax

In 1998 kebabs were temporarily banned in Almaty, Kazakhstan, following several cases of anthrax infection from eating infected meat.

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anthropoid

(Greek anthropos 'man', eidos 'resemblance')

any primate belonging to the suborder Anthropoidea, including monkeys, apes, and humans.

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anthropology

(Greek anthropos 'man', logos 'discourse')

the study of humankind. It investigates the cultural, social, and physical diversity of the human species, both past and present. It is divided into two broad categories: biological or physical anthropology, which attempts to explain human biological variation from an evolutionary perspective; and the larger field of social or cultural anthropology, which attempts to explain the variety of human cultures. This differs from sociology in that anthropologists are concerned with cultures and societies other than their own.

biological anthropology

Biological anthropology is concerned with human palaeontology, primatology, human adaptation, demography, population genetics, and human growth and development.

social anthropology

Social or cultural anthropology is divided into three subfields: social or cultural anthropology proper, prehistory or prehistoric archaelogy, and anthropological linguistics. The term 'anthropology' is frequently used to refer solely to social anthropology. With a wide range of theoretical perspectives and topical interests, it overlaps with many other disciplines. It is a uniquely Western social science.

participant observation

Anthropology's primary method involves the researcher living for a year or more in another culture, speaking the local language and participating in all aspects of everyday life; and writing about it afterwards.

By comparing these accounts, anthropologists hope to understand who we are.

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antibiotic

drug that kills or inhibits the growth of bacteria and fungi.

The earliest antibiotics, the penicillins, came into use from 1941 and were quickly joined by chloramphenicol, the cephalosporins, erythromycins, tetracyclines, and aminoglycosides. A range of broad-spectrum antibiotics, the 4-quinolones, was developed in 1989, of which ciprofloxacin was the first. Each class and individual antibiotic acts in a different way and may be effective against either a broad spectrum or a specific type of disease-causing agent. Use of antibiotics has become more selective as side effects, such as toxicity, allergy, and resistance, have become better understood. Bacteria have the ability to develop resistance following repeated or subclinical (insufficient) doses, so more advanced antibiotics and synthetic antimicrobials are continually required to overcome them.

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antibody

protein molecule produced in the blood by lymphocytes in response to the presence of foreign or invading substances (antigens); such substances include the proteins carried on the surface of infecting micro-organisms. Antibody production is only one aspect of immunity in vertebrates.

Each antibody acts against only one kind of antigen, and combines with it to form a 'complex'. This action may render antigens harmless, or it may destroy micro-organisms by setting off chemical changes that cause them to self-destruct.

In other cases, the formation of a complex will cause antigens to form clumps that can then be detected and engulfed by white blood cells, such as macrophages and phagocytes.

Each bacterial or viral infection will bring about the manufacture of a specific antibody, which will then fight the disease. Many diseases can only be contracted once because antibodies remain in the blood after the infection has passed, preventing any further invasion. Vaccination boosts a person's resistance by causing the production of antibodies specific to particular infections.

Large quantities of specific antibodies can now be obtained by the monoclonal technique (see monoclonal antibody).

Antibodies were discovered in 1890 by the German physician Emil von Behring and the Japanese bacteriologist Shibasaburo Kitasato.

Antibody Resource Page

Go to site

Fascinating access site for all you could ever want to know about antibodies and some things you'd probably rather not know! This site contains several educational resources (aimed at university level), but also contains images, animations, and descriptions of research into many different types of antibodies.

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anticline

in geology, rock layers or beds folded to form a convex arch (seldom preserved intact) in which older rocks comprise the core. Where relative ages of the rock layers, or stratigraphic ages, are not known, convex upward folded rocks are referred to as antiforms.

The fold of an anticline may be undulating or steeply curved. A steplike bend in otherwise gently dipping or horizontal beds is a **monocline**. The opposite of an anticline is a syncline.

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anticoagulant

substance that inhibits the formation of blood clots. Common anticoagulants are heparin, produced by the liver and some white blood cells, and derivatives of coumarin, such as warfarin. Anticoagulants are used medically in the prevention and treatment of thrombosis and heart attacks. Anticoagulant substances are also produced by blood-feeding animals, such as mosquitoes, leeches, and vampire bats, to keep the victim's blood flowing.

Most anticoagulants prevent the production of thrombin, an enzyme that induces the formation from blood plasma of fibrinogen, to which blood platelets adhere and form clots.

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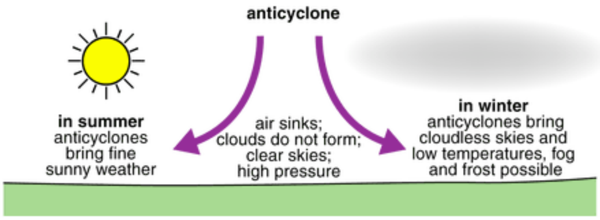
anticyclone

area of high atmospheric pressure caused by descending air, which becomes warm and dry. Winds radiate from a calm centre, taking a clockwise direction in the northern hemisphere and an anticlockwise direction in the southern hemisphere. Anticyclones are characterized by clear weather and the absence of rain and violent winds. In summer they bring hot, sunny days and in winter they bring fine, frosty spells, although fog and low cloud are not uncommon in the UK. Blocking anticyclones, which prevent the normal air circulation of an area, can cause summer droughts and severe winters.

anticyclone


anticyclone
in summer anticyclones bring fine sunny weather
air sinks; clouds do not form; clear skies; high pressure
in winter anticyclones bring cloudless skies and low temperatures, fog and frost possible

(Image © Research Machines plc)

Anticyclones are formed when areas of descending air result in high pressure. They bring more stable conditions and can stay in place for days or even months. Summer anticyclones bring hot sunny days. Winter anticyclones bring cooler weather with a possibility of fog and freezing conditions.

antidepressant

any drug used to relieve symptoms in depressive illness. The main groups are the selective serotonin-reuptake inhibitors (SSRIs), the tricyclic antidepressants (TCADs), and the monoamine oxidase inhibitors (MAOIs). They all act by altering chemicals available to the central nervous system. All may produce serious side effects.

antidiarrhoeal

any substance that controls diarrhoea.

Choice of treatment depends on the underlying cause. One group, including opiates, codeine, and atropine, produces constipation by slowing down motility (muscle activity of the intestine wall).

Bulking agents, such as vegetable fibres (for example, methylcellulose), absorb fluid. Antibiotics may be appropriate for certain systemic bacterial infections, such as typhoid fever, salmonella, and infective enteritis. Current therapy of acute diarrhoea is based on fluid and electrolyte replacement. Chronic diarrhoea, a feature of some bowel disorders (for example, Crohn's disease, colitis, coeliac disease) responds to drugs such as antispasmodics and corticosteroids, and special diet.

anti-emetic

any substance that counteracts nausea or vomiting.

antifreeze

substance added to a water-cooling system (for example, that of a car) to prevent it freezing in cold weather.

antigen

any substance that causes the production of antibodies by the body's immune system. Common antigens include the proteins carried on the surface of bacteria, viruses, and pollen grains. The proteins of incompatible blood groups or tissues also act as antigens, which has to be taken into account in medical procedures such as blood transfusions and organ transplants.

antihistamine

any substance that counteracts the effects of histamine. Antihistamines may occur naturally or they may be synthesized.

H_1 antihistamines are used to relieve allergies, alleviating symptoms such as runny nose, itching, swelling, or asthma. H_2 antihistamines suppress acid production by the stomach, and are used in the treatment of peptic ulcers, often making surgery unnecessary.

anti-inflammatory

any substance that reduces swelling in soft tissues. Antihistamines relieve allergic reactions; aspirin and NSAIDs are effective in joint and musculoskeletal conditions; and rubefacients (counterirritant liniments) ease painful joints, tendons, and muscles.

Steroids, because of their severe side effects, are only prescribed if other therapy is ineffective, or if a condition is life-threatening. A corticosteroid injection into the affected joint usually gives prolonged relief from inflammation.

antiknock

substance added to petrol to reduce knock in car engines, caused by premature combusting. It is a mixture of dibromoethane and tetraethyl lead. Its use in leaded petrol has resulted in atmospheric pollution by lead compounds.

antilogarithm

or antilog

inverse of logarithm, or the number whose logarithm to a given base is a given number. If $y = \log_a x$, then $x = \text{antilog}_a y$.

antimatter

in physics, form of matter in which most of the attributes (such as electrical charge, magnetic moment, and spin) of elementary particles are reversed. These antiparticles can be created in particle accelerators, such as those at CERN in Geneva, Switzerland, and at Fermilab in the USA. In 1996 physicists at CERN created the first atoms of antimatter: nine atoms of antihydrogen survived for 40 nanoseconds (40 billionths of a second).

The Alpha Magnetic Spectrometer was flown on the space shuttle Discovery in June 1998, searching unsuccessfully for antihelium and measuring the energy spectra of positrons and antiprotons. A successor experiment is planned for the *International Space Station*.

Antimatter

first atoms of antimatter produced

In Sept 1995 Walter Oelert and an international team at CERN, the European particle physics laboratory near Geneva, Switzerland, succeeded in making the first atoms of antimatter. Over a period of three weeks, nine antimatter atoms were produced in collisions between antiprotons and xenon atoms. The atoms remained in existence for about forty billionths of a second. During this time, the atoms travelled about ten metres at nearly the speed of light, and then were annihilated as they collided with ordinary matter.

the production process

The antimatter atoms produced were of anti-hydrogen. Ordinary hydrogen atoms consists of a proton around which a single electron circulates. It is simple to make anti-hydrogen - in principle. Take one anti-electron (also called a positron) and put it in orbit around an antiproton. In practice, making anti-hydrogen is very difficult. Antiprotons have to be made in a particle accelerator since they do not exist naturally on Earth. Then positrons must somehow be made to orbit the antiprotons.

LEAR: the Low Energy Antiproton Ring

The world's first antiproton 'factory' - a complex of specially-built machines which produces a dense beam of antiprotons for physics experiments - was built at CERN in 1980. CERN also had a machine called LEAR (or the Low Energy Antiproton Ring), which slows antiprotons to the energy range where anti-atoms form. Thus CERN was in an ideal position to produce the first anti-atoms.

The anti-hydrogen atoms were created by firing a beam of xenon atoms across an antiproton beam whirling around inside LEAR. Occasionally, collisions between antiprotons and protons (in the xenon nuclei) generated an electron-positron pair. Very occasionally, the positrons then combined with other antiprotons in the beam to make anti-hydrogen.

detecting anti-matter

LEAR is shaped like a running track with straight sections joined by circular bends. The anti-hydrogen was created in one of the straight sections, and silicon detectors were placed just after the next bend. Because anti-hydrogen is not affected by the strong magnetic fields, the anti-hydrogen atoms were not pulled around the bend by the magnetic fields inside LEAR, but travelled straight on into the detectors.

Anti-hydrogen is difficult to detect directly because the anti-atoms annihilate as soon as they collide with the ordinary matter in their surroundings. However, when an anti-hydrogen atom passes through the thin silicon detectors, it breaks down into a antiproton and a positron. The two particles stay close together and the tell-tale sign or 'signature' that anti-hydrogen has been produced is the simultaneous appearance of an antiproton-positron pair in the detector. Over 23,000 measurements were made and carefully sifted for the anti-hydrogen signature before the researchers were sure that they had produced the first antimatter atoms.

the future and the anti-world

The creation of the first anti-atoms has begun the systematic exploration of the anti-world. More experiments are planned to check the properties of anti-hydrogen atoms. If the behaviour of anti-hydrogen differs even slightly from that of ordinary hydrogen, scientists will have to abandon many of the accepted ideas about matter and antimatter.

antimony

chemical symbol Sb

silver-white, brittle, semimetallic element (a metalloid), atomic number 51, relative atomic mass 121.75. Its chemical symbol comes from Latin *stibium*. It occurs chiefly as the ore stibnite, and is used to make alloys harder; it is also used in photosensitive substances in colour photography, optical electronics, fireproofing, pigments, and medicine. It was employed by the ancient Egyptians in a mixture to protect the eyes from flies.

antinode

in physics, the position in a standing wave pattern at which the amplitude of vibration is greatest (compare node). The standing wave of a stretched string vibrating in the fundamental mode has one antinode at its midpoint. A vibrating air column in a pipe has an antinode at the pipe's open end and at the place where the vibration is produced.

anti-oxidant

any substance that prevents deterioration of fats, oils, paints, plastics, and rubbers by oxidation. When used as food additives, anti-oxidants prevent fats and oils from becoming rancid when exposed to air, and thus extend their shelf life.

Vegetable oils contain natural anti-oxidants, such as vitamin E, which prevent spoilage, but anti-oxidants are nevertheless added to most oils. They are not always listed on food labels because if a food manufacturer buys an oil to make a food product, and the oil has anti-oxidant already added, it does not have to be listed on the label of the product.

antiparticle

in nuclear physics, a particle corresponding in mass and properties to a given elementary particle but with the opposite electrical charge, magnetic properties, or coupling to other fundamental forces. For example, an electron carries a negative charge whereas its antiparticle, the positron, carries a positive one. When a particle and its antiparticle collide, they destroy each other, in the process called 'annihilation', their total energy being converted to lighter particles and/or photons. A substance consisting entirely of antiparticles is known as antimatter.

antipodes

(Greek 'opposite feet')

places at opposite points on the globe.

antipruritic

any skin preparation or drug administered to relieve itching.

antipyretic

any drug, such as aspirin, used to reduce fever.

antirrhinum

any of several plants in the figwort family, including the snapdragon (*Antirrhinum majus*). Foxgloves and toadflax are relatives. Antirrhinums are native to the Mediterranean region and western North America. (Genus *Antirrhinum*, family Scrophulariaceae.)

antiseptic

any substance that kills or inhibits the growth of micro-organisms. The use of antiseptics was pioneered by Joseph Lister. He used carbolic acid (phenol), which is a weak antiseptic; antiseptics such as TCP are derived from this.

Lister's work was extended by surgeons such as William Cheyne, professor of surgery at Kings College Hospital, London, and author of *Antiseptic Surgery* (1882).

antispasmodic

any drug that reduces motility, the spontaneous action of the intestine wall. Anticholinergics are a type of antispasmodic that act indirectly by way of the autonomic nervous system, which controls involuntary movement.

Other drugs act directly on the smooth muscle to relieve spasm (contraction).

antitussive

any substance administered to suppress a cough. Coughing, however, is an important reflex in clearing secretions from the airways; its suppression is usually unnecessary and possibly harmful, unless damage is being done to tissue during excessive coughing spasms.

antiviral

any drug that acts against viruses, usually preventing them from multiplying. Most viral infections are not susceptible to antibiotics. Antivirals have been difficult drugs to develop, and do not necessarily cure viral diseases.

antler

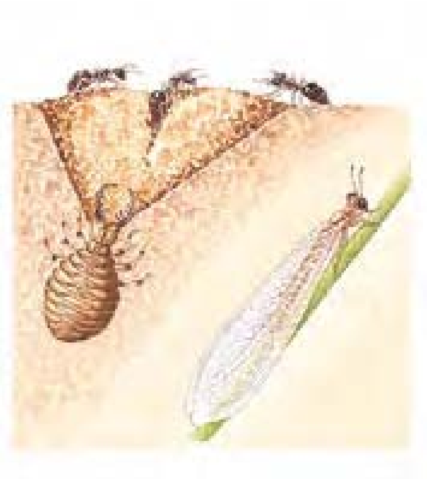
'horn' of a deer, often branched, and made of bone rather than horn. Antlers, unlike true horns, are shed and regrown each year. Reindeer of both sexes grow them, but in all other types of deer, only the males have antlers.

During growth the antler is covered by a sensitive, hairy skin, known as 'velvet', which dries up and is rubbed off when maturity is attained. The number and complexity of the branches increase year by year.

ant lion

larva of one of the insects of the family Myrmeleontidae, order Neuroptera, which traps ants by waiting at the bottom of a pit dug in loose, sandy soil. Ant lions are mainly tropical, but also occur in parts of Europe, where there are more than 40 species, and in the USA, where they are called doodlebugs.

ant lion



(Image © Research Machines plc)

There are about 1,000 species of ant lion; all larvae, and many adults, are carnivorous, feeding on insects and spiders. Eggs are laid singly in sand or dry soil. Larvae of the genus *Myrmeleon* live in funnel-shaped sandy pits, with their strong, toothed jaws ready to trap any insect that stumbles in.

anus

or anal canal

opening at the end of the alimentary canal which allows undigested foods and other waste materials to pass out of the body in the form of faeces. In humans the term is also used to describe the last 4 cm/1.5 in of the alimentary canal. It is normally kept closed by a ring of muscle called a sphincter. A common medical condition in humans associated with the anus is haemorrhoids (piles).

The anus is found in all types of multicellular animal except the coelenterates (sponges) and the platyhelminths (flatworms), which have a mouth only.

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anxiety

unpleasant, distressing emotion usually to be distinguished from fear. Fear is aroused by the perception of actual or threatened danger; anxiety arises when the danger is imagined or cannot be identified or clearly perceived. It is a normal response in stressful situations, but is frequently experienced in many mental disorders.

Anxiety is experienced as a feeling of suspense, helplessness, or alternating hope and despair together with excessive alertness and characteristic bodily changes such as tightness in the throat, disturbances in breathing and heartbeat, sweating, and diarrhoea.

In psychiatry, an anxiety state is a type of neurosis in which the anxiety either seems to arise for no reason or else is out of proportion to what may have caused it. 'Phobic anxiety' refers to the irrational fear that characterizes phobia.

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anxiolytic

any drug that relieves an anxiety state.

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aorta

the body's main artery, arising from the left ventricle of the heart in birds and mammals. Carrying freshly oxygenated blood, it arches over the top of the heart and descends through the trunk, finally splitting in the lower abdomen to form the two iliac arteries. Arteries branching off the arch of the aorta carry blood to the upper body. Loss of elasticity in the aorta provides evidence of atherosclerosis, which may lead to heart disease.

In fish a ventral aorta carries deoxygenated blood from the heart to the gills, and the dorsal aorta carries oxygenated blood from the gills to other parts of the body.

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a.p.

in physics, abbreviation for **atmospheric pressure**.

Apache Point Observatory

US observatory in the Sacramento Mountains of New Mexico containing a 3.5-m/138-in reflector, opened in 1990, and operated by the Astrophysical Research Consortium, a group of collaborating universities and other institutions.

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apastron

point at which an object travelling in an elliptical orbit around a star is at its farthest from the star. The term is usually applied to the position of the minor component of a binary star in relation to the primary. Its opposite is the periastron.

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apatite

common calcium phosphate mineral, $Ca_5(PO_4)_3(F,OH,Cl)$. Apatite has a hexagonal structure and occurs widely in igneous rocks, such as pegmatite, and in contact metamorphic rocks, such as marbles. It is used in the manufacture of fertilizer and as a source of phosphorus. Carbonate hydroxylapatite, $Ca_5(PO_4,CO_3)_3(OH)_2$, is the chief constituent of tooth enamel and, together with other related phosphate minerals, is the inorganic constituent of bone. Apatite ranks 5 on the Mohs scale of hardness.

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apatosaurus

large plant-eating dinosaur, formerly called brontosaurus, which flourished about 145 million years ago. Up to 21 m/69 ft long and 30 tonnes in weight, it stood on four elephantlike legs and had a long tail, long neck, and small head. It probably snipped off low-growing vegetation with peglike front teeth, and swallowed it whole to be ground by pebbles in the stomach.

apatosaurus

The head of the apatosaurus was only 50 cm/20 in, that is one forty-second of its entire body length.

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ape

primate of the family Pongidae, closely related to humans, including gibbon, orang-utan, chimpanzee, and gorilla.

The earliest known ape is believed by US researchers to have lived 20 million yeas ago in Uganda. *Morotopithecus* was about the size of a modern chimpanzee.

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aperture

in photography, an opening in the camera that allows light to pass through the lens to strike the film. Controlled by the iris diaphragm, it can be set mechanically or electronically at various diameters.

The **aperture ratio** or **relative aperture**, more commonly known as the f-number, is a number defined as the focal length of the lens divided by the effective diameter of the aperture. A smaller f-number implies a larger diameter lens and therefore more light available for high-speed photography, or for work in poorly illuminated areas. However, small f-numbers involve small depths of focus.

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aperture synthesis

in astronomy, technique used in radio astronomy in which several small radio dishes are linked together over an area that can be many kilometres in diameter. This is done to simulate the performance of one very large radio telescope.

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apex

the highest point of a triangle, cone, or pyramid - that is, the vertex (corner) opposite a given base.

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aphasia

general term for the many types of disturbance in language that are due to brain damage, especially in the speech areas of the dominant hemisphere.

National Aphasia Association

Go to site

US-based site with a lot of straightforward information about aphasia; for example, there is a page of important facts and a true/false quiz. The site also contains information about current research and links to support groups for sufferers, their friends, and families.

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aphelion

point at which an object, travelling in an elliptical orbit around the Sun, is at its farthest from the Sun. This is a solar-orbit apoapsis. The Earth is at its aphelion on 5 July.

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aphid

any of the family of small insects, Aphididae, in the order Hemiptera, suborder Homoptera, that live by sucking sap from plants. There are many species, often adapted to particular plants; some are agricultural pests.

In some stages of their life cycle, wingless females rapidly produce large numbers of live young by parthenogenesis, leading to enormous infestations, and numbers can approach 2 billion per hectare/1 billion per acre. They can also cause damage by transmitting viral diseases. An aphid that damages cypress and cedar trees appeared in Malawi in 1985 and by 1991 was attacking millions of trees in central and East Africa. Some research suggests, however, that aphids may help promote fertility in the soil through the waste they secrete, which is termed honeydew. Aphids are also known as plant lice, greenflies, or blackflies.

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aphrodisiac

(from Aphrodite, the Greek goddess of love)

any substance that arouses or increases sexual desire.

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apogee

point at which a spacecraft, or other object, travelling in an elliptical orbit around the Earth is at its farthest from the Earth. This is an Earth-orbit apoapsis.

Apollo asteroid

member of a group of asteroids whose orbits cross that of the Earth. They are named after the first of their kind, Apollo, to be discovered. Apollo was discovered in 1932 by German astronomer Karl Reinmuth and then lost until 1973. Apollo asteroids are so small and faint that they are difficult to see except when close to the Earth (Apollo is about 2 km/1.2 mi across).

Apollonius of Perga (c. 262-c. 190 BC)

Greek mathematician, called 'the Great Geometer'. In his work *Konica/The Conics* he showed that a plane intersecting a cone will generate an ellipse, a parabola, or a hyperbola, depending on the angle of intersection. In astronomy, he used a system of circles called epicycles and deferents to explain the motion of the planets; this system, as refined by Ptolemy, was used until the Renaissance.

Apollonius of Perga

Go to site

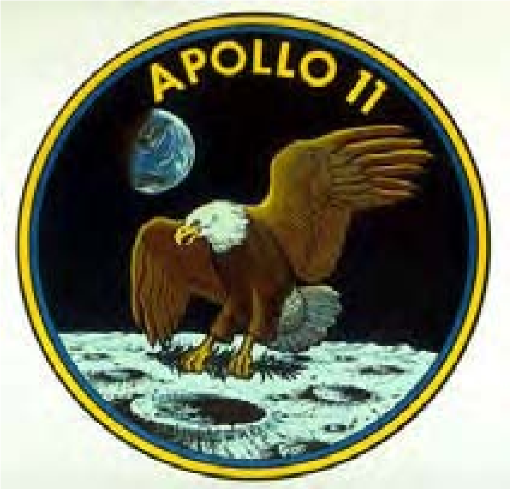
Biography of the Greek philosopher and mathematician Apollonius of Perga. Excerpts from an early 18th-century translation of Apollonius' greatest work, *Conics*, are included on this Web site, as are links to other important works. A list of publication references for further reading is also shown.

Apollo project

US space project to land a person on the Moon, achieved on 20 July 1969, when Neil Armstrong was the first to set foot there. He was accompanied on the Moon's surface by Buzz Aldrin; Michael Collins remained in the orbiting command module.

The programme was announced in 1961 by US president John F Kennedy. The world's most powerful rocket, Saturn V (see Saturn rocket), was built to launch the *Apollo* spacecraft, which carried three astronauts. When the spacecraft was in orbit around the Moon, two astronauts would descend to the surface in the lunar module to take samples of rock and soil and set up experiments that would send data back to Earth. After four preparatory flights, *Apollo 11* made the first lunar landing. Five more crewed landings followed, the last in 1972. The total cost of the programme was over US$24 billion.

Apollo project



(Image © Corel)

The *Apollo* project crest; a bald eagle, the symbol of the USA. The lunar module used for the Moon landing in July 1969 was called *Eagle*.

Apollo project

(Image © NASA)

The crew of *Apollo 8* at the Kennedy Space Center simulator. From left to right are: James Lovell, William Anders, and Frank Borman.

Apollo project

(Image © NASA)

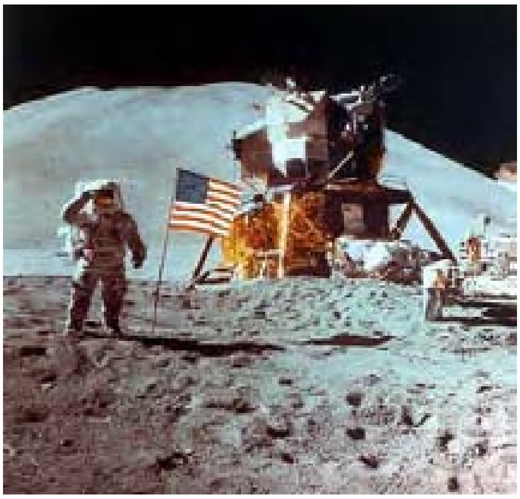
An *Apollo 12* astronaut walking on the Moon in November 1969. The *Apollo* project sent 17 spacecraft to the Moon between 1969 and 1972. Six of these missions involved landing astronauts on the Moon and featured space walks during which they collected rocks and soil, took photographs, and set up scientific equipment.

Apollo project

(Image © NASA)

In a life raft following splashdown, *Apollo 11* astronauts Neil Armstrong, Michael Collins, and Buzz Aldrin wear biological isolation garments put on within their spacecraft. They are undergoing disinfection by US Navy personnel.

Apollo project



(Image © Corel)

A US astronaut on one of the *Apollo* missions to the Moon, with the lunar landing module (centre) and the 'lunar rover' (right). The landing module was flown down to the lunar surface from the command module which remained in orbit around the Moon. The 'lunar rover', a battery powered car, was used for transport during the last three moon landings.

Apollo project

(Image © Corel)

US astronauts landed on the Moon in July and November 1969. They collected samples of Moon rock for analysis and set up experiments to send data back to Earth. During moon walks the astronauts wore protective suits incorporating an oxygen supply, and weighted boots to compensate for the low gravity on the Moon.

Apollo project

(Image © Corel)

Apollo project astronauts being picked up following splashdown of the command module. On return to Earth the spacecraft re-entered the atmosphere and part of the command module parachuted down into the sea, where the astronauts were picked up by a waiting ship.

Apollo 11

Go to site

NASA page reliving the excitement of the *Apollo 11* mission, with recollections from the participating astronauts, images, audio clips, access to key White House documents, and a bibliography.

Apollo and Skylab

Go to site

Simple site giving an overview of the *Apollo* programme, with information about each *Apollo* and *Skylab* mission, statistics, and a brief summary. There are links to other NASA *Apollo*-related pages.

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aposematic coloration

in biology, the technical name for warning coloration markings that make a dangerous, poisonous, or foul-tasting animal particularly conspicuous and recognizable to a predator. Examples include the yellow and black stripes of bees and wasps, and the bright red or yellow colours of many poisonous frogs and snakes. See also mimicry.

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apothecaries' weights

obsolete units of mass, formerly used in pharmacy: 20 grains equal one scruple; three scruples equal one dram; eight drams equal an apothecary's ounce (oz apoth.), and 12 such ounces equal an apothecary's pound (lb apoth.). There are 7,000 grains in one pound avoirdupois (0.454 kg).

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apothecary

person who prepares and dispenses medicines; a pharmacist.

The word 'apothecary' retains its original meaning in the USA and other countries, but in England it came to mean a licensed medical practitioner.

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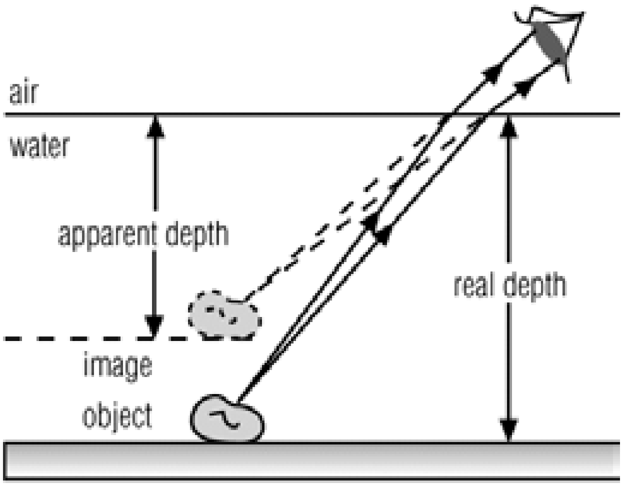
apparent depth

depth that a transparent material such as water or glass appears to have when viewed from above. This is less than its real depth because of the refraction that takes place when light passes into a less dense medium. The ratio of the real depth to the apparent depth of a transparent material is equal to its refractive index.

apparent depth



(Image © Research Machines plc)

The apparent depth of an object in water when viewed from above. This is less than the object's real depth because of refractive effects: the light wave bends as it passes from the denser water into the less dense air.

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appendicitis

inflammation of the appendix, a small, blind extension of the bowel in the lower right abdomen. In an acute attack, the pus-filled appendix may burst, causing a potentially lethal spread of infection. Treatment is by removal (appendicectomy). ...VTXT:

There were 50,000 appendicectomies carried out in the UK in 1998. - delete. Contrib. says he assumes figure is unchanged but I don't think we can keep information on the basis of an assumption!

Childhood Infections - Appendicitis

Go to site

Useful information about appendicitis. There is a detailed description of the infection, its incubation period, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

---

appendix

short, blind-ended tube attached to the caecum. It has no known function in humans, but in herbivores it may be large, containing millions of bacteria that secrete enzymes to digest grass (as no vertebrate can secrete enzymes that will digest cellulose, the main constituent of plant cell walls).

The appendix secretes antibodies into the gut and so plays a role in the body's immune system, though it is not a vital one, as patients survive perfectly well following removal of the appendix.

---

apple

fruit of several species of apple tree. There are several hundred varieties of cultivated apples, grown all over the world, which may be divided into eating, cooking, and cider apples. All are derived from the wild crab apple. (Genus *Malus*, family Rosaceae.)

Apple trees grow best in temperate countries with a cool climate and plenty of rain during the winter. The desired variety is grafted onto rootstocks, and the tree must grow for six to eight years before it produces a good crop of fruit. The tree requires a winter period, in which it is dormant, in order to fruit in the spring, but must be protected from frost while the flowers and fruit are young. Pruning is necessary to produce strong branches, and sprays are used to protect the fruit from pests and to influence its development. The apple has been an important food plant in Europe and Asia for thousands of years.

Apple

Go to site

Large source of information relating to apples. Included here are a detailed description of the tree and its habitat, as well as a brief introduction to the role of the apple in history. Also featured are details of the tree's constituents and of the many uses of the apple tree - not only in cooking, but also in aiding digestion, curing constipation, and cleaning teeth.

Appleton layer

or F-layer

band containing ionized gases in the Earth's upper atmosphere, at a height of 150-1,000 km/94-625 mi, above the E-layer (formerly the Kennelly-Heaviside layer). It acts as a dependable reflector of radio signals as it is not affected by atmospheric conditions, although its ionic composition varies with the sunspot cycle.

The Appleton layer has the highest concentration of free electrons and ions of the atmospheric layers. It is named after the English physicist Edward Appleton.

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application

in computing, program or job designed for the benefit of the end user. Examples of **general-purpose** application programs include word processors, desktop publishing programs, databases, spreadsheet packages, and graphics programs (see CAD and CAM). **Application-specific** programs include payroll and stock control systems. Applications may also be **custom designed** to solve a specific problem, not catered for in other types of application.

The term is used to distinguish such programs from those that control the computer (systems programs) or assist the programmer, such as a compiler.

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apricot

yellow-fleshed fruit of the apricot tree, which is closely related to the almond, peach, plum, and cherry. Although native to the Far East, it has long been cultivated in Armenia, from where it was introduced into Europe and the USA. (Genus *Prunus armeniaca*, family Rosaceae.)

Apricot

Go to site

Detailed information about the apricot tree, including notes on its history, its habitat, and the tree itself. It also features sections about the tree's constituents and its numerous uses in cosmetics and perfumes.

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aquaculture

the cultivation of fish and shellfish for human consumption; see fish farming.

aquaculture

(Image © Research Machines plc)

Mussel farming in Chile. Mussel farming is an increasingly popular and profitable form of aquaculture. Fishermen collect the mussels from lines to which dense clusters have attached themselves. The most commonly farmed mussel is the blue mussel, *Mytilus edulis*.

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aqualung

or scuba

underwater breathing apparatus worn by divers, developed in the early 1940s by French diver Jacques Cousteau. Compressed-air cylinders strapped to the diver's back are regulated by a valve system and by a mouth tube to provide air to the diver at the same pressure as that of the surrounding water (which increases with the depth).

DiverNet

Go to site

This massive site, from UK magazine *Diver*, is packed with articles. For the beginner, there's the 'Discover diving' section, with features on getting the gear, where to go diving, getting further training, and basic underwater photography. For the more advanced diver, there are sections on equipment, travel, marine biology, archaeology, wrecks, photography, and much more.

Panic Underwater

Go to site

Part of the Why Files project, published by the National Institute for Science Education (NISE) and funded by the National Science Foundation, this page examines the nature of underwater panic attacks that occasionally afflict scuba divers. The highly readable text, laid out over several pages, includes information on what is commonly meant by 'panic behaviour'. Find out if the panic grips novice and experienced divers alike and how the behaviour differs in men and women, discover the primary cause of scuba diving deaths, and learn psychological strategies that can reduce the risk of having an attack. Numerous images enhance the text throughout.

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aquamarine

blue variety of the mineral beryl. A semi-precious gemstone, it is used in jewellery.

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aquaplaning

phenomenon in which the tyres of a road vehicle cease to make direct contact with the road surface, owing to the presence of a thin film of water. As a result, the vehicle can go out of control, particularly if the steered wheels are involved.

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aqua regia

(Latin 'royal water')

mixture of three parts concentrated hydrochloric acid and one part concentrated nitric acid, which dissolves 'noble' metals such as gold and platinum.

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aquarium

tank or similar container used for the study and display of living aquatic plants and animals. The same name is used for institutions that exhibit aquatic life. These have been common since Roman times, but the first modern public aquarium was opened in Regent's Park, London, in 1853. A recent development is the oceanarium or seaquarium, a large display of marine life forms.

FINS - Fish Information Service

Go to site

Huge source of practical information on all aspects of keeping fish in aquariums. The needs of all manner of tropical and temperate fish, marine, and freshwater fish are covered in detail. There is a good listing of frequently asked questions and a comprehensive picture library of just about every fish in the world. With the help of FINS you can learn whatever you want about ichthyology.

Aquarius

zodiacal constellation a little south of the celestial equator near Pegasus. Aquarius is represented as a man pouring water from a jar. The Sun passes through Aquarius from late February to early March. In astrology, the dates for Aquarius, the 11th sign of the zodiac, are between about 20 January and 18 February (see precession).

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aquatic

living in water. All life on Earth originated in the early oceans, because the aquatic environment has several advantages for organisms. Dehydration is almost impossible, temperatures usually remain stable, and the density of water provides physical support.

Life forms that cannot exist out of water, amphibians that take to the water on occasions, animals that are also perfectly at home on land, and insects that spend a stage of their life cycle in water can all be described as aquatic. Aquatic plants are known as hydrophytes.

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aquatic insect

insect that spends all or part of its life in water. Of the 29 insect orders, 11 members have some aquatic stages. Most of these have aquatic, immature stages, which usually take place in fresh water, sometimes in brackish water (very few species are truly marine); the adults are terrestrial, but in some orders there are species where all stages (egg, larva, and adult) live in the water.

partially aquatic

Three orders, Ephemeroptera (mayflies), Odonata (dragonflies), and Plecoptera (stone-flies) have aquatic larvae, but the adults are terrestrial. In the orders Neuroptera (alder flies), Tricoptera (caddis flies), Lepidoptera (butterflies and moths), and Diptera (true flies), some species have aquatic larvae, but the adults of all species are terrestrial. Hymenoptera, the social insect order which includes the ants and bees, has some aquatic species of ichneumon fly: immature stages of *Agriotypus* are aquatic, and adults of *Caraphractus* and *Prestwitchia*.

totally aquatic

The order Collembola (springtails) has two species in which all stages are aquatic: *Hydropodura aquatica* and *Isotoma palustris*. In Hemiptera (bugs), and Coleoptera (beetles), some members, for example the water bugs, spend all stages of the lifecycle in the water.

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aqueduct

any artificial channel or conduit for water, originally applied to water supply tunnels, but later used to refer to elevated structures of stone, wood, or iron carrying navigable canals across valleys. One of the first great aqueducts was built in 691 BC, carrying water for 80 km/50 mi to Ninevah, capital of the ancient Assyrian Empire. Many Roman aqueducts are still standing, for example the one carried by the Pont du Gard at Nîmes in southern France, built about 8 BC (48 m/160 ft high).

The largest Roman aqueduct, at Carthage in Tunisia, is 141 km/87 mi long and was built during the reign of Publius Aelius Hadrianus between AD 117 and 138. A recent aqueduct is the California State Water Project taking water from Lake Oroville in the north, through two power plants and across the Tehachapi Mountains, more than 177 km/110 mi to southern California.

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aqueous humour

watery fluid found in the chamber between the cornea and lens of the vertebrate eye. Similar to blood serum in composition, it is constantly renewed.

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aqueous solution

solution in which the solvent is water.

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aquifer

a body of rock through which appreciable amounts of water can flow. The rock of an aquifer must be porous and permeable (full of interconnected holes) so that it can conduct water. Aquifers are an important source of fresh water, for example for drinking and irrigation, in many arid areas of the world, and are exploited by the use of artesian wells.

An aquifer may be underlain, overlain, or sandwiched between less permeable layers, called **aquicludes** or **aquitards**, which impede water movement. Sandstones and porous limestones make the best aquifers.

aquifer

Water can remain in aquifers for a very long time. Water in the limestone rocks of Romania, for example, has been there for 25,000 years.

aquifer

The Ogallala aquifer in the USA contains 4 trillion tonnes of water - more than Lake Huron, the second-largest of the North American Great Lakes.

Edwards Aquifer Home Page

Go to site

Guide to the Edwards Aquifer (a rock formation containing water) in Texas - one of the most prolific artesian aquifers in the world.

Aquila

constellation on the celestial equator (see celestial sphere). Its brightest star is first-magnitude Altair, flanked by the stars Beta and Gamma Aquilae. It is represented by an eagle.

Nova Aquilae, which appeared June 1918, shone for a few days nearly as brightly as Sirius.

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arable farming

cultivation of crops, as opposed to the keeping of animals. Crops may be cereals, vegetables, or plants for producing oils or cloth. Arable farming generally requires less attention than livestock farming. In a mixed farming system, crops may therefore be found farther from the farm centre than animals.

arable farming

(Image © Research Machines plc)

Farming in Turkey. One quarter of the land area in Turkey is used for the cultivation of crops, 80% of which are grains. Maize is the chief grain crop, grown primarily for cattle feed. Most farms in Turkey are small landholdings of less than 11 ha/25 acres.

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arachnid

or arachnoid

type of arthropod of the class Arachnida, including spiders, scorpions, ticks, and mites. They differ from insects in possessing only two main body regions, the cephalothorax and the abdomen, and in having eight legs.

---

araucaria

coniferous tree related to the firs, with flat, scalelike needles. Once widespread, it is now native only to the southern hemisphere. Some grow to gigantic size. Araucarias include the monkey-puzzle tree (*Araucaria araucana*), the Australian bunya bunya pine (*A. bidwillii*), and the Norfolk Island pine (*A. heterophylla*). (Genus *Araucaria*, family Araucariaceae.)

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arboretum

collection of trees. An arboretum may contain a wide variety of species or just closely related species or varieties – for example, different types of pine tree.

---

arbor vitae

any of several coniferous trees or shrubs belonging to the cypress family, with flattened branchlets covered in overlapping aromatic green scales. The northern white cedar (*Thuja occidentalis*) and the western red cedar (*T. plicata*) are found in North America. The Chinese or oriental species *T. orientalis*, reaching 18 m/60 ft in height, is widely grown as an ornamental. (Genus *Thuja*, family Cupressaceae.)

Arbus, Diane (1923-1971)

US photographer. Although she practised as a fashion photographer for 20 years, Arbus is best known for her later work which examined the fringes of American society: the misfits, the eccentrics, and the bizarre. Her work has been attacked as cruel and voyeuristic, but it is essentially sympathetic in its unflinching curiosity. *A Box of Ten Photographs*, a limited edition of her work, was published in 1970.

Arbus, Diane

Go to site

Review of a book on the life and legacy of the US photographer. The power of Arbus' bizarre photos of the giants, midgets, freaks, transvestites, nudists, and the disabled is ascribed to her use of a square camera. The role of her daughter in protecting her reputation after her suicide is described.

---

arbutus

any of a group of evergreen shrubs belonging to the heath family, found in temperate regions. The strawberry tree (*Arbutus unedo*) is grown for its ornamental, strawberrylike fruit. (Genus *Arbutus*, family Ericaceae.)

Arbutus (Strawberry Tree)

Go to site

Detailed information about this shrub. Contained here are detailed notes on its habitat and characteristics, as well as notes on many uses which range from wine production to tanning.

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arc

in geometry, a section of a curved line or circle. A circle has three types of arc: a **semicircle**, which is exactly half of the circle; **minor arcs**, which are less than the semicircle; and **major arcs**, which are greater than the semicircle.

An arc of a circle is measured in degrees, according to the angle formed by joining its two ends to the centre of that circle. A semicircle is therefore 180°, whereas a minor arc will always be less than 180° (acute or obtuse) and a major arc will always be greater than 180° but less than 360° (reflex).

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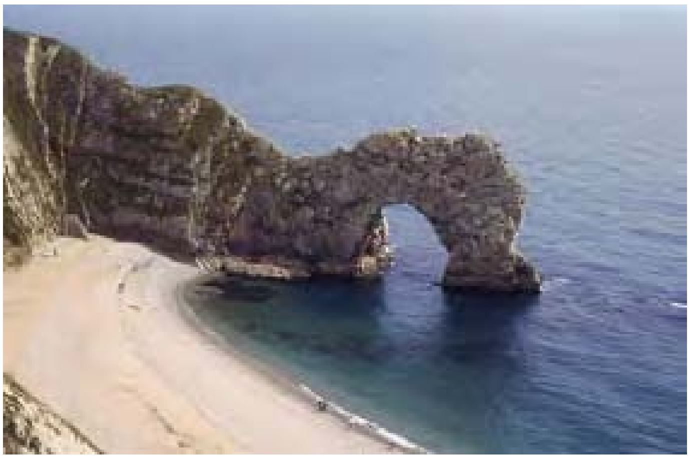
arch

in geomorphology (the study of landforms), any natural bridge-like land feature formed by erosion. Most sea arches are formed from the wave erosion of a headland where the backs of two caves have met and broken through. The roof of the arch eventually collapses to leave part of the headland isolated in the sea as a stack. A natural bridge is formed on land by wind or water erosion and spans a valley or ravine.

In some cases, as at Stair Hole, Dorset, England, an arch is formed when the sea has battered a hole through a cliff of hard rock (such as limestone) and has removed soft rock (such as clay) behind.

arch



(Image © Garret Nagle)

Coastal arch at Durdle Door, on the Dorset coast, England. Beds of resistant limestone form the Durdle promontory. Weaknesses in the limestone, such as faults and joints, have been exploited by forces of erosion and mass wasting (downslope movements of loose materials such as sand). The sea has eroded the limestone to form first a cave, and finally an arch, as the cave reaches through to the far side of the Durdle promontory.

Archaea

singular archaeon; formerly archaebacteria

group of micro-organisms that are without a nucleus and have a single chromosome. They are now known to constitute a separate domain in the tree of life, next to and equally distant from bacteria and eukarya. All are strict anaerobes, that is, they are killed by oxygen. This is thought to be a primitive condition and to indicate that Archaea are related to the earliest life forms, which appeared about 4 billion years ago, when there was little oxygen in the Earth's atmosphere. They are found in undersea vents, hot springs, the Dead Sea, and salt pans, and have even adapted to refuse tips.

The recognition of archaea as a separate domain unrelated to ordinary bacteria goes back to the work of Carl Woese, who investigated the family tree of methanogenic bacteria using fragments of ribosomal RNA. He concluded that these organisms should be set apart from ordinary bacteria. Although subsequent research revealed many differences between archaea and bacteria (for example in the composition of the cell membranes), the new classification remained controversial until 1996, when the complete genome sequencing of *Methanococcus jannaschii* (an archaeaon that lives in undersea vents at temperatures around 100°C/212°F) revealed that 56% of its genes were unlike those of any other organism, making Archaea unique.

Archaean

or Archaeozoic

widely used term for the earliest era of geological time; the first part of the Precambrian **Eon**, spanning the interval from the formation of Earth to about 2,500 million years ago.

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archaeology

(Greek archaia 'ancient things', logos 'study')

study of prehistory and history, based on the examination of physical remains. Principal activities include preliminary field (or site) surveys, excavation (where necessary), and the classification, dating, and interpretation of finds.

history

A museum found at the ancient Sumerian city of Ur indicates that interest in the physical remains of the past stretches back into prehistory. In the Renaissance this interest gained momentum among dealers in and collectors of ancient art and was further stimulated by discoveries made in Africa, the Americas, and Asia by Europeans during the period of imperialist colonization in the 16th–19th centuries, such as the antiquities discovered during Napoleon's Egyptian campaign in the 1790s. Romanticism in Europe stimulated an enthusiasm for the mouldering skull, the ancient potsherds, ruins, and dolmens; relating archaeology to a wider context of art and literature.

Towards the end of the 19th century archaeology became an academic study, making increasing use of scientific techniques and systematic methodologies such as aerial photography. Since World War II new developments within the discipline include medieval, postmedieval, landscape, and industrial archaeology; underwater reconnaissance enabling the excavation of underwater sites; and rescue archaeology (excavation of sites risking destruction).

related disciplines

Useful in archaeological studies are dendrochronology (tree-ring dating), geochronology (science of measuring geological time), stratigraphy (study of geological strata), palaeobotany (study of ancient pollens, seeds, and grains), archaeozoology (analysis of animal remains), epigraphy (study of inscriptions), and numismatics (study of coins).

Archaeology

Go to site

Online edition of the prestigious journal of the Archaeological Institute of America. The well-written articles give a glimpse of the range of archaeological research being done around the globe. The full texts of short articles are available online, together with abstracts (and often the full text) of a large number of longer articles. Two years of back issues can be accessed.

Mercury Project

Go to site

Intriguing presentation of what claims to be the first World Wide Web experiment with tele-robotics. Web users took part in a seven-month (September 1994–March 1995) artificial excavation of an experimental terrarium in Los Angeles, with the help of a tele-robot remotely controlled through a simple Web interface. This site is a must-see for technology enthusiasts. It features descriptions of all phases of the experiment, explanations of the buried artefacts and the user interface, a QuickTime movie from the excavations, and excerpts from the log kept during the experiment.

Odyssey in Egypt

Go to site

Interactive archaeological dig, recorded and arranged week by week during the excavation of a 4th-century Coptic monastery at Wadi Natrun, Egypt. Learn about daily life on the dig, as well as science, archaeology, and Egyptian history and culture.

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archaeopteryx

(Greek archaios 'ancient', pterux 'wing')

extinct primitive bird, known from fossilized remains, about 160 million years old, found in limestone deposits in Bavaria, Germany. It is popularly known as 'the first bird', although some earlier bird ancestors are now known. It was about the size of a crow and had feathers and wings, with three clawlike digits at the end of each wing, but in many respects its skeleton is reptilian (teeth and a long, bony tail) and very like some small meat-eating dinosaurs of the time.

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archegonium

(Greek arche 'origin', gonos 'offspring')

female sex organ found in bryophytes (mosses and liverworts), pteridophytes (ferns, club mosses, and horsetails), and some gymnosperms. It is a multicellular, flask-shaped structure consisting of two parts: the swollen base or venter containing the egg cell, and the long, narrow neck. When the egg cell is mature, the cells of the neck dissolve, allowing the passage of the male gametes, or antherozoids.

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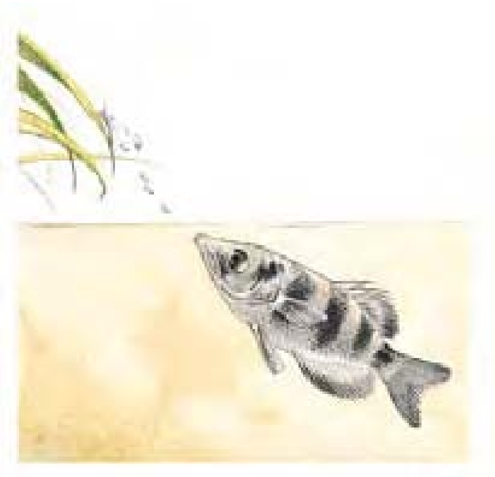
archerfish

surface-living fish of the family Toxotidae, such as the genus *Toxotes*, native to Southeast Asia and Australia. The archerfish grows to about 25 cm/10 in and is able to shoot down insects up to 1.5 m/5 ft above the water by spitting a jet of water from its mouth.

archerfish



(Image © Research Machines plc)

The archerfish inhabits the brackish waters of river estuaries around the coasts of Southeast Asia and northern Australia.

Archimedes (c. 287-212 BC)

Greek mathematician and philosopher who made major discoveries in geometry, hydrostatics, and mechanics, and established the sciences of statics and hydrostatics. He formulated a law of fluid displacement (Archimedes' principle), and is credited with the invention of the Archimedes screw, a cylindrical device for raising water. His method of finding mathematical proof to substantiate experiment and observation became the method of modern science in the High Renaissance.

hydrostatics and Archimedes' principle

The best-known result of Archimedes' work on hydrostatics is Archimedes' principle, which states that a body immersed in water will displace a volume of fluid that weighs as much as the body would weigh in air. It is alleged that Archimedes' principle was discovered when he stepped into the public bath and saw the water overflow. He was so delighted that he rushed home naked, crying 'Eureka! Eureka!' ('I have found it! I have found it!').

He used his discovery to prove that the goldsmith of Hieron II, King of Syracuse, had adulterated a gold crown with silver. Archimedes realized that if the gold had been mixed with silver (which is less dense than gold), the crown would have a greater volume and therefore displace more water than an equal weight of pure gold. The story goes that the crown was found to be impure, and that the unfortunate goldsmith was executed.

statics and the lever

In the field of statics, he is credited with working out the rigorous mathematical proofs behind the law of the lever. The lever had been used by other scientists, but it was Archimedes who demonstrated mathematically that the ratio of the effort applied to the load raised is equal to the inverse ratio of the distances of the effort and load from the pivot or fulcrum of the lever. Archimedes is credited with having claimed that if he had a sufficiently distant place to stand, he could use a lever to move the world.

This claim is said to have given rise to a challenge from King Hieron to Archimedes to show how he could move a truly heavy object with ease, even if he could not move the world. In answer to this, Archimedes developed a system of compound pulleys. According to Plutarch's *Life of Marcellus* (who sacked Syracuse), Archimedes used this to move with ease a ship that had been lifted with great effort by many men out of the harbour on to dry land. The ship was laden with passengers, crew and freight, but Archimedes - sitting at a distance from the ship - was reportedly able to pull it over the land as though it were gliding through water.

mathematics

Archimedes wrote many mathematical treatises, some of which still exist in altered forms in Arabic. Archimedes' approximation for the value for π was more accurate than any previous estimate - the value lying between 223/71 and 220/70. The average of these two numbers is less than 0.0003 different from the modern approximation for π. He also examined the expression of very large numbers, using a special notation to estimate the number of grains of sand in the Universe. Although the result, 10^{63}, was far from accurate, Archimedes demonstrated that large numbers could be considered and handled effectively.

Archimedes also evolved methods to solve cubic equations and to determine square roots by approximation. His formulae for the determination of the surface areas and volumes of curved surfaces and solids anticipated the development of integral calculus, which did not come for another 2,000 years. Archimedes had decreed that his gravestone be inscribed with a cylinder enclosing a sphere together with the formula for the ratio of their volumes - a discovery that he regarded as his greatest achievement.

Archimedes Home Page

Go to site

Extensive material on the ancient Greek philosopher and mathematician Archimedes. The sites includes sections on his life and travels, as well as extracts from ancient sources about his inventions and some famous problems associated with him.

Archimedes' principle

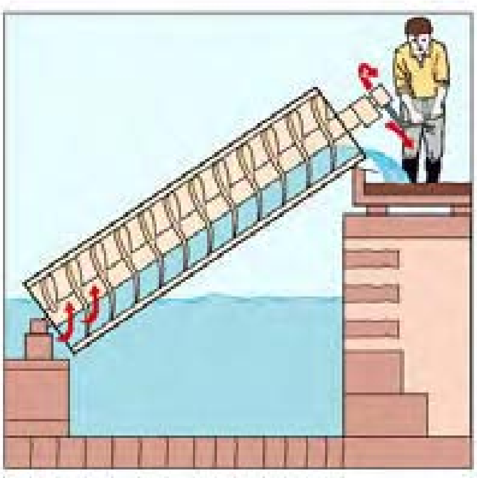
in physics, the principle that the weight of the liquid displaced by a floating body is equal to the weight of the body. The principle is often stated in the form: 'an object totally or partially submerged in a fluid displaces a volume of fluid that weighs the same as the apparent loss in weight of the object (which, in turn, equals the upwards force, or upthrust, experienced by that object).' It was discovered by the Greek mathematician Archimedes.

Archimedes screw

one of the earliest kinds of pump, associated with the Greek mathematician Archimedes. It consists of a large spiral screw revolving inside a close-fitting cylinder. It is used, for example, to raise water for irrigation.

The lowest portion of the screw just dips into the water, and as the cylinder is turned a small quantity of water is scooped up. The inclination of the cylinder is such that at the next revolution the water is raised above the next thread, whilst the lowest thread scoops up another quantity. The successive revolutions, therefore, raise the water thread by thread until it emerges at the top of the cylinder.

Archimedes screw



(Image © Research Machines plc)

The Archimedes screw, a spiral screw turned inside a cylinder, was once commonly used to lift water from canals. The screw is still used to lift water in the Nile delta in Egypt, and is often used to shift grain in mills and powders in factories.

archipelago

group of islands, or an area of sea containing a group of islands. The islands of an archipelago are usually volcanic in origin, and they sometimes represent the tops of peaks in areas around continental margins flooded by the sea.

Volcanic islands are formed either when a hot spot within the Earth's mantle produces a chain of volcanoes on the surface, such as the Hawaiian Archipelago, or at a destructive plate margin (see plate tectonics) where the subduction of one plate beneath another produces an arc-shaped island group called an `island arc', such as the Aleutian Archipelago. Novaya Zemlya in the Arctic Ocean, the northern extension of the Ural Mountains, resulted from continental flooding.

arc lamp

or arc light

electric light that uses the illumination of an electric arc maintained between two electrodes. The English chemist Humphry Davy demonstrated the electric arc in 1802 and electric arc lighting was first introduced by English electrical engineer W E Staite in 1846. The lamp consists of two carbon electrodes, between which a very high voltage is maintained. Electric current arcs (jumps) between the two electrodes, creating a brilliant light. Its main use in recent years has been in cinema projectors.

arc minute

symbol '

unit for measuring small angles, used in geometry, surveying, map-making, and astronomy. An arc minute is one-sixtieth of a degree and is divided into 60 arc seconds (symbol "). Small distances in the sky, as between two close stars or the apparent width of a planet's disc, are expressed in minutes and seconds of arc.

arctic animals

animals inhabiting the Arctic. The birds are chiefly sea birds, such as petrels, eider ducks, cormorants, auks, gulls, puffins, and guillemots; all are migratory. The mammals include the walrus, seals, and several varieties of whale; the polar bear, reindeer, elk, fox, wolf, ermine, and musk ox are the principal terrestrial mammals.

Insectivorous and herbivorous habits are almost absent in arctic animals, which are either fish- or meat-eating. Many of them become snowy-white in winter; among these are birds, such as the ptarmigan, and mammals, such as the hare and lemming, which are brown in summer, and the arctic fox, which is salty-blue in summer; the polar bear is white all year round.

Molluscs, annelids, and jellyfish are common to all the northern seas, while such fish as salmon, cod, and halibut are plentiful. Insects found in the far north include bees, flies, and butterflies, but as the flora is scanty they do not occur in great abundance.

Arctic Circle

imaginary line that encircles the North Pole at latitude 66° 30' north. Within this line there is at least one day in the summer during which the Sun never sets, and at least one day in the winter during which the Sun never rises.

Arcturus

or Alpha Boötis

brightest star in the constellation Boötes and the fourth-brightest star in the night sky. Arcturus is a red giant about 28 times larger than the Sun and 70 times more luminous, 36 light years away from the Sun.

are

metric unit of area, equal to 100 square metres (119.6 sq yd); 100 ares make one hectare.

area

the size of a surface. It is measured in square units, usually square inches (in^2), square yards (yd^2), or square miles (mi^2). Surface area is the area of the outer surface of a solid.

The areas of geometrical plane shapes with straight edges are determined using the area of a rectangle. Integration may be used to determine the area of shapes enclosed by curves.

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areca

any of a group of palm trees native to Asia and Australia. The betel nut comes from the species *Areca catechu*. (Genus *Areca*.)

Arecibo

town in northwest Puerto Rico; population (2001 est) 49,800. It is located on the Atlantic Ocean at the mouth of the Arecibo River, 77 km/48 mi to the west of San Juan. This colonial centre was originally settled in the mid-16th century. A port with some light manufacturing facilities and the site of a college of the University of Puerto Rico, it is also a trade, processing, and distribution hub for an agricultural region producing sugar cane, coffee, fruit, and tobacco. The rum, pharmaceutical, plastics, machinery, and clothing industries are also important. The Cueva del Indio caves and the Río Camuy Cave Park are nearby, and 19 km/12 mi to the south is Cornell University's Arecibo Observatory, the site of the world's largest single-dish radio telescope.

National Astronomy and Ionosphere Centre

Go to site

Reports from the world's largest radio telescope, at Arecibo, Puerto Rico. There is readily understandable information on the work of NAIC and facilities for visitors. There is a wealth of data for professional radio astronomers, a newsletter reporting latest research, a gallery of photos, and links to a number of related sites.

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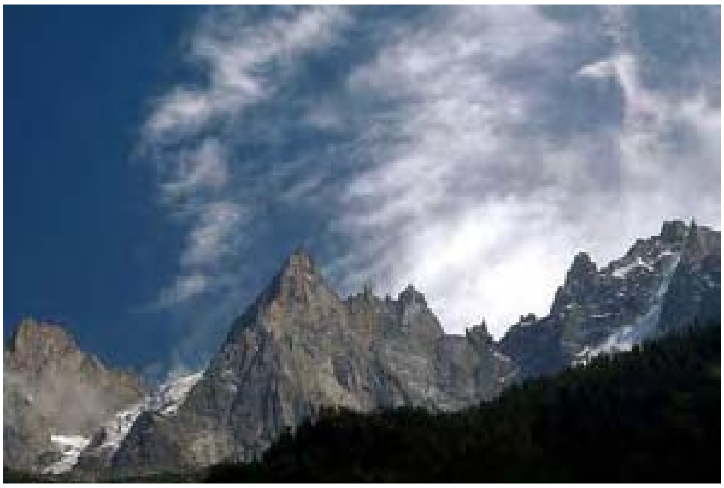
arête

German grat; North American combe-ridge

sharp narrow ridge separating two glacial troughs (U-shaped valleys), or corries. They are formed by intense freeze-thaw weathering on the sides of mountains. The typical U-shaped cross-sections of glacial troughs give arêtes very steep sides. Arêtes are common in glaciated mountain regions such as the Rockies, the Himalayas, and the Alps. There are also several in the UK, for example Striding Edge and Swirral Edge in the English Lake District.

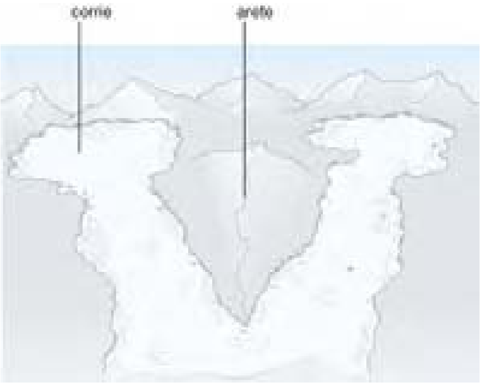
arête



(Image © Corel)

A steep-sided arête in the Alps. The Alps were formed when the sea-bed was lifted up by the movement of tectonic plates, and were shaped by the movement of glaciers during the Ice Age.

arête



(Image © Research Machines plc)

An arête is a steep-sided ridge between two glacially-formed valleys, or corries. If three corries all erode towards the same point, a triangular arête may be formed.

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argali

wild sheep from the mountains of Central Asia. It is the largest species of sheep with a shoulder height of up to 1.2 m/4 ft. Argali *Ovis ammon* is in family Bovidae, order Artiodactyla.

Argand diagram

in mathematics, a method for representing complex numbers by Cartesian coordinates (*x*, *y*). Along the *x*-axis (horizontal axis) are plotted the real numbers, and along the *y*-axis (vertical axis) the nonreal, or imaginary, numbers.

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argon

chemical symbol Ar

(Greek argos 'idle')

colourless, odourless, non-metallic, gaseous element, atomic number 18, relative atomic mass 39.948. It is grouped with the noble gases (rare gases) in Group 0 of the periodic table of the elements. It was long believed not to react with other substances, but observations now indicate that it can be made to combine with boron fluoride to form compounds. It constitutes almost 1% of the Earth's atmosphere, and was discovered in 1894 by British chemists John Rayleigh and William Ramsay after all oxygen and nitrogen had been removed chemically from a sample of air. It is used in electric discharge tubes and argon lasers.

Discovery of Argon - A Case Study in Scientific Method

Go to site

Account of the background to Ramsay and Raleigh's discovery of argon. This is part of a course designed to show the influence of scientific method on the progress of science. The reasons for the failure of earlier chemists to isolate the inert gas are also set out here.

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argonaut

or paper nautilus

octopus living in the open sea, genus *Argonauta*. The female of the common paper nautilus, *A. argo*, is 20 cm/8 in across, and secretes a spiralled papery shell for her eggs from the web of the first pair of arms. The male is a shell-less dwarf, 1 cm/0.4 in across.

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argument

in computing, value on which a function operates. For example, if the argument 16 is operated on by the function 'square root', the answer 4 is produced.

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argument

in mathematics, a specific value of the independent variable of a function of *x*. It is also another name for amplitude.

Ariane rocket

series of launch vehicles built by the European Space Agency, mainly to put telecommunications satellites into orbit two at a time. The first flight was in 1979. The launch site is the Centre Spatial Guyanais, at Kourou in French Guiana. Ariane is a three-stage rocket using liquid fuels. Small solid-fuel and liquid-fuel boosters can be attached to its first stage to increase carrying power. Since 1984 it has been operated commercially by Arianespace.

A more powerful version of the rocket, Ariane 5, was launched on 4 June 1996. However, it pitched over and disintegrated. A fault in the software controlling the take-off trajectory was to blame. In October 1998, another Ariane 5 rocket completed a successful mission, launching a dummy satellite into orbit. The model has had further successes, including the launch of India's Insat 3B satellite in March 2000, and the European Space Agency's *Rosetta* spacecraft launched on 2 March 2004.

Ariane rocket

(Image © NASA)

The Ariane 5 fairing on a test stand inside the Glenn Research Center's Plumbrook facility in Sandusky, Ohio. The extended 17-m/56-ft fairing (4.3 m/14 ft longer than the standard Ariane 5 fairing) is being developed to allow the European booster to launch heavier payloads, which require additional height.

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arid region

in earth science, a region that is very dry and has little vegetation. Aridity depends on temperature, rainfall, and evaporation, and so is difficult to quantify, but an arid area is usually defined as one that receives less than 250 mm/10 in of rainfall each year. (By comparison, New York City receives 1,120 mm/44 in per year.) There are arid regions in North Africa, Pakistan, Australia, the USA, and elsewhere. Very arid regions are deserts.

arid region

(Image © Garret Nagle)

The semi-arid landscape of southern Africa. In relatively dry areas such as this, weathering processes differ slightly from those in wetter places, such as northern Europe. The small amount of water available is enough for some freeze-thaw action, especially since the cloudless skies allow heat to escape at night. Occasional flash floods also help break down the rock.

Aries

zodiacal constellation in the northern hemisphere between Pisces and Taurus, near Auriga, represented as the legendary ram whose golden fleece was sought by Jason and the Argonauts.

Its most distinctive feature is a curve of three stars of decreasing brightness. The brightest of these is Hamal or Alpha Arietis, 65 light years from Earth.

The Sun passes through Aries from late April to mid-May. In astrology, the dates for Aries, the first sign of the zodiac, are between about 21 March and 19 April (see precession). The spring equinox once lay in Aries, but has now moved into Pisces through the effect of the Earth's precession (wobble).

aril

accessory seed cover other than a fruit; it may be fleshy and sometimes brightly coloured, woody, or hairy. In flowering plants (angiosperms) it is often derived from the stalk that originally attached the ovule to the ovary wall. Examples of arils include the bright-red, fleshy layer surrounding the yew seed (yews are gymnosperms so they lack true fruits), and the network of hard filaments that partially covers the nutmeg seed and yields the spice known as mace.

Another aril, the horny outgrowth found towards one end of the seed of the castor-oil plant *Ricinus communis*, is called a caruncle. It is formed from the integuments (protective layers enclosing the ovule) and develops after fertilization.

Aristarchus of Samos (c. 320-c. 250 BC)

Greek astronomer. The first to argue that the Earth moves around the Sun, he was ridiculed for his beliefs. He was also the first astronomer to estimate (quite inaccurately) the sizes of the Sun and Moon and their distances from the Earth.

arithmetic

branch of mathematics concerned with the study of numbers and their properties. The fundamental operations of arithmetic are addition, subtraction, multiplication, and division. Raising to powers (for example, squaring or cubing a number), the extraction of roots (for example, square roots), percentages, fractions, and ratios are developed from these operations.

Forms of simple arithmetic existed in prehistoric times. In China, Egypt, Babylon, and early civilizations generally, arithmetic was used for commercial purposes, records of taxation, and astronomy. During the Dark Ages in Europe, knowledge of arithmetic was preserved in India and later among the Arabs. European mathematics revived with the development of trade and overseas exploration. Hindu-Arabic numerals replaced Roman numerals, allowing calculations to be made on paper, instead of by the abacus.

The essential feature of this number system was the introduction of zero, which allows us to have a **place-value** system. The decimal numeral system employs ten numerals (0,1,2,3,4,5,6,7,8,9) and is said to operate in 'base ten'. In a base-ten number, each position has a value ten times that of the position to its immediate right; for example, in the number 23 the numeral 3 represents three units (ones), and the numeral 2 represents two tens. The Babylonians, however, used a complex base-sixty system, residues of which are found today in the number of minutes in each hour and in angular measurement (6 x 60 degrees). The Mayas used a base-twenty system.

There have been many inventions and developments to make the manipulation of the arithmetic processes easier, such as the invention of logarithms by Scottish mathematician John Napier in 1614 and of the slide rule in the period 1620-30. Since then, many forms of ready reckoners, mechanical and electronic calculators, and computers have been invented.

Modern computers fundamentally operate in base two, using only two numerals (0,1), known as a **binary** system. In binary, each position has a value twice as great as the position to its immediate right, so that for example binary 111 (or 111_2) is equal to 7 in the decimal system, and binary 1111 (or 1111_2) is equal to 15. Because the main operations of subtraction, multiplication, and division can be reduced mathematically to addition, digital computers carry out calculations by adding, usually in binary numbers in which the numerals 0 and 1 can be represented by off and on pulses of electric current.

Modular or modulo arithmetic, sometimes known as residue arithmetic or clock arithmetic, can take only a specific number of digits, whatever the value. For example, in modulo 4 (mod 4) the only values any number can take are 0, 1, 2, or 3. In this system, 7 is written as 3 mod 4, and 35 is also 3 mod 4. Notice 3 is the residue, or remainder, when 7 or 35 is divided by 4. This form of arithmetic is often illustrated on a circle. It deals with events recurring in regular cycles, and is used in describing the functioning of petrol engines, electrical generators, and so on. For example, in the mod 12, the answer to a question as to what time it will be in five hours if it is now ten o'clock can be expressed 10 + 5 = 3.

Multiplication table

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75
4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100
5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125
6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150
7	14	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147	154	161	168	175
8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160	168	176	184	192	200
9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180	189	198	207	216	225
10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250
11	22	33	44	55	66	77	88	99	110	121	132	143	154	165	176	187	198	209	220	231	241	253	264	275
12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300
13	26	39	52	65	78	91	104	117	130	143	156	169	182	195	208	221	234	247	260	273	286	299	312	325
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308	322	336	350
15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375
16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320	336	352	368	384	400
17	34	51	68	85	102	119	136	153	170	187	204	221	238	255	272	289	306	323	340	357	374	391	408	425
18	36	54	72	90	108	126	144	162	180	198	216	234	252	270	288	306	324	342	360	378	396	414	432	450
19	38	57	76	95	114	133	152	171	190	209	228	247	266	285	304	323	342	361	380	399	418	437	456	475
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500
21	42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357	378	399	420	441	462	483	504	525
22	44	66	88	110	132	154	176	198	220	242	264	286	308	330	352	374	396	418	440	462	484	506	528	550
23	46	69	92	115	138	161	184	207	230	253	276	299	322	345	368	391	414	437	460	483	506	529	552	575
24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	504	528	552	576	600
25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625

arithmetic and logic unit

ALU

in computing, the part of the central processing unit (CPU) that performs the basic arithmetic and logic operations on data.

arithmetic mean

average of a set of *n* numbers, obtained by adding the numbers and dividing by *n*. For example, the arithmetic mean of the set of 5 numbers 1, 3, 6, 8, and 12 is $(1 + 3 + 6 + 8 + 12) \div 5 = 30 \div 5 = 6$.

The term average is often used to refer only to the arithmetic mean, even though the mean is in fact only one form of average (the others include median and mode). In addition it is useful to know the range or spread of the data.

arithmetic progression

or arithmetic sequence

sequence of numbers or terms that have a common difference between any one term and the next in the sequence. For example, 2, 7, 12, 17, 22, 27, ... is an arithmetic sequence with a common difference of 5.

The *n*th term in any arithmetic progression can be found using the formula:

nth term = $a + (n - 1)d$

where a is the first term and d is the common difference.

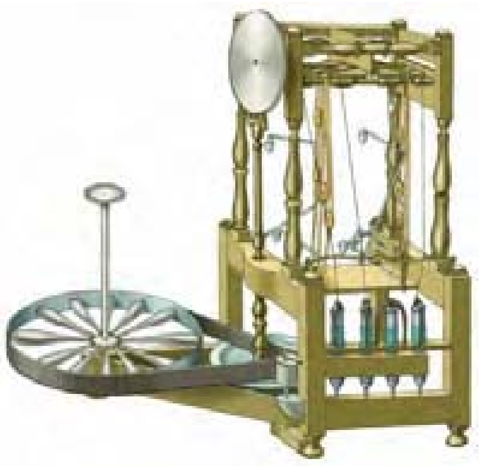
An **arithmetic series** is the sum of the terms in an arithmetic sequence. The sum S of n terms is given by:

$S = n/2[2a + (n -1)d]$

Arkwright, Richard (1732-1792)

English inventor and manufacturing pioneer who in 1768 developed a machine for spinning cotton (he called it a 'water frame'). In 1771 he set up a water-powered spinning factory and in 1790 he installed steam power in a Nottingham factory. He was knighted in 1786.

Arkwright



(Image © Research Machines plc)

The 'water frame' for spinning cotton, designed by British inventor Richard Arkwright in 1768. Although so-called because it was water-powered, it was originally driven by mule. From 1790 onwards it was powered by steam engine. Its increased efficiency allowed Arkwright's factories to successfully compete with Indian calico manufacturers.

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armadillo

mammal of the family Dasypodidae, with an armour of bony plates along its back or, in some species, almost covering the entire body. Around 20 species live between Texas and Patagonia and range in size from the fairy armadillo, or pichiciego, *Chlamyphorus truncatus*, at 13 cm/5 in, to the giant armadillo *Priodontes giganteus*, 1.5 m/4.5 ft long. Armadillos feed on insects, snakes, fruit, and carrion. Some can roll into an armoured ball if attacked; others defend themselves with their claws or rely on rapid burrowing for protection.

They belong to the order Edentata ('without teeth') which also includes sloths and anteaters. However, only the latter are toothless. Some species of armadillos can have up to 90 peglike teeth.

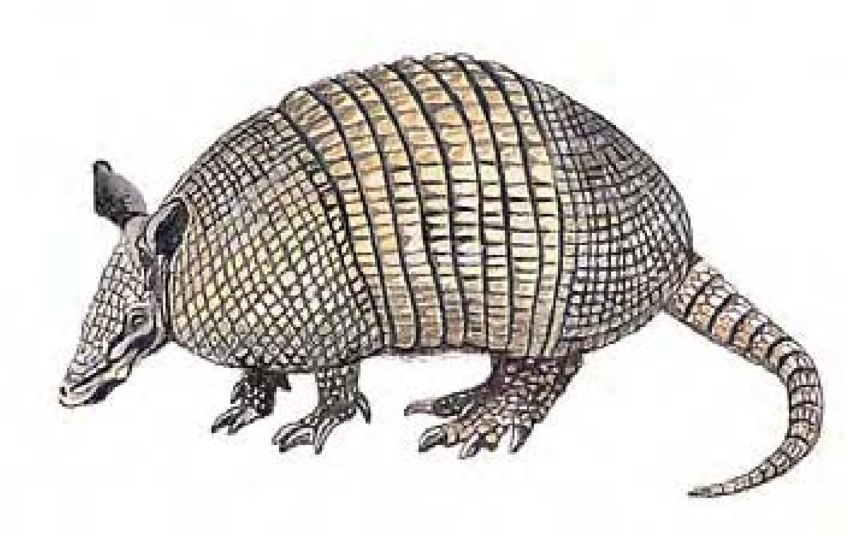
armadillo: penis size

The penis of the nine-banded armadillo is about a third of its body length when erect.

armadillo: reproduction

Nine-banded armadillos almost always produce litters of quadruplets. The one fertilized egg divides into four to produce a single-sex litter of identical babies. The female armadillo can delay the implantation of her egg for up to three years to maximize the chances of her offspring's survival.

armadillo



(Image © Research Machines plc)

The horny bands and plates of the armadillo serve as armour. Many species can draw in their feet beneath the shell when attacked. The three-banded armadillo can roll itself into a ball.

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armature

in a motor or generator, the wire-wound coil that carries the current and rotates in a magnetic field. (In alternating-current machines, the armature is sometimes stationary.) The pole piece of a permanent magnet or electromagnet and the moving, iron part of a solenoid, especially if the latter acts as a switch, may also be referred to as armatures.

---

armillary sphere

earliest known astronomical device, in use from the 3rd century BC. It showed the Earth at the centre of the universe, surrounded by a number of movable metal rings representing the Sun, Moon, and planets. The armillary sphere was originally used to observe the heavens and later for teaching navigators about the arrangements and movements of the heavenly bodies.

---

armoured personnel carrier

APC

wheeled or tracked military vehicle with light to medium armour protection used to carry infantry into and out of battle; it carries up to ten people. Many APCs are amphibious and most mount light weapons for close defence and support.

armoured personnel carrier

(Image © Corel)

An armoured personnel carrier with caterpillar tracks for driving over rough terrain. They are used for transporting troops.

Armstrong, Neil Alden (1930-)

US astronaut. On 20 July 1969, he became the first person to set foot on the Moon and made his now famous remark, 'That's one small step for man, one giant leap for mankind.' The Moon landing was part of the *Apollo* project.

He joined the US National Aerospace Program in 1962, and commanded *Gemini 8* in March 1966, linking with an uncrewed Agena rocket. With Buzz Aldrin and Michael Collins in *Apollo 11* on 16 July 1969, he lifted off from the Kennedy Space Center in Florida, to land four days later on the Moon. The mission collected soil samples, explored, and set up scientific instruments during 22 hours on the lunar surface.

Armstrong, Neil

Go to site

Biographical notes from NASA of the very first Moon walker. Details include personal information and education, as well as his work at NASA.

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aromatherapy

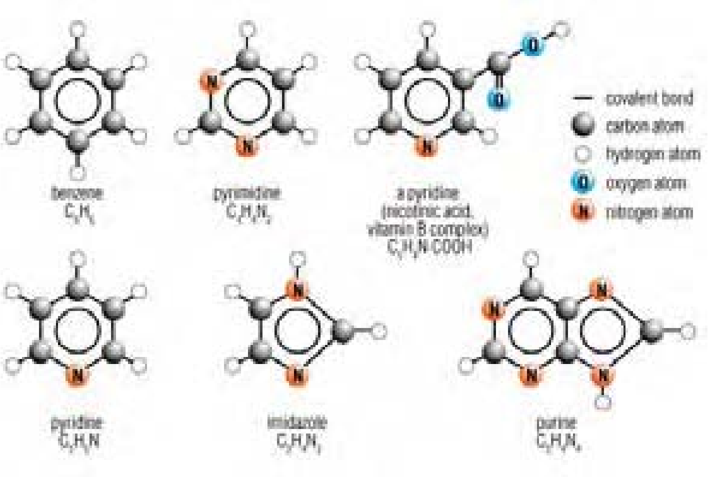
in alternative medicine, use of oils and essences derived from plants, flowers, and wood resins. Bactericidal properties and beneficial effects upon physiological functions are attributed to the oils, which are sometimes ingested but generally massaged into the skin.

Aromatherapy was first used in ancient Greece and Egypt, but became a forgotten art until the 1930s, when a French chemist accidentally spilt lavender over a cut and found that the wound healed without a scar. However, it was not until the 1970s that it began to achieve widespread popularity.

aromatic compound

organic chemical compound in which some of the bonding electrons are delocalized (shared among several atoms within the molecule and not localized in the vicinity of the atoms involved in bonding). The commonest aromatic compounds have ring structures, the atoms comprising the ring being either all carbon or mostly carbon with one or more different atoms (usually nitrogen, sulphur, or oxygen). Typical examples are benzene (C_6H_6) and pyridine (C_6H_5N).

aromatic compound



(Image © Research Machines plc)

Compounds whose molecules contain the benzene ring, or variations of it, are called aromatic. The term was originally used to distinguish sweet-smelling compounds from others.

Arrhenius, Svante August (1859-1927)

Swedish scientist, the founder of physical chemistry. He was awarded the Nobel Prize for Chemistry in 1903 for his study of electrolysis. In 1905 he predicted global warming as a result of carbon dioxide emission from burning fossil fuels.

Arrhenius explained that in an electrolyte the dissolved substance is dissociated into electrically charged ions. The electrolyte conducts electricity because the ions migrate through the solution.

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arrhythmia

disturbance of the normal rhythm of the heart. There are various kinds of arrhythmia, some benign, some indicative of heart disease. In extreme cases, the heart may beat so fast as to be potentially lethal and surgery may be used to correct the condition.

Extra beats between the normal ones are called **extrasystoles**; abnormal slowing is known as **bradycardia** and speeding up is known as **tachycardia**.

---

arrowroot

starchy substance used as a thickener in cooking, produced from the clumpy roots of various tropical plants. The true arrowroot (*Maranta arundinacea*) was used by native South Americans as an antidote against the effects of poisoned arrows.

The West Indian island of St Vincent is the main source of supply today. The plant roots and tubers are dried, finely powdered, and filtered. Because of the small size of the starch particles, the powder becomes translucent when cooked.

Arrowroot

Go to site

Contains detailed information about this plant. This site includes a description of the plant, its history, and its habitat. There are also extensive notes on its medicinal uses, which include acting as an antidote for certain poisons, arresting gangrene, and as food for convalescents. It also features details of other species of this plant.

arsenic

chemical symbol As

semimetallic element (a metalloid), atomic number 33, relative atomic mass 74.92. Like phosphorus, the element can appear in different modifications, of which the grey, 'metallic' arsenic is the most stable. Arsenic occurs in many ores and occasionally in its elemental state, and is widely distributed, being present in minute quantities in the soil, sea, and the human body. In larger quantities, it is poisonous. The chief source of arsenic compounds is as a by-product from metallurgical processes. It is used in making semiconductors, alloys, and solders.

arsenic poisoning

As it is a cumulative poison, its presence in food and drugs is very dangerous. The symptoms of arsenic poisoning are vomiting, diarrhoea, tingling and possibly numbness in the limbs, and collapse. It featured in some drugs, including Salvarsan, the first specific treatment for syphilis. Its name derives from the Latin *arsenicum*. The maximum safe level for arsenic in drinking water, as recommended by the World Health Organization (WHO), is 10 micrograms per litre. Drinking water contaminated with arsenic remains a major concern in several countries, such as India and Bangladesh.

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arteriosclerosis

hardening of the arteries, with thickening and loss of elasticity. It is associated with smoking, ageing, and a diet high in saturated fats. The term is used loosely as a synonym for atherosclerosis.

---

artery

blood vessel that carries blood from the heart to any part of the body. It is built to withstand considerable pressure, having thick walls that contain muscle and elastic fibres. As blood pulses out of the heart, arteries expand to allow for the increase in pressure – this elasticity helps the blood to flow evenly. The pulse or pressure wave generated can be felt at the wrist. Not all arteries carry oxygenated (oxygen-rich) blood – the pulmonary arteries convey deoxygenated (oxygen-poor) blood from the heart to the lungs.

Arteries are flexible, elastic tubes, consisting of three layers. The middle layer is muscular and its rhythmic contraction aids the pumping of blood around the body. In middle and old age, artery walls become damaged. Some of this damage is caused by the build-up of fatty deposits (see fats). This reduces elasticity and narrows the space (or bore) through which the blood can flow. This condition is known as hardening of the arteries or atherosclerosis and can lead to high blood pressure, loss of circulation, and death. When it affects the arteries supplying blood to the muscle of the heart wall it is called heart disease. People with heart disease run an increased risk of having a heart attack. In a heart attack blood vessels supplying the heart muscles are blocked by a blood clot and this can result in sudden death. Research indicates that for some people a typical Western diet, high in fat from animals, increases the chances of heart disease developing.

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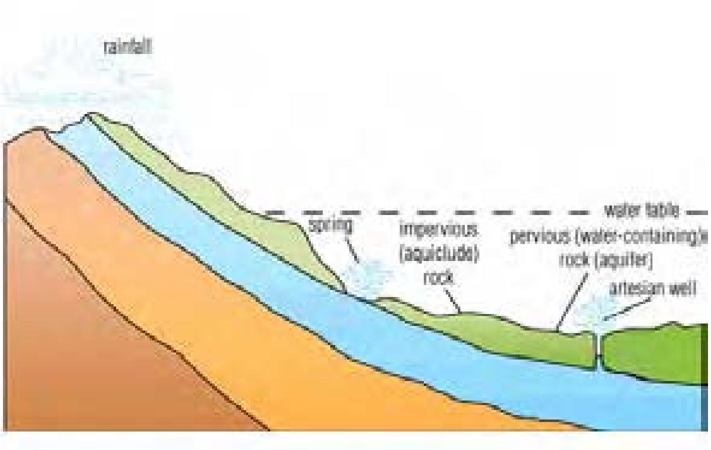
artesian well

well that is supplied with water rising naturally from an underground water-saturated rock layer (aquifer). The water rises from the aquifer under its own pressure. Such a well may be drilled into an aquifer that is confined by impermeable rocks both above and below. If the water table (the top of the region of water saturation) in that aquifer is above the level of the well head, hydrostatic pressure will force the water to the surface.

Artesian wells are often overexploited because their water is fresh and easily available, and they eventually become unreliable. There is also some concern that pollutants such as pesticides or nitrates can seep into the aquifers.

artesian well



(Image © Research Machines plc)

In an artesian well, water rises from an underground water-containing rock layer under its own pressure. Rain falls at one end of the water-bearing layer, or aquifer, and percolates through the layer. The layer fills with water up to the level of the water table. Water will flow from a well under its own pressure if the well head is below the level of the water table.

arthritis

inflammation of the joints, with pain, swelling, and restricted motion. Many conditions may cause arthritis, including gout, infection, and trauma to the joint. There are three main forms of arthritis: rheumatoid arthritis; osteoarthritis; and septic arthritis.

arthropod

member of the phylum Arthropoda; an invertebrate animal with jointed legs and a segmented body with a horny or chitinous casing (exoskeleton), which is shed periodically and replaced as the animal grows. Included are arachnids such as spiders and mites, as well as crustaceans, millipedes, centipedes, and insects.

artichoke

either of two plants belonging to the sunflower family, parts of which are eaten as vegetables. The common or globe artichoke (*Cynara scolymus*) is a form of thistle native to the Mediterranean. It is tall, with purplish-blue flowers; the leaflike structures (bracts) around the unopened flower are eaten. The Jerusalem artichoke (*Helianthus tuberosus*), which has edible tubers, is a native of North America (its common name is a corruption of the Italian for sunflower, *girasole*). (Family Compositae.)

Artichoke, Globe

Go to site

Contains detailed information about this plant. This site includes a description of the plant and its place in history. There are also notes on the different way of cultivating artichokes. This page forms part of a larger site which also has information on the Jerusalem artichoke.

artificial insemination

AI

introduction by instrument of semen from a sperm bank or donor into the female reproductive tract to bring about fertilization. Originally used by animal breeders to improve stock with sperm from high-quality males, in the 20th century it was developed for use in humans, to help the infertile. See in vitro fertilization.

artificial intelligence

AI

branch of science concerned with creating computer programs that can perform actions comparable with those of an intelligent human, including learning and adaptation. AI research covers such areas as planning (for robot behaviour), language understanding, pattern recognition, and knowledge representation.

The possibility of artificial intelligence was first proposed by the English mathematician Alan Turing in 1950. Early AI programs, developed in the 1960s, attempted simulations of human intelligence or were aimed at general problem-solving techniques. By the mid-1990s, scientists were concluding that AI was more difficult to create than they had imagined. It is now thought that intelligent behaviour depends as much on the knowledge a system possesses as on its reasoning power. Present emphasis is on knowledge-based systems, such as expert systems, while research projects focus on neural networks, which attempt to mimic the structure of the human brain.

On the Internet, small bits of software that automate common routines or attempt to predict human likes or behaviour based on past experience are called intelligent agents or bots.

artificial radioactivity

natural and spontaneous radioactivity arising from radioactive isotopes or elements that are formed when elements are bombarded with subatomic particles - protons, neutrons, or electrons - or small nuclei.

artificial respiration

emergency procedure to restart breathing once it has stopped; in cases of electric shock or apparent drowning, for example, the first choice is the expired-air method, the kiss of life by mouth-to-mouth breathing until natural breathing is restored.

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artificial selection

in biology, selective breeding of individuals that exhibit particular characteristics that a plant or animal breeder wishes to develop. In plants, desirable features might include resistance to disease, high yield (in crop plants), or attractive appearance. In animal breeding, selection has led to the development of particular breeds of cattle for improved meat production (such as the Aberdeen Angus) or milk production (such as Holsteins).

Artificial selection was practised by the Sumerians at least 5,500 years ago and carried on through the succeeding ages, with the result that all common vegetables, fruit, and livestock are long modified by selective breeding. Artificial selection, particularly of pigeons, was studied by the English evolutionist Charles Darwin who saw a similarity between this phenomenon and the processes of natural selection.

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arum

any of a group of mainly European plants with narrow leaves and a single, usually white, special leaf (spathe) surrounding the spike of tiny flowers. The ornamental arum called the trumpet lily (*Zantedeschia aethiopica*) is a native of South Africa. (Genus *Arum*, family Araceae.)

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asbestos

any of several related minerals of fibrous structure that offer great heat resistance because of their nonflammability and poor conductivity. Commercial asbestos is generally either made from serpentine ('white' asbestos) or from sodium iron silicate ('blue' asbestos). The fibres are woven together or bound by an inert material. Over time the fibres can work loose and, because they are small enough to float freely in the air or be inhaled, asbestos usage is now strictly controlled; exposure to its dust can cause cancer.

asbestos: Charlemagne

In around 800, Charlemagne used an asbestos tablecloth to impress his dinner guests, by putting it in the fire and then withdrawing it unscorched.

asbestos: first mention

The first mention of asbestos is in Theophrastus' *On Stones* in 300 BC. He refers to a substance that resembles wood and burns without being damaged when doused in oil.

Ten Most Commonly Asked Questions About Asbestos

Go to site

As its title suggests, this site offers the ten most popular questions and answers relating to asbestos. It describes what asbestos is, how it can be a hazard, and what course of action you should take if you are concerned.

ASCII

acronym for American Standard Code for Information Interchange

in computing, coding system in which numbers are assigned to letters, digits, and punctuation symbols. Although computers work in code based on the binary number system, ASCII numbers are usually quoted as decimal or hexadecimal numbers. For example, the decimal number 45 (binary 0101101) represents a hyphen, and 65 (binary 1000001) a capital A. The first 32 codes are used for control functions, such as carriage return and backspace.

Strictly speaking, ASCII is a 7-bit binary code, allowing 128 different characters to be represented, but an eighth bit is often used to provide parity or to allow for extra characters. The system is widely used for the storage of text and for the transmission of data between computers.

ASCII codes

The American Standard Code for Information Interchange (ASCII) table gives numerical representations to characters, to allow ease of understanding when using computers.

Character	Binary (base 2)	Decimal (base 10)	Hexadecimal (base 16)
Space	00100000	32	20
!	00100001	33	21
"	00100010	34	22

#	00100011	35	23
$	00100100	36	24
%	00100101	37	25
&	00100110	38	26
`	00100111	39	27
(	00101000	40	28
)	00101001	41	29
*	00101010	42	2A
+	00101011	43	2B
,	00101100	44	2C
-	00101101	45	2D
.	00101110	46	2E
/	00101111	47	2F
0	00110000	48	30
1	00110001	49	31
2	00110010	50	32
3	00110011	51	33
4	00110100	52	34
5	00110101	53	35
6	00110110	54	36
7	00110111	55	37
8	00111000	56	38
9	00111001	57	39
:	00111010	58	3A
;	00111011	59	3B
<	00111100	60	3C
=	00111101	61	3D
>	00111110	62	3E
?	00111111	63	3F
@	01000000	64	40
A	01000001	65	41
B	01000010	66	42
C	01000011	67	43
D	01000100	68	44
E	01000101	69	45
F	01000110	70	46
G	01000111	71	47
H	01001000	72	48
I	01001001	73	49
J	01001010	74	4A
K	01001011	75	4B
L	01001100	76	4C
M	01001101	77	4D
N	01001110	78	4E
O	01001111	79	4F
P	01010000	80	50
Q	01010001	81	51
R	01010010	82	52
S	01010011	83	53
T	01010100	84	54
U	01010101	85	55
V	01010110	86	56
W	01010111	87	57
X	01011000	88	58
Y	01011001	89	59
Z	01011010	90	5A
[	01011011	91	5B
\	01011100	92	5C
]	01011101	93	5D
^	01011110	94	5E
_	01011111	95	5F
'	01100000	96	60
a	01100001	97	61
b	01100010	98	62
c	01100011	99	63

d	01100100	100	64
e	01100101	101	65
f	01100110	102	66
g	01100111	103	67
h	01101000	104	68
i	01101001	105	69
j	01101010	106	6A
k	01101011	107	6B
l	01101100	108	6C
m	01101101	109	6D
n	01101110	110	6E
o	01101111	111	6F
p	01110000	112	70
q	01110001	113	71
r	01110010	114	72
s	01110011	115	73
t	01110100	116	74
u	01110101	117	75
v	01110110	118	76
w	01110111	119	77
x	01111000	120	78
y	01111001	121	79
z	01111010	122	7A
{	01111011	123	7B
|	01111100	124	7C
}	01111101	125	7D
~	01111110	126	7E
Delete	01111111	127	7F

ASCII Chart and Other Resources

Go to site

Features a brief introduction to American Standard Code for Information Interchange (ASCII), as well as an ASCII chart, a series of related questions and answers, and numerous other ASCII resources.

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ascorbic acid

or vitamin C; $C_6H_8O_6$

relatively simple organic acid found in citrus fruits and vegetables. It is soluble in water and destroyed by prolonged boiling, so soaking or overcooking of vegetables reduces their vitamin C content. Lack of ascorbic acid results in scurvy.

In the human body, ascorbic acid is necessary for the correct synthesis of collagen. Lack of vitamin C causes skin sores or ulcers, tooth and gum problems, and burst capillaries (scurvy symptoms) owing to an abnormal type of collagen replacing the normal type in these tissues.

Unlike other vitamins, ascorbic acid has not been found to have any negative effects if it is 'overdosed'.

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asepsis

practice of ensuring that bacteria are excluded from open sites during surgery, wound dressing, blood sampling, and other medical procedures. Aseptic technique is a first line of defence against infection.

---

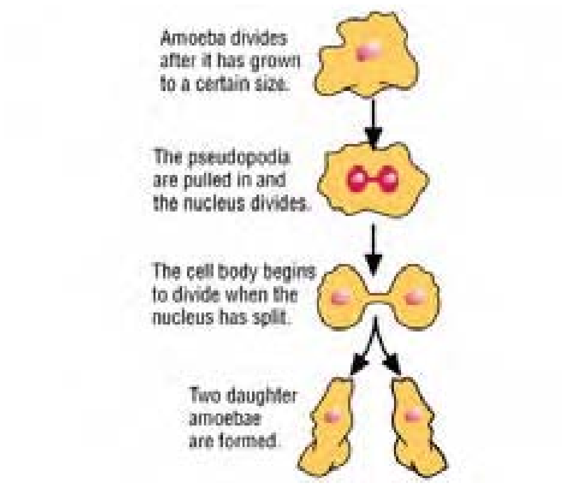
asexual reproduction

reproduction that does not involve the manufacture and fusion of sex cells (gametes) from two parents. Asexual reproduction has advantages in that there is no need to search for a mate; every asexual organism can reproduce on its own. Asexual reproduction can therefore lead to a rapid population build-up. However, every new organism produced by asexual reproduction is genetically identical to the parent – a clone.

In evolutionary terms, the disadvantage of asexual reproduction arises from the fact that only identical individuals (clones) are produced – there is no variation. In agriculture and horticulture, where standardized production is needed, this is useful. Taking cuttings of a good variety of fruit tree is an example of artificial asexual reproduction. However, in the wild, an asexual population that cannot adapt to a changing environment or evolve defences against a new disease is at risk of extinction. Many asexually reproducing organisms are therefore capable of reproducing sexually as well.

Asexual reproduction is very common in micro-organisms. But there are also many plants that use it naturally. The blackberry or bramble spreads by allowing its stems to root where they touch the ground. However, the blackberry also reproduces sexually using its flowers.

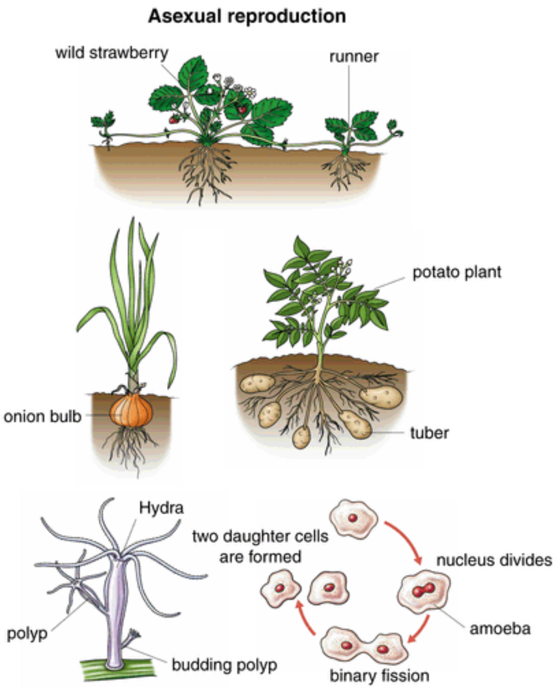
asexual reproduction


Amoeba divides after it has grown to a certain size.
The pseudopodia are pulled in and the nucleus divides.
The cell body begins to divide when the nucleus has split.
Two daughter amoebae are formed.

(Image © Research Machines plc)

Asexual reproduction is the simplest form of reproduction, occurring in many simple plants and animals. Binary fission, shown here occurring in an amoeba, is one of a number of asexual reproduction processes

asexual reproduction


Asexual reproduction
wild strawberry
runner
potato plant
onion bulb
tuber
Hydra
two daughter cells are formed
nucleus divides
polyp
amoeba
budding polyp
binary fission

(Image © Research Machines plc)

Examples of asexual reproduction. Asexual reproduction is the simplest form of reproduction, occurring in many plants and simple animals. Strawberry plants can reproduce by sending out runners; onion plants form bulbs; and potato plants form tubers. Amoebas divide into two (binary fission) and hydra form new hydra by budding. The offspring are always genetically identical to the parent.

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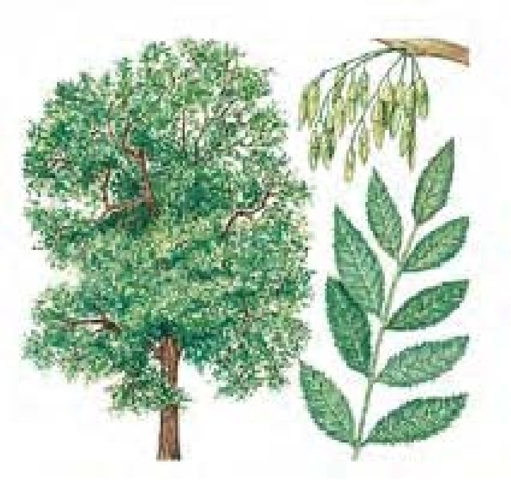
ash

any tree of a worldwide group belonging to the olive family, with winged fruits. The mountain ash or rowan, which resembles the ash, belongs to the family Rosaceae. (Genus *Fraxinus*, family Oleaceae.)

ash



(Image © Research Machines plc)

Ash is the name given to a few northern European trees and shrubs of the *Fraxinus* genus. They belong to the same family as the olive, lilac, and jasmine. Ashes generally have a compound leaf with leaflets arranged on either side of a stem and a winged fruit.

Ash

Go to site

Contains detailed information about the ash. This site also features an extensive description of the different types of this tree, as well as notes on its constituents. There is also information about its medicinal uses, which include treating dropsy, jaundice, as well as gout and rheumatic complaints.

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ashen light

in astronomy, faint glow occasionally reported in the dark hemisphere of Venus when the planet is in a crescent phase. The glow probably originates from the high temperatures at the surface and in the lower atmosphere of Venus.

Asiatic wild ass

alternative name for both the kiang and the onager.

Asimov, Isaac (1920-1992)

Russian-born US author and editor of science fiction and nonfiction. He published more than 400 books, including his science fiction novels *I, Robot* (1950) and the *Foundation* trilogy (1951-53), continued in *Foundation's Edge* (1983). His two-volume work *The Intelligent Man's Guide to Science* (1960) gained critical acclaim.

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asp

any of several venomous snakes, including *Vipera aspis* of southern Europe, allied to the adder, and the Egyptian cobra *Naja haje*, reputed to have been used by the Egyptian queen Cleopatra for her suicide.

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asparagus

any of a group of plants with small scalelike leaves and many fine, feathery branches. Native to Europe and Asia, *Asparagus officinalis* is cultivated and the tender young shoots (spears) are greatly prized as a vegetable. (Genus *Asparagus*, family Liliaceae.)

Asparagus

Go to site

Informative guide to asparagus from the Virginia Cooperative Extension. There is a guide to planting asparagus, as well as the types of soil and sunlight that yield best results. This site also features solutions to common problems and information about harvesting and storage.

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aspartame

noncarbohydrate sweetener used in foods under the tradename Nutrasweet. It is about 200 times as sweet as sugar and, unlike saccharine, has no aftertaste.

The aspartame molecule consists of two amino acids (aspartic acid and phenylalanine) linked by a methylene (—CH_2 —) group. It breaks down slowly at room temperature and rapidly at higher temperatures. It is not suitable for people who suffer from phenylketonuria.

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aspect

in earth sciences the direction in which a slope faces. In the northern hemisphere a slope with a southerly aspect receives more sunshine than other slopes and is therefore better suited for growing crops that require many hours of sunshine in order to ripen successfully. Vineyards in northern Europe are usually situated on south-facing slopes.

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aspen

any of several species of poplar tree. The European quaking aspen (*Populus tremula*) has flattened leafstalks that cause the leaves to flutter in the slightest breeze. The soft, light-coloured wood is used for matches and paper pulp. (Genus *Populus*.)

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asphalt

mineral mixture containing semisolid brown or black bitumen, used in the construction industry. Asphalt is mixed with rock chips to form paving material, and the purer varieties are used for insulating material and for waterproofing masonry. It can be produced artificially by the distillation of petroleum.

The availability of recycled coloured glass led in 1988 to the invention of **glassphalt**, asphalt that is 15% crushed glass. It is used to pave roads in New York.

Considerable natural deposits of asphalt occur around the Dead Sea and in the Philippines, Cuba, Venezuela, and Trinidad. Bituminous limestone occurs at Neufchâtel, France.

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asphodel

either of two related Old World plants of the lily family. The white asphodel or king's spear (*Asphodelus albus*) is found in Italy and Greece, sometimes covering large areas, and providing grazing for sheep. The other asphodel is the yellow asphodel (*Asphodeline lutea*). (Genera *Asphodelus* and *Asphodeline*, family Liliaceae.)

The ancient Greeks connected the beautiful plants of *A. lutea* with the dead, and they were supposed to grow in the mythological Elysian fields where heroes enjoyed new life after death.

Asphodel

Go to site

Includes detailed information about this plant, including a detailed description of both the plant itself and its habitat. The site also features details of the constituents of asphodel, as well as notes on its medicinal uses. There is also a brief introduction to other species of this plant.

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asphyxia

suffocation; a lack of oxygen that produces a potentially lethal build-up of carbon dioxide waste in the tissues.

Asphyxia may arise from any one of a number of causes, including inhalation of smoke or poisonous gases, obstruction of the windpipe (by water, food, vomit, or a foreign object), strangulation, or smothering. If it is not quickly relieved, brain damage or death ensues.

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aspidistra

any of several Asiatic plants of the lily family. The Chinese *Aspidistra elatior* has broad leaves which taper to a point and, like all aspidistras, grows well in warm indoor conditions. (Genus *Aspidistra*, family Liliaceae.)

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aspirin

acetylsalicylic acid, a popular pain-relieving drug (analgesic) developed in the late 19th century as a household remedy for aches and pains. It relieves pain and reduces inflammation and fever. It is the world's most widely used drug.

Aspirin was first refined from salicylic acid by German chemist Felix Hoffman, and marketed in 1899. Although salicylic acid occurs naturally in bark of willow *Salix alba* (and has been used for pain relief since 1763) the acetyl derivative is less bitter and less likely to cause vomiting.

Aspirin: A History

a hundred years of headaches

What common drug was known to the Greeks and is currently being investigated for the treatment of cataracts, cancer of the colon, and senile dementia? It is a drug of proven efficacy in the treatment of heart disease, and 38 million tonnes of it are sold worldwide every year. The drug is aspirin. It has a simple chemical formula, and aspirin-like substances are found quite naturally in plants.

the discovery of aspirin

A hundred years ago, German chemist Felix Hoffmann was working for the Bayer company and wanted to help his father, who was painfully afflicted with arthritis. He already knew about salicylic acid and its ability to relieve pain. With his colleague Heinrich Dresser he developed aspirin, which Bayer patented in 1899. Aspirin is the acetylated form of salicylic acid. It is stable, and does not have the unpleasant taste, or cause the irritation of the mouth of the parent compound. Successfully marketed, aspirin soon replaced cannabis, the pain reliever then widely used.

The wild flower meadowsweet contains salicin, a substance from which aspirin can be made. Aspirin got its name from meadowsweet, or *Spiraea ulmaria*; the German chemists simply added an 'a' (for acetyl) at the beginning.

aspirin's long history

To ease the pain of childbirth, Hippocrates recommended tea made from willow bark. Willow bark contains salicin. The ability of a white willow brew to reduce fever was proved by a Cotswold parson, the Reverend Edmund Stone. Quite by accident, he noticed that the bark of the willow tree tasted bitter and wondered if it had the same properties as the bark of the cinchona, or fever tree, which also tasted bitter. It did; he tested his concoction on 50 people with considerable success and reported his results to the Royal Society in 1763.

Aspirin the painkiller now has many competitors, all more expensive. But aspirin retains a quarter of the market and, as new uses are found for it, will surely continue to be sold well.

Aspirin - Molecule of the Month

Go to site

Interactive presentation on aspirin with information on its properties and uses and a rotatable image of its molecule from the Department of Chemistry at Bristol University, UK, for those with Java-enabled browsers.

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ass

any of several horselike, odd-toed, hoofed mammals of the genus *Equus*, family Equidae. Species include the African wild ass *E. asinus*, and the Asian wild ass *E. hemionus*. They differ from horses in their smaller size, larger ears, tufted tail, and characteristic bray. Donkeys and burros are domesticated asses.

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assassin bug

member of a family of blood-sucking bugs that contains about 4,000 species. Assassin bugs are mainly predators, feeding on other insects, but some species feed on birds and mammals, including humans. They are found, mainly in tropical regions, although some have established themselves in Europe and North America.

classification

Assassin bugs are in the family Reduviidae, suborder Heteroptera, order Hemiptera (true bugs), class Insecta, phylum Arthropoda.

The general characteristics of the family include bright coloration, a long four-segmented antenna, and a cone-shaped proboscis which, when the insect is not feeding, is folded under the head. Because of this they are sometimes called **cone-nosed** bugs.

species

Reduvius personatus is about 15 mm/0.5 in long and dark brown. In the wild it inhabits hollow trees where it feeds on the blood of other insects. It can invade houses, where it hides in holes and crevices in the wall. Like other assassin bugs, it is nocturnal, emerging at night to feed on bedbugs and other insects. It is widely distributed in Europe and North America.

Kissing bugs comprise several Central and South American genera that have earned their name from their habit of biting sleeping people on the face. *Rhodnius*, *Triatoma*, and *Panstrongylus*, are vectors for the parasite that causes Chagas's disease.

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assay

in chemistry, the determination of the quantity of a given substance present in a sample. Usually it refers to determining the purity of precious metals. In biochemistry, it refers to quantitative measurements, for example of enzyme activity.

The assay may be carried out by 'wet' methods, when the sample is wholly or partially dissolved in some reagent (often an acid), or by 'dry' or 'fire' methods, in which the compounds present in the sample are combined with other substances.

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assembler

in computing, program that translates a program written in an assembly language into a complete machine code program that can be executed by a computer. Each instruction in the assembly language is translated into only one machine-code instruction.

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assembly language

low-level computer-programming language closely related to a computer's internal codes. It consists chiefly of a set of short sequences of letters (mnemonics), which are translated, by a program called an assembler, into machine code for the computer's central processing unit (CPU) to follow directly. In assembly language, for example, 'JMP' means 'jump' and 'LDA' means 'load accumulator'. Assembly code is used by programmers who need to write very fast or efficient programs.

Because they are much easier to use, high-level languages are normally used in preference to assembly languages. An assembly language may still be used in some cases, however, particularly when no suitable high-level language exists or where a very efficient machine-code program is required.

Assembler Zone

Go to site

Great programming resource. The Assembler Zone has information, code, tools, and source code in a variety of languages, including assembler. It is packed with news and information, it has useful downloads, discussion forums, and it features programming books recommended by users of the Web site.

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assembly line

method of mass production in which a product is built up step-by-step by successive workers adding one part at a time. It is commonly used in industries such as the car industry.

US inventor Eli Whitney pioneered the concept of industrial assembly in the 1790s, when he employed unskilled labour to assemble muskets from sets of identical precision-made parts produced by machine tools. In 1901 Ransome Olds in the USA began mass-producing motor cars on an assembly-line principle, a method further refined by the introduction of the moving conveyor belt by Henry Ford in 1913 and the time-and-motion studies of Frederick Winslow Taylor. On the assembly line human workers now stand side by side with robots.

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assimilation

in animals, the process by which absorbed food molecules, circulating in the blood, pass into the cells and are used for growth, tissue repair, and other metabolic activities. The actual destiny of each food molecule depends not only on its type, but also on the body requirements at that time.

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associative operation

in mathematics, an operation in which the outcome is independent of the grouping of the numbers or symbols concerned. For example, multiplication is associative, as $4 \times (3 \times 2) = (4 \times 3) \times 2 = 24$; however, division is not, as $12 \div (4 \div 2) = 6$, but $(12 \div 4) \div 2 = 1.5$. Compare commutative operation and distributive operation.

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assortative mating

in population genetics, selective mating in a population between individuals that are genetically related or have similar characteristics. If sufficiently consistent, assortative mating can theoretically result in the evolution of new species without geographical isolation (see speciation).

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astatine

chemical symbol At

(Greek astatos 'unstable')

non-metallic, radioactive element, atomic number 85, relative atomic mass 210. It is a member of the halogen group, and is found at the bottom of Group 7 of the periodic table of the elements. It is very rare in nature. Astatine is highly unstable, with at least 19 isotopes; the longest lived has a half-life of about eight hours.

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aster

any plant of a large group belonging to the same subfamily as the daisy. All asters have starlike flowers with yellow centres and outer rays (not petals) varying from blue and purple to white. Asters come in many sizes. Many are cultivated as garden flowers, including the Michaelmas daisy (*Aster nova-belgii*). (Genus *Aster*, family Compositae.)

The China aster (*Callistephus chinensis*) belongs to a closely related genus; it was introduced to Europe and the USA from China in the early 18th century.

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asteroid

any of many thousands of small bodies, made of rock and minerals, that orbit the Sun. Most lie in a region called the **asteroid belt** between the orbits of Mars and Jupiter, and are thought to be fragments left over from the formation of the Solar System. About 100,000 asteroids may exist, but their total mass is only a few hundredths of the mass of the Moon. These rocky fragments range in size from 1 km/0.6 mi to 900 km/560 mi in diameter.

The largest asteroids are sometimes called minor planets; these include Ceres (the largest asteroid, 940 km/584 mi in diameter) and Vesta (which has a light-coloured surface and is the brightest as seen from Earth). Some asteroids are in orbits that bring them close to Earth and some, such as the Apollo asteroids, which include Eros and Icarus, even cross Earth's orbit. They may be remnants of former comets.

Asteroid Introduction

Go to site

What is the difference between an asteroid and a meteorite? Find out at this site, which contains a table of statistics about asteroids, a chronology of asteroid exploration, and images of selected asteroids.

Asteroids and Comets

Go to site

Documents spacecraft encounters with asteroids and comets, and outlines future missions. The site contains a wealth of useful background information, an image gallery, and links to many important asteroid resources on the Internet.

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asthenosphere

layer within Earth's mantle lying beneath the lithosphere, typically beginning at a depth of approximately 100 km/63 mi and extending to depths of approximately 260 km/160 mi. Sometimes referred to as the 'weak sphere', it is characterized by being weaker and more elastic than the surrounding mantle.

The asthenosphere's elastic behaviour and low viscosity allow the overlying, more rigid plates of lithosphere to move laterally in a process known as plate tectonics. Its elasticity and viscosity also allow overlying crust and mantle to move vertically in response to gravity to achieve isostatic equilibrium (see isostasy).

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asthma

chronic condition characterized by difficulty in breathing due to spasm of the bronchi (air passages) in the lungs. Attacks may be provoked by allergy, infection, and stress. The incidence of asthma may be increasing as a result of air pollution and occupational hazard. Treatment is with bronchodilators to relax the bronchial muscles and thereby ease the breathing, and in severe cases by inhaled steroids that reduce inflammation of the bronchi.

Extrinsic asthma, which is triggered by exposure to irritants such as pollen and dust, is more common in children and young adults. Less common, intrinsic asthma tends to start in the middle years.

Approximately 5-10% of children suffer from asthma, but about a third of these will show no symptoms after adolescence, while another 5-10% of people develop the condition as adults. Growing evidence that the immune system is involved in both forms of asthma has raised the possibility of a new approach to treatment.

Although the symptoms are similar to those of bronchial asthma, **cardiac asthma** is an unrelated condition and is a symptom of heart deterioration.

asthma

Dust mites live in large numbers on the human scalp, feeding on skin flakes - an activity which causes allergic reactions in asthmatic children. This discovery was announced by Brazilian researchers in 1997, and may explain why repeated vacuuming of bedding does not get rid of dust mites.

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astigmatism

aberration occurring in the lens of the eye. It results when the curvature of the lens differs in two perpendicular planes, so that rays in one plane may be in focus while rays in the other are not. With astigmatic eyesight, the vertical and horizontal cannot be in focus at the same time; correction is by the use of a lens that reduces the overall focal length of one plane so that both planes are seen in sharp focus.

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astrolabe

ancient navigational instrument, forerunner of the sextant. Astrolabes usually consisted of a flat disc with a sighting rod that could be pivoted to point at the Sun or bright stars.

From the altitude of the Sun or star above the horizon, the local time could be estimated.

Astrolabe - An Instrument with a Past and a Future

Go to site

Good guide to this ancient astronomical computer. The long history of the instrument, and its importance in the history of astrology and astronomy, is explained with the help of good photographs. A section on the parts of the astrolabe explains how the instrument works and its uses.

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astrometry

measurement of the precise positions of stars, planets, and other bodies in space. Such information is needed for practical purposes including accurate timekeeping, surveying and navigation, and calculating orbits and measuring distances in space. Astrometry is not concerned with the surface features or the physical nature of the body under study.

Before telescopes, astronomical observations were simple astrometry. Precise astrometry has shown that stars are not fixed in position but have a proper motion caused as they and the Sun orbit the Milky Way galaxy. The nearest stars also show parallax (apparent change in position), from which their distances can be calculated. Above the distorting effects of the atmosphere, satellites such as the European Space Agency's Hipparcos, which operated from 1989 to 1993, can make even more precise measurements than ground telescopes, so refining the distance scale of space.

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astronaut

person trained to make flights into space; the general term is often used to include cosmonauts (the Russian equivalent).

As of April 2006, NASA had selected only 321 astronauts. Potential astronauts apply to the **Astronaut Candidate Program** and receive appointments from the **Astronaut Selection Office**. European Space Agency astronauts train at the European Astronauts Centre in Cologne, Germany. More than 440 people had travelled to altitudes over 100 km/62 mi, qualifying for the international designation of 'astronaut'.

astronaut

Astronauts in space cannot burp. It is gravity that causes bubbles to rise to the top of a liquid, so space shuttle crews were forced to request less gas in their fizzy drinks to avoid discomfort.

Spacefacts

Go to site

Fascinating directory of space travellers. The site offers portraits and biographies of US, Russian, and international astronauts, in an easy-to-navigate database. The entries include personal data, missions, and career information.

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astronautics

science of space travel. It was formerly subsumed under aeronautics.

Both subjects include **hypersonics**, the study of airflows and forces at speeds above five times that of sound (Mach 5), as experienced by space rockets and guided missiles.

Basics of Space Flight

Go to site

Illustrated tutorials covering essential aspects of space flight, including the space environment, flight projects, and operations. The site has a useful glossary of technical terms and abbreviations.

Astronomical Almanac

in astronomy, international work of reference published jointly every year by the Royal Greenwich Observatory and the US Naval Observatory, containing detailed tables of planetary motions, eclipses, and other astronomical phenomena.

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astronomical unit

AU

unit equal to the mean distance of the Earth from the Sun: 149.6 million km/92.96 million mi. It is used to describe planetary distances. Light travels this distance in approximately 8.3 minutes.

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astronomy

science of the celestial bodies: the Sun, the Moon, and the planets; the stars and galaxies; and all other objects in the universe. It is concerned with their positions, motions, distances, and physical conditions and with their origins and evolution. Astronomy thus divides into fields such as astrophysics, celestial mechanics, and cosmology. See also gamma-ray astronomy, infrared astronomy, radio astronomy, ultraviolet astronomy, and X-ray astronomy.

Greek astronomers

Astronomy is perhaps the oldest recorded science; there are observational records from ancient Babylonia, China, Egypt, and Mexico. The first true astronomers, however, were the Greeks, who deduced the Earth to be a sphere and attempted to measure its size. Ancient Greek astronomers included Thales and Pythagoras. Eratosthenes of Cyrene measured the size of the Earth with considerable accuracy. Star catalogues were drawn up, the most celebrated being that of Hipparchus. The *Almagest*, by Ptolemy of Alexandria, summarized Greek astronomy and survived in its Arabic translation. The Greeks still regarded the Earth as the centre of the universe, although this was doubted by some philosophers, notably Aristarchus of Samos, who maintained that the Earth moves around the Sun.

Ptolemy, the last famous astronomer of the Greek school, died in about AD 180, and little progress was made for some centuries.

Arab revival

The Arabs revived the science, developing the astrolabe and producing good star catalogues. Unfortunately, a general belief in the pseudoscience of astrology continued until the end of the Middle Ages (and has been revived from time to time).

the Sun at the centre

The dawn of a new era came in 1543, when a Polish canon, Copernicus, published a work entitled *De revolutionibus orbium coelestium/On the Revolutions of the Heavenly Spheres*, in which he demonstrated that the Sun, not the Earth, is the centre of our planetary system. (Copernicus was wrong in many respects – for instance, he still believed that all celestial orbits must be perfectly circular.) Tycho Brahe, a Dane, increased the accuracy of observations by means of improved instruments allied to his own personal skill, and his observations were used by German mathematician Johannes Kepler to prove the validity of the Copernican system. Considerable opposition existed, however, to removing the Earth from its central position in the universe; the Catholic Church was openly hostile to the idea, and, ironically, Brahe never accepted the idea that the Earth could move around the Sun. Yet before the end of the 17th century, the theoretical work of Isaac Newton had established celestial mechanics.

Galileo and the telescope

The first practical refracting telescope was invented about 1608, by Hans Lippershey in Holland, and was first applied to astronomy by Italian scientist Galileo in the winter of 1609–10. Immediately, Galileo made a series of spectacular discoveries. He found the four largest satellites of Jupiter, which gave strong support to the Copernican theory; he saw the craters of the Moon, the phases of Venus, and the myriad faint stars of our Galaxy, the Milky Way.

Galileo's most powerful telescope magnified only 30 times, but it was not long before larger telescopes were built and official observatories were established.

Galileo's telescope was a refractor; that is to say, it collected its light by means of a glass lens or object glass. Difficulties with his design led Newton, in 1671, to construct a reflector, in which the light is collected by means of a curved mirror.

further discoveries

In the 17th and 18th centuries astronomers were mostly concerned with positional measurements. Uranus was discovered in 1781 by William Herschel, and this was soon followed by the discovery of the first four asteroids, Ceres in 1801, Pallas in 1802, Juno in 1804, and Vesta in 1807. In 1846 Neptune was located by Johann Galle, following calculations by British astronomer John Couch Adams and French astronomer Urbain Jean Joseph Leverrier. Also significant was the first measurement of the distance of a star, when in 1838 the German astronomer Friedrich Bessel measured the parallax of the star 61 Cygni, and calculated that it lies at a distance of about 6 light years (about half the modern value).

Astronomical spectroscopy was developed, first by Fraunhofer in Germany and then by people such as Pietro Angelo Secchi and William Huggins, while Gustav Kirchhoff successfully interpreted the spectra of the Sun and stars. By the 1860s good photographs of the Moon had been obtained, and by the end of the century photographic methods had started to play a leading role in research.

galaxies

William Herschel investigated the shape of our Galaxy during the latter part of the 18th century and concluded that its stars are arranged roughly in the form of a double-convex lens. Basically Herschel was correct, although he placed our Sun near the centre of the system; in fact, it is well out towards the edge, and lies 25,000 light years from the galactic nucleus. Herschel also studied the luminous 'clouds' or nebulae, and made the tentative suggestion that those nebulae capable of resolution into stars might be separate galaxies, far outside our own Galaxy.

It was not until 1923 that US astronomer Edwin Hubble, using the 2.5 m/100 in reflector at the Mount Wilson Observatory, was able to verify this suggestion. It is now known that the 'spiral nebulae' are galaxies in their own right, and that they lie at immense distances. The most distant galaxy visible to the naked eye, the Great Spiral in Andromeda, is 2.2 million light years away; the most remote galaxy so far measured lies over 10 billion light years away. It was also found that galaxies tended to form groups, and that the groups were apparently receding from each other at speeds proportional to their distances.

a growing universe

This concept of an expanding and evolving universe at first rested largely on Hubble's law, relating the distance of objects to the amount their spectra shift towards red – the red shift. Subsequent evidence derived from objects studied in other parts of the electromagnetic spectrum, at radio and X-ray wavelengths, has provided confirmation. Radio astronomy established its place in probing the structure of the universe by demonstrating in 1954 that an optically visible distant galaxy was identical with a powerful radio source known as Cygnus A. Later analysis of the comparative number, strength, and distance of radio sources suggested that in the distant past these, including the quasars discovered in 1963, had been much more powerful and numerous than today. This fact suggested that the universe has been evolving from an origin, and is not of infinite age as expected under a steady-state theory.

The discovery in 1965 of microwave background radiation was evidence for the enormous temperature of the giant explosion, or Big Bang, that brought the universe into existence.

further exploration

The siting of telescopes at new observatories in the previously neglected southern hemisphere has opened fresh areas of the sky to search. Australia has been in the forefront of these developments. The most remarkable recent extension of the powers of astronomy to explore the universe is in the use of rockets, satellites, space stations, and space probes. Even the range and accuracy of the conventional telescope may be greatly improved free from the Earth's atmosphere. The USA launched the Hubble Space Telescope, with a 2.4 m/94.5 in mirror, into permanent orbit in 1990. It detects celestial phenomena more distant (up to 14 billion light years) than any Earth-based telescope.

See also black hole and infrared radiation.

Investigating the Solar System

early knowledge

The ancients knew of just five planets, other than Earth, and to these they attached romantic names and descriptions. Mercury was named after the fleet-footed messenger of the gods, because it moved across the sky so quickly and could only be faintly discerned, close to the Sun. Venus, in contrast, is a brilliant object, the most conspicuous in the sky after the Sun and Moon, casting shadows at night, and sometimes can be glimpsed during broad daylight. Like Mercury, Venus follows the Sun, known as the evening star when it sets after the Sun, and as the morning star when it rises before the Sun. To the Greeks and Romans these were separate entities, called Hesperos and Vesper, respectively, when trailing the Sun in the evening to appear brilliantly after sunset, and Phosphoros and Lucifer when the planet led the Sun in the morning. The baleful red glow of Mars identified that planet with the god of war; and majestic, slowly moving Jupiter with the king of the gods. Saturn, finally, crawled across the sky so slowly that it suggested to our ancestors the bringer of old age.

Of course, people did not know then the nature of the planets; that is something we came to appreciate only in the 20th century. Even the planets that have been known and discussed since antiquity had to be discovered twice: once when they were identified as members of the Solar System and distinguished from stars and other heavenly phenomena, and again when their main characteristics were finally mapped and measured. The second of these had to wait, mostly, for the space age, and of course it is still going on.

the telescope age: moons and rings

The first major discovery after the invention of astronomically useful telescopes, at the beginning of the 17th century, was Galileo Galilei's observation in 1610 of the four large satellites of Jupiter, now known as the Galilean moons in his honour (he called them the 'Medici stars'). They were independently discovered by the German astronomer Simon Marius, who provided their individual names of Io, Europa, Ganymede, and Callisto.

As telescopes gradually got better, even more exciting discoveries were made. In 1655 Christiaan Huygens observed a satellite orbiting the then most distant known planet, Saturn. Realizing it must be enormous, or he would not have seen it, he called it Titan. Huygens's skill at making telescopes also brought him the answer to a question that had puzzled Galileo 50 years earlier, as to why Saturn had a strange and apparently changing shape. Huygens saw that Saturn was girdled by a beautiful system of rings, and in 1675 Giovanni Cassini observed the dark division in the rings that now bears his name, and surmised correctly that the rings are composed of thousands of tiny satellites, all in independent orbits.

the discovery of Uranus and Neptune

The discovery that Earth was no longer alone in having a moon, and that planets could have rings, were momentous enough, but the greatest prize was the discovery of a new planet altogether. Interestingly, the planet beyond Saturn can in fact be observed with the naked eye from Earth, but is so faint and slow moving that it eluded the early, pre-telescope observers. Uranus was discovered in 1781 by William Herschel, after the Titus-Bode law had been used to predict correctly its distance from the Sun. That law fails for Neptune, however, and it was not until 1840 when Friedrich Bessel proposed that the irregularities in the orbit of Uranus were due to the gravitational effects of an unknown planet that astronomers knew where to look for a further, even more distant member of the Solar System. Detailed calculations by Urbain Leverrier in France and John Adams in England preceded the first detection of the new planet by Johann Galle and Johann Encke at the Berlin Observatory on 23 September 1846.

beyond Neptune

Reports that Uranus, and now Neptune as well, had discrepancies between their predicted and actual orbits led to a search for another planet still further out. In fact, the reports were in error and all that lies outside the orbit of Neptune is a cloud of planetesimals, relatively small, icy bodies left over from the formation of the planets. These become comets if they are perturbed, by interactions with the giant planets, each other, or even nearby stars, into orbits that approach the Sun. The largest known members of this family are Pluto and Charon, two bodies physically similar to the large icy satellites of the giant planets, which orbit each other once a week and circle the Sun in an eccentric, tilted orbit that passes inside that of Neptune. Pluto was discovered by Clyde Tombaugh in 1930 and shown to be a double object when James Christy detected Charon in 1978.

the space age: the terrestrial planets revealed

The first space mission to a planet, not crewed of course, was that of Mariner 2, which flew past Venus at a distance of about 34,000 km/19,000 mi on 14 December 1962. Its mission was to investigate the microwave emission from Venus which, as measured from Earth, seemed to imply that the surface was scorching hot, at a time when verdant swamps formed the prevailing vision of Earth's sister planet. The close-up data confirmed the high temperatures and the first of many long-standing misconceptions and dreams about the planets fell, to be replaced by scientific facts no less fascinating.

Mars, too, was initially a disappointment when Mariner 4 arrived in November 1964. Instead of canals and vegetation, the probe's cameras saw a barren landscape with craters, which looked more like the Moon than Earth. It was not until the arrival of Mariner 9 in 1971 that it became clear how diverse the surface of Mars is, with giant mountains, deep canyons, plains, polar caps, as well as cratered terrain.

Mariner 10 reached Mercury in March 1973 and remains the only spacecraft to have been to the innermost planet. It mapped a hot, airless, and desolate world dominated by planet-wide cracks and craters and other impact features.

exploring the giant planets

Missions to the outer Solar System naturally came somewhat later than those to Earth's nearest neighbours, but by the end of 1972 Pioneer 10 and Pioneer 11 were on their way to Jupiter and Saturn. That early reconnaissance was followed by the two much larger Voyager probes, launched in 1977, which visited the two largest gas giants, with Voyager 2 going on to Uranus (in 1986) and Neptune (in 1989) as well. They found incredibly active atmospheres of hydrogen and helium on all four giant planets, with high winds and huge, turbulent eddies. The satellites are also fascinating, especially Titan, which is found to have an atmosphere remarkably like a colder version of Earth, being mainly nitrogen and having a surface pressure actually 50% higher than the mean terrestrial value.

landing on Mars and Venus

The first probe to land on another planet was Venera 3 in 1966, and the torrid conditions there were explored by a whole series of Soviet landing spacecraft continuing into the 1980s, complemented by the US Pioneer Venus orbiter/probe missions in 1978. The surface and atmosphere of Venus show evidence for massive amounts of volcanic activity, including sulphuric acid clouds that are a major contributor to the greenhouse effect that keeps the surface of Venus so hot.

The US Viking 1 and Viking 2 landed on Mars in 1976. The search for life was inconclusive, but evidence was accumulated for a warm, wet phase, more conducive to biological activity, in the early history of the red planet. When Pathfinder landed in 1996, it photographed rocks worn smooth by rushing water at its landing site in an ancient channel.

the future

Japanese and European missions to Mars are underway, and missions to return samples are to be undertaken by NASA. The focus in the outer Solar System is now on Titan, to be explored by Cassini and its Huygens probe in 2004, and on Europa, the Galilean moon of Jupiter, which is believed to harbour an ocean of warm water just below its icy surface. Perhaps most exciting of all, giant space telescopes are being developed to study planets in other solar systems. These will be capable of finding Earth-like planets around Sun-like stars, and analysing their atmospheres for water, ozone, and other signs of life.

Studying the Stars

the Solar System

People have been interested in astronomy since civilization began. In the classical Greek era, Aristarchus estimated the distances to the Sun and Moon, Eratosthenes measured the size of the Earth, and Hipparchus detected the precession of its rotation axis. But until 1781, only five planets, in addition to the Earth, were known: Mercury, Venus, Mars, Jupiter, and Saturn. In the 17th century, Johannes Kepler worked out three laws governing planetary motion from data collected by Tycho Brahe. Galileo's introduction of the telescope to astronomy started an explosion in our knowledge. William Herschel discovered a sixth planet, Uranus, in 1781, and small perturbations of the orbit of Uranus led to the discovery of Neptune and subsequently Pluto. In the 20th century, the Voyager spacecraft visited Jupiter, Saturn, Uranus, and Neptune, obtaining a wealth of new data. Rings were discovered around Jupiter and Uranus, superb pictures obtained of the rings of Saturn, and additional satellites found around the planets.

stars

Stars vary in mass, brightness, and energy output, called 'luminosity'. Even a small telescope reveals a multitude of stars too faint to be seen with the naked eye. If we compare other stars to the Sun, we find that luminosities can be anywhere from 1,000 times less to 100,000 times greater than that of the Sun, and masses between 10 times less and 60 times greater. Surface temperatures vary between 3,000 and 50,000 K, as compared with the sun at 5,770 K. (Astronomers give temperatures on the Kelvin (K) scale. The zero of the Centigrade scale (or 32° Fahrenheit) is at 273.15 K.)

The energy radiated by stars comes mainly from fusion of light atomic nuclei into heavy nuclei, a process that releases energy. Of this energy, 90% comes from the fusion (or burning) of hydrogen (which forms helium), and this is the source for most of a star's life. Burning is quickest at the centre of a star and eventually uses all the hydrogen there, leaving a helium core. After that, burning takes place in a shell around the core. As this happens, the star expands rapidly, while its core becomes hot and dense. Eventually the helium burns, forming carbon, oxygen, and neon. Heavier elements may be produced later on.

the death of a star: supernovae, neutron stars, and black holes

Many stars exhaust their nuclear fuel and become white dwarfs. These have radii of a few thousand kilometres and central densities up to 1,000 tonnes per cubic centimetre. They continue to glow with thermal energy, but they slowly cool down. Some stars are too massive to become white dwarfs. Instead, their central regions collapse, causing a supernova explosion which, for a short time, is as bright as an entire galaxy. The outer layers are ejected, leaving a remnant behind. This type of explosion was seen by Chinese astronomers in 1054 in the constellation of the Crab. Today we can see the remnant of this explosion, which is a neutron star surrounded by a hot nebula (a cloud of dust and gas). A neutron star has a radius of just a few kilometres and is 100,000 times more dense than a white dwarf. This one spins rapidly and has a powerful magnetic field, a combination which generates pulses of radiation 30 times a second. Such objects are called pulsars. The interval between pulses is remarkably constant and is usually between a few milliseconds and several seconds. After a supernova explosion, some remnants are too massive to form neutron stars and collapse to become black holes. Black holes are so dense that their gravitational fields are too strong for even light to escape, and so they cannot be seen directly.

developments in technology

Our knowledge of the universe was accelerated in the 19th century with the introduction of photography and spectroscopy. Spectroscopy is the analysis of electromagnetic radiation, which includes light, into different wavelengths. Radio telescopes built after World War II extended observation to a new wavelength range and enabled the discovery of several new classes of astronomical object, such as pulsars. Currently, observations use almost all wavelengths from the very long radio waves to the very short gamma rays. Ground-based observations are hampered by the atmosphere, which smears images and is opaque to important wavelength bands, such as the ultraviolet. Instruments in orbit, notably the Hubble Space Telescope, reveal detail invisible from the ground. Terrestrial observations have found massive planets in orbits around nearby stars but techniques are not yet sufficiently sensitive to detect planetary satellites.

the Milky Way

Stars gather into groups, called galaxies, held together by gravity. The Sun is part of the Milky Way, which appeared to our ancestors as a diffuse band of light across the sky. Galileo's telescope resolved it into a multitude of faint stars. They form the shape of a disc, which has a radius exceeding 40,000 light years and a thickness of 2,000 light years. Around the disc there is a halo of old stars in the shape of a sphere. The disc rotates slowly, rotating faster towards the centre. The sun is about 25,000 light years from the centre and takes 200 million years to circle it. The rotation provides a centrifugal force that balances the Milky Way's gravitational field in the disc plane, thus supporting the disc structure.

In the disc there are dusty clouds with temperatures between 10 and 40 K. Inside these clouds hydrogen and other elements form simple molecules. The clouds are denser than most gas clouds and are the regions where stars are forming now.

galaxies

The Milky Way is one of several thousand million galaxies in the Universe and is typical of large disc galaxies. Galaxies vary considerably in appearance. Some, but not all, have spiral arms. Some are irregular in shape and contain a lot of gas. Some galaxies appear elliptical in the sky and consist of old stars. Some abnormal galaxies have bright sources at the centre that can outshine the rest of the system. These are believed to be black holes, between a few million and a thousand million times more massive than the sun. The light comes from gas compressed and heated as it falls into the hole; astronomers often see jets of gas emerging from the centre of the galaxy. There is evidence that massive black holes exist at the centres of many, possibly all, galaxies.

Galaxies are not isolated. The Milky Way and the nearby Andromeda galaxy are the principal members of a small local cluster. The Milky Way also has satellite galaxies, the most conspicuous of which are the two small, irregular Magellanic Clouds. Astronomers have identified many clusters of galaxies beyond our local group. Collisions can occur between galaxies in a cluster with spectacular results. One example of this occurring is the Cartwheel galaxy, thought to have been produced by the transit of a small elliptical galaxy through the disc of the larger galaxy. Other groups of galaxies have conspicuous bridges and tails produced by tidal effects during collisions.

dark matter

Measurements of the rotation of disc galaxies show that the gravity from the visible material is insufficient to hold the stars in circular orbits, especially in the outer regions. This is one indication that the universe contains unseen 'dark matter', – matter that does not emit any radiation. We know very little about dark matter, but experiments to detect it are currently in progress.

cosmology

In 1929 US astronomer Edwin Hubble showed that the universe is expanding and that distant galaxies move away from us with a speed proportional to their distance. The obvious explanation for the expansion is the Big Bang model, the theory that the universe has expanded from a dense initial state. The theory implies the existence of background radiation left over from the initial explosion. This radiation was discovered by Penzias and Wilson in 1965 and led to general acceptance of the Big Bang theory.

We would expect the expansion to be decelerated by gravity, but recent evidence suggests that it is accelerating instead. There is a vigorous debate about the soundness of the results and their implications. The distribution of galaxies also provides evidence for how the universe is built and how it came into existence. They are found in clusters, superclusters, filaments, and sheets, separated by large voids. Numerical simulations, using the most powerful computers available, have examined a variety of cosmological models. The most promising show a filamentary structure resembling that found observationally, but much work remains to be done before we can be confident that we understand the universe.

The 20th century saw tremendous progress in our understanding of the universe, arising from observational and theoretical developments and the availability of powerful computers. There is no sign that progress is slowing down. Powerful telescopes are being built, new satellite observations are planned, and technical development is rapid. Great as our progress has been, many problems remain unsolved and await the attention of future astronomers.

(Image © NASA)

Radio telescopes, like this one (the world's largest) at Arecibo, Puerto Rico, allow astronomers to analyse a broad range of low-frequency electromagnetic waves – visible light is only a small part of the electromagnetic spectrum. Pulsars and quasars were first discovered by radio telescopes.

Astronomy: key dates

2300 BC	Chinese astronomers make their earliest observations.
2000	Babylonian priests make their first observational records.
1900	Stonehenge is constructed: first phase.
434	Anaxagoras claims the Sun is made up of hot rock.
4th century	Eudoxus of Cnidus develops a system of homocentric spheres in an effort to explain the motions of heavenly bodies in mathematical terms.
3rd century	Aristarchus of Samos argues that the Sun is the centre of the universe.
150	Hipparchus, using his own accurate observations and earlier records from Babylonian and Greek astronomers, produces the first satisfactory theory for the motions of the Sun and Moon and discovers the precession of the equinoxes.
2nd century AD	Ptolemy's complicated Earth-centred system is promulgated, which dominates the astronomy of the Middle Ages.
1054	Chinese astronomers observe a 'new star' in the constellation Taurus. It is a supernova, the remnants of which are still visible as the Crab Nebula.
1543	Nicolaus Copernicus revives the ideas of Aristarchus and postulates a Sun-centred universe in *De revolutionibus orbium coelestium/On the Revolutions of the Heavenly Spheres*.
1572	Tycho Brahe observes a supernova in the constellation Cassiopeia. His accuracy as an observer makes him the greatest optical astronomer of the pre-telescopic age.
1608	Dutch lens-maker Hans Lippershey is granted a patent for a telescope. Galileo first uses the telescope as an astronomical instrument in 1609.
1609	Johannes Kepler's first two laws of planetary motion are published (the third appears in 1619).

1610	Using the telescope, Galileo sees the rugged landscape of the Moon, observes Jupiter's four largest satellites, and discovers that Venus shows phases and must therefore orbit the Sun. These observations challenge traditional cosmology and support the Copernican view that the Earth is not the centre of the universe.
1632	The world's first official observatory is established in Leiden in the Netherlands.
1633	Galileo's pro-Copernican theories are condemned by the Inquisition.
1655	Christiaan Huygens discovers Titan, the largest of Saturn's moons. In 1659 Huygens discovers the true shape of the rings of Saturn.
1675	The Royal Greenwich Observatory is founded in England. John Flamsteed becomes first Astronomer Royal.
1687	Isaac Newton's *Principia* is published, including his 'law of universal gravitation'.
1705	Edmond Halley correctly predicts that the comet that had passed the Earth in 1682 will return in 1758; the comet is later known by his name.
1728	James Bradley discovers the aberration of starlight, an apparent minute change in the observed positions of stars resulting from the annual motion of the Earth as it orbits the Sun. Bradley's discovery confirms the Copernican model, placing the Sun at the centre of a family of planets now called the Solar System.
1758	The return of Halley's Comet is observed.
1781	William Herschel discovers the planet Uranus and recognizes stellar systems beyond the Galaxy.
1796	Pierre Laplace elaborates his 'nebular hypothesis', the theory that the Solar System originated from a flat cloud of gas. Like his compatriot Lagrange, he also studies the motions of the planets, particularly the gravitational interaction between Earth, Moon, and Sun.
1801	Giuseppe Piazzi discovers the first asteroid, Ceres.
1814	Joseph von Fraunhofer first studies mysterious dark lines in the solar spectrum.
1838	German astronomer Friedrich Wilhelm Bessel uses parallax to measure the distance from the Earth to the star 61 Cygni. This is the first distance measurement for an object outside the Solar System and helps to reveal the vast scale of the universe.
1846	The planet Neptune is identified by Johann Galle, following predictions by John Adams and Urbain Leverrier.
1859	Gustav Kirchhoff explains the significance of the dark Fraunhofer lines in the Sun's spectrum, identifying them as absorption lines uniquely characteristic of chemical elements present in the Sun.
1862	Italian astronomer and Roman Catholic priest Angelo Secchi proves by stellar spectral analysis that the Sun is a star.
1877	US astronomer Asaph Hall discovers Phobos and Deimos, the two satellites of Mars.
1887	The earliest photographic star charts are produced.
1920	Arthur Eddington begins the study of interstellar matter.
1923	Edwin Hubble proves that the galaxies are systems independent of the Milky Way, and by 1930 has confirmed the concept of an expanding universe.
1930	The planet Pluto is discovered by Clyde Tombaugh at the Lowell Observatory, Arizona, USA.
1931	Karl Jansky founds radio astronomy.
1945	Radar contact with the Moon is established by Z Bay of Hungary and the US Army Signal Corps Laboratory.
1948	The 5-m/200-in Hale reflector telescope is installed at Mount Palomar, California, USA.
1957	The Jodrell Bank telescope dish in England is completed.
1957	The first Sputnik satellite (USSR) opens the age of space observation.
1961	Major Yuri Gagarin becomes the first man to travel in space, making one orbit of the Earth aboard the spacecraft *Vostok 1*.
1962	The first X-ray source is discovered in the constellation Scorpius.
1963	The first quasar is discovered.
1965	Robert Wilson and Arno Penzias discover the cosmic background radiation now believed to be the faint remnant of the 'Big Bang', the explosion out of which the universe was created billions of years ago.
1966	The Soviet spacecraft Venera 3 crash-lands on Venus and so becomes the first human-made object to reach the surface of another planet.
1967	The first pulsar is discovered by Jocelyn Bell Burnell and Antony Hewish.
1969	The first crewed Moon landing is made by US astronauts.
1974	The US spacecraft Mariner 10 flies past the planet Mercury for the first time.
1975	The Soviet probes Venera 9 and Venera 10 send back the first photographs from the surface of Venus before they are crushed by the pressure of the planet's atmosphere.
1976	A 6-m/240-in reflecting telescope is installed at Mount Semirodniki, USSR.
1976	The US space probes Viking 1 and Viking 2 make the first uncrewed landings on Mars.
1977	Uranus is discovered to have rings.
1977	The US spacecraft Voyager 1 and Voyager 2 are launched, passing Jupiter and Saturn 1979-81. They reveal a ring around Jupiter, a complex of thousands of ringlets around Saturn in addition to the rings already known, and many previously unobserved moons orbiting both planets.
1978	The US space probes Pioneer Venus 1 and Pioneer Venus 2 reach Venus.
1978	A satellite of Pluto, Charon, is discovered by James Christy of the US Naval Observatory.
1983	Launch of the Infrared Astronomy Satellite (IRAS). It surveys 96% of the sky in four separate infrared frequency bands, penetrates the dust-obscured centre of the Milky Way, and reveals thousands of celestial objects never seen from the Earth.
1985	The Soviet Union launches the spacecraft *Mir* into Earth orbit. Despite many setbacks, it remains in use as a state-run crewed space station for the next 15 years.
1986	Halley's Comet returns and is investigated by the European Space Agency probe Giotto. Voyager 2 flies past Uranus and discovers six new moons.
1987	Supernova SN1987A flares up, becoming the first supernova to be visible to the naked eye since 1604. The 4.2-m/165-in William Herschel Telescope on La Palma, Canary Islands, and the James Clerk Maxwell Telescope on Mauna Kea, Hawaii, begin operation.

1988	The most distant individual star so far known is recorded - a supernova, 5 billion light years away, in the AC118 cluster of galaxies.
1989	Voyager 2 flies by Neptune and discovers eight moons and three rings. The US spacecraft Galileo blasts off to Jupiter.
1990	Hubble Space Telescope is launched into orbit by the US space shuttle.
1990	The joint NASA/European Space Agency probe Ulysses is launched to investigate the environment of space near the poles of the Sun.
1992	The Cosmic Background Explorer (COBE) satellite detects ripples from the 'Big Bang' that mark the first stage in the formation of galaxies.
1994	Fragments of the comet Shoemaker-Levy 9 strike Jupiter.
1995	SOHO (Solar and Heliospheric Observatory), a joint European and US project, is launched into interplanetary space to make long-term observations of the Sun and its atmosphere. Swiss astronomers Michel Mayor and Didier Queloz discover evidence of a large planet orbiting the star 51 Pegasi, a nearby star in the constellation Pegasus. The US spacecraft Galileo goes into orbit around Jupiter and deploys a probe that descends into the planet's atmosphere, sending back data to Earth for nearly an hour before it is destroyed by immense pressure and heat.
1996	US astronomers discover the most distant galaxy so far detected. It is in the constellation Virgo and is thought to be 14 billion light years from Earth.
1997	Data from the satellite Hipparcos improve estimates of the age of the universe and of the distances to many nearby stars. Launch of US crewless spacecraft Cassini to Jupiter and Saturn.
1998	NASA announces that there may be up to 300 million tonnes of ice on the surface of the Moon. The ice exists as a thin layer of crystals inside some craters that are permanently in shadow.
1998	A Russian Proton rocket lifts the first part of the *International Space Station* into Earth orbit.
1999	The Russian space agency abandons the problem-ridden *Mir* space station. NASA loses two costly Mars probes.
2000	The Near-Earth Asteroid Rendezvous (NEAR Shoemaker) spacecraft closely investigates the asteroid Eros. MirCorp, a Dutch-based commercial company, takes over control of the abandoned *Mir* space station in an effort to prolong its scientific usefulness. Astronomers detect what may be an enormous black hole at the centre of the Milky Way Galaxy. The most distant gamma-ray burst ever recorded is detected in the constellation Carina: it is 11 billion light years away. The first crew of scientists are scheduled to move into the completed *International Space Station*. Spacecraft Cassini reaches the Jupiter system. It is scheduled to reach Saturn in 2004.
2001	The Near-Earth Asteroid Rendezvous (NEAR) becomes the first spacecraft to land on an asteroid. NASA's High-Energy Solar Spectroscopic Imager mission is launched to study the Sun's corona. The Russian space station *Mir* is brought down and crash-landed in the Pacific Ocean. The 2001 Mars Odyssey reaches Mars.
2003	Mars Express, carrying the British built Beagle 2 landing probe arrives at Mars. However, contact is lost with Beagle 2 on its descent to the surface.
2004	Two Nasa exploration robots, Spirit and Opportunity, reach Mars successfully, and begin sending back images of the surface.
2005	Nasa send a probe to collide with a comet. Analysing the resulting debris is helping to understand the origin of the solar system.
2006	An object orbiting the sun is measured to be larger than Pluto, raising claims for it to be given the status of a planet.

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Need a quick answer to a question about astronomy? Pick an astronomer to answer questions about stars, telescopes, planets, and more at this site.

Astronomy Course for Students Using the Internet

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Well-presented and interesting introduction to astronomy including sections on 'Finding your way around the sky', 'Stars, nebulae, and star clusters', and 'Messages from the cosmos'.

Bad Astronomy

Go to site

Pages designed and maintained by Phil Plait, an astronomer and teacher, that are dedicated to exposing misinformation and myths about astronomy. As well as keeping you up-to-date on astronomical events, this site also has a section called 'Bite-sized astronomy' which contains an essay explaining one concept about the science, which is changed on a weekly basis.

Learning Centre for Young Astronomers

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Introduction to our universe for young astronomers. The presentation covers a wide range of issues with discussions of quasars, comets, meteoroids, the Milky Way, black holes, the Hubble Space Telescope, space wardrobes, and space probes. The tutorial is offered at two levels - one basic and one more advanced - and also includes online activities, visual material, and an illuminating glossary of space terms.

Practical Guide to Astronomy

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Well-illustrated guide to astronomy that contains explanations of many aspects of the subject, including the 'Big Bang' theories of English physicist Stephen Hawking, a list of early astronomers and their key discoveries, and an in-depth look at all the main elements of our Solar System.

Sky and Telescope

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Online edition of the astronomy magazine *Sky and Telescope*. Information is included about daily astronomical events, and tips are provided on how to get the best view.

Spacewatch

Go to site

Updated daily with a brief of what is currently visible in the night sky and what to look out for, the site has many useful features including star charts and graphics showing the present alignment of the planets. Pages devoted to space weather give details of expected solar, auroral, and meteor activity.

Star Child: A Learning Centre for Young Astronomers

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Choose between two levels of understanding to explore the solar system, the universe and other 'Space stuff'.

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astrophotography

use of photography in astronomical research. The first successful photograph of a celestial object was the daguerreotype plate of the Moon taken by English Scientist John W Draper in March 1840. The first photograph of a star, Vega, was taken by US astronomer William Bond in 1850. Modern-day astrophotography uses techniques such as charge-coupled devices (CCDs), which are often carried aboard a spacecraft.

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astrophysics

study of the physical nature of stars, galaxies, and the universe. It began with the development of spectroscopy in the 19th century, which allowed astronomers to analyse the composition of stars from their light. Astrophysicists view the universe as a vast natural laboratory in which they can study matter under conditions of temperature, pressure, and density that are unattainable on Earth.

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asymptote

in coordinate geometry, a straight line that a curve approaches progressively more closely but never reaches. The x and y axes are asymptotes to the graph of xy = constant (a rectangular hyperbola).

If a point on a curve approaches a straight line such that its distance from the straight line is d, then the line is an asymptote to the curve if limit d tends to zero as the point moves towards infinity. Among conic sections (curves obtained by the intersection of a plane and a double cone), a hyperbola has two asymptotes, which in the case of a rectangular hyperbola are at right angles to each other.

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atavism

(Latin atavus 'ancestor')

in genetics, the reappearance of a characteristic not apparent in the immediately preceding generations; in psychology, the manifestation of primitive forms of behaviour.

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ataxia

loss of muscular coordination due to neurological damage or disease.

Atget, Eugène (1857-1927)

French photographer. He took up photography at the age of 40, and for 30 years documented urban Paris in some 10,000 images. His photographs were sometimes used by painters and he was admired by the Surrealists. After his death his work was rescued and promoted by the photographer Berenice Abbott.

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atheroma

furring-up of the interior of an artery by deposits, mainly of cholesterol, within its walls.

Associated with atherosclerosis, atheroma has the effect of narrowing the lumen (channel) of the artery, thus restricting blood flow. This predisposes to a number of conditions, including thrombosis, angina, and stroke.

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atherosclerosis

thickening and hardening of the walls of the arteries, associated with atheroma. Arteriosclerosis is often loosely used as a synonym.

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atlas

book of maps. The first modern atlas was the *Theatrum orbis terrarum* (1570); the first English atlas was a collection of the counties of England and Wales by Christopher Saxten (1579). Mercator began work on the first great world atlas in 1585; it was completed by his son in 1594. Early atlases had a frontispiece showing Atlas (a figure in Greek mythology) supporting the globe.

Atlas rocket

US rocket, originally designed and built in 1946 as an intercontinental missile for the US Air Force but subsequently adapted for space use. Each Atlas originally cost US$3 million to build.

NASA engineers called the rocket a 'gasbag' because its thin stainless steel sections had to be pressurized by helium gas to prevent their collapse. Atlas rockets, using a liquid oxygen fuel, launched US astronauts into orbit during the *Mercury* project (1961-63).

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atmosphere

mixture of gases surrounding a planet. Planetary atmospheres are prevented from escaping by the pull of gravity. On Earth, atmospheric pressure decreases with altitude. In its lowest layer, the atmosphere consists of nitrogen (78%) and oxygen (21%), both in molecular form (two atoms bonded together) and argon (1%). Small quantities of other gases are important to the chemistry and physics of the Earth's atmosphere, including water, carbon dioxide, and traces of other noble gases (rare gases), as well as ozone. The atmosphere plays a major part in the various cycles of nature (the water cycle, the carbon cycle, and the nitrogen cycle). It is the principal industrial source of nitrogen, oxygen, and argon, which are obtained by the fractional distillation of liquid air.

The Earth's atmosphere is divided into four regions of atmosphere classified by temperature.

troposphere

This is the lowest level of the atmosphere (altitudes from 0 to 10 km/6 mi) and it is heated to an average temperature of 15°C/59°F by the Earth, which in turn is warmed by infrared and visible radiation from the Sun. Warm air cools as it rises in the troposphere and this rising of warm air causes rain and most other weather phenomena. The temperature at the top of the troposphere is approximately -60°C/-76°F.

stratosphere

Temperature increases with altitude in this next layer (from 10 km/6 mi to 50 km/31 mi), from -60°C/-76°F to near 0°C/32°F.

mesosphere

Temperature again decreases with altitude through the mesosphere (50 km/31 mi to 80 km/50 mi), from 0°C/32°F to below -100°C/-148°F.

thermosphere

In the highest layer (80 km/50mi to about 700 km/450 mi), temperature rises with altitude to extreme values of thousands of degrees. The meaning of these extreme temperatures can be misleading. High thermosphere temperatures represent little heat because they are defined by motions among so few atoms and molecules spaced widely apart from one another.

Atmosphere: composition

gas	symbol	volume (%)	role
nitrogen	N_2	78.08	cycled through human activities and through the action of micro-organisms on animal and plant waste
oxygen	O_2	20.94	cycled mainly through the respiration of animals and plants and through the action of photosynthesis
carbon dioxide	CO_2	0.03	cycled through respiration and photosynthesis in exchange reactions with oxygen. It is also a product of burning fossil fuels
argon	Ar	0.93	chemically inert and with only a few industrial uses
neon	Ne	0.0018	as argon

helium	He	0.0005	as argon
krypton	Kr	trace	as argon
xenon	Xe	trace	as argon
ozone	O_3	0.00006	a product of oxygen molecules split into single atoms by the Sun's radiation and unaltered oxygen molecules
hydrogen	H_2	0.00005	unimportant

Main components of the Earth's atmosphere

Component	Percentage by volume
nitrogen	78.09
oxygen	20.95
argon	0.93
carbon dioxide	0.03
neon	0.002
helium	0.0005
methane	0.0003
krypton	0.0001
nitrous oxide	0.000050
xenon	0.000009

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atmosphere

symbol atm; or standard atmosphere

in physics, a unit of pressure equal to 760 mmHg, 1013.25 millibars, or 1.01325×10^5 pascals, or newtons per square metre. The actual pressure exerted by the atmosphere fluctuates around this value, which is assumed to be standard at sea level and 0°C/32°F, and is used when dealing with very high pressures.

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atmospheric pollution

contamination of the atmosphere with the harmful by-products of human activity; see air pollution.

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atmospheric pressure

pressure at any point on the Earth's surface that is due to the weight of the column of air above it; it therefore decreases as altitude increases, because there is less air above. Particles in the air exert a force (pressure) against surfaces; when large numbers of particles press against a surface, the overall effect is known as air pressure. At sea level the average pressure is 101 kilopascals (1,013 millibars, or 760 mm Hg, or 14.7 lb per sq in, or 1 atmosphere). Changes in atmospheric pressure, measured with a barometer, are used in weather forecasting. Areas of relatively high pressure are called anticyclones; areas of low pressure are called depressions.

For every square metre of a surface, a force of 10 tonnes of air pressure is exerted. This air pressure does not crush objects because they exert an equal amount of force to balance the air pressure. At higher altitudes the air is thinner and the air pressure is lower. Here, water boils at a temperature less than that at sea level. In space there are no air particles and so no air pressure is exerted on an astronaut's body. Astronauts wear spacesuits that supply an air pressure against their bodies.

A barometer is an instrument used to measure air pressure. If a glass tube is filled with mercury and turned upside down with its end in a bowl of mercury, then the height of the column of mercury is held by the air particles pressing on the mercury in the bowl. This measures the air pressure. A standard measurement for atmospheric pressure at sea level is a column of mercury 760 mm/30 in high. At higher altitudes the height of the mercury column would be less, as the air pressure is lower.

atmospheric pressure

To remember the effects of falling and rising atmospheric pressure:

When pressure is falling, storms may come a'calling
When pressure is high, expect clear blue sky

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atoll

continuous or broken circle of coral reef and low coral islands surrounding a lagoon.

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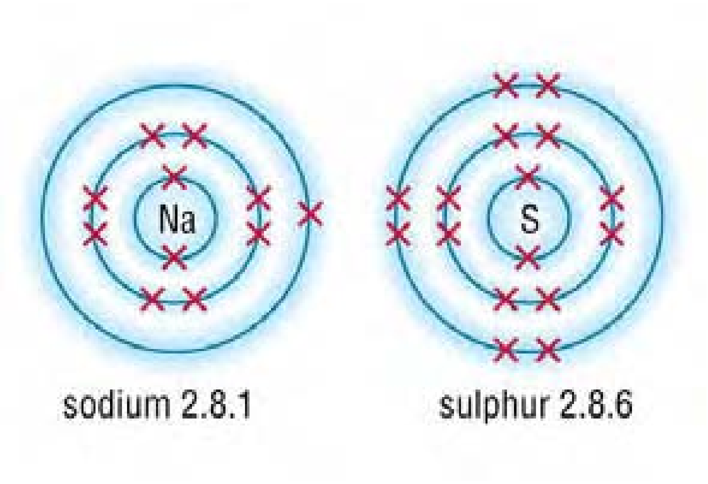
atom

(Greek atomos 'undivided')

smallest unit of matter that can take part in a chemical reaction, and which cannot be broken down chemically into anything simpler. An atom is made up of protons and neutrons in a central nucleus (except for hydrogen, which has a single proton in its nucleus) surrounded by electrons (see atomic structure). The atoms of the various elements differ in atomic number, relative atomic mass, and chemical behaviour.

Atoms are much too small to be seen by even the most powerful optical microscope (the largest, caesium, has a diameter of 0.0000005 mm/0.00000002 in), and they are in constant motion. However, modern electron microscopes, such as the scanning tunnelling microscope (STM) and the atomic force microscope (AFM), can produce images of individual atoms and molecules.

atom, electronic structure



(Image © Research Machines plc)

The arrangement of electrons in a sodium atom and a sulphur atom. The number of electrons in a neutral atom gives that atom its atomic number: sodium has an atomic number of 11 and sulphur has an atomic number of 16.

Atoms and Nuclei

Go to site

Covering all aspects of atomic structure, this site contains separate pages on 'Atomic structure', 'Atomic mass', 'Atomic number', 'Chemical symbols', 'Isotopes', and 'Symbols for isotopes'. A good resource for learning the basics.

Common Sense Science

Go to site

Alternative science site that explores new, 'common sense' models for elementary particles, the atom, and the nucleus.

Electric Charge and Ionic Bonds

Go to site

Introduction to ionic bonds, and the processes involved in creating and destroying them. Animations demonstrate the interaction between atoms when an ionic bond is being formed. Electron valences are also explained, and shown on a simplified periodic table.

Electron Sharing and Covalent Bonds

Go to site

Introduction to electron sharing and covalent bonds. This page outlines what a covalent chemical bond is, and how electrons are involved. Click on the forward arrow under the picture to see an animation of a covalent bond forming, and being broken apart.

Elementary Particles

Go to site

Detailed explanation of elementary particles, 'the most basic physical constituents of the universe', with links to other sources of related information.

Nucleus

Go to site

Short, sharp definition of a nucleus. This site is good for revising the very basics of atoms. It contains links to further definitions of structures mentioned, such as electrons, protons, and neutrons.

Particle Theory

Go to site

Description and explanation of particle theory by Elaine Wilson, of Homerton College, Cambridge. Clear and simple diagrams accompany the concise and insightful text. Also mentioned are isotopes.

Theory of Atoms in Molecules

Go to site

Canadian research paper about atoms that assumes some level of knowledge about the subject. The introductory topics include sections on 'What is an atom?' and 'What is a bond?' and will be of interest to the GCSE student or general reader.

World of Particles

Go to site

Divided into three sections, this site deals with fundamental particles. It covers the modern understanding of particles, the history of the search for and the discovery of new particles, and the story of the universe and how particles came into existence. At the end of each section there is a question to answer.

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atom, electronic structure of

arrangement of electrons around the nucleus of an atom, in distinct energy levels, also called atomic orbitals, or shells. These shells can be regarded as a series of concentric spheres, each of which can contain a certain maximum number of electrons; the noble gases (rare gases) have an arrangement in which every shell contains this number (see noble gas structure). The energy levels are usually numbered beginning with the shell nearest to the nucleus. The outermost shell is known as the valency shell as it contains the valence electrons.

The lowest energy level, or innermost shell, can contain no more than two electrons. Outer shells are considered to be stable when they contain eight electrons but additional electrons can sometimes be accommodated provided that the outermost shell has a stable configuration. Electrons in unfilled shells are available to take part in chemical bonding, giving rise to the concept of valency. In ions, the electron shells contain more or fewer electrons than are required for a neutral atom, resulting in negative or positive charges.

The atomic number of an element indicates the number of electrons in a neutral atom. From this it is possible to deduce its electronic structure. For example, sodium has atomic number 11 ($Z = 11$) and its electronic arrangement (configuration) is two electrons in the first energy level, eight electrons in the second energy level and one electron in the third energy level - generally written as 2.8.1. Similarly for sulphur ($Z = 16$), the electron arrangement is 2.8.6. The electronic structure dictates whether two elements will combine by ionic or covalent bonding (see bond) or not at all.

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atomic clock

timekeeping device regulated by various periodic processes occurring in atoms and molecules, such as atomic vibration or the frequency of absorbed or emitted radiation.

The first atomic clock was the **ammonia clock**, invented at the US National Bureau of Standards in 1948. It was regulated by measuring the speed at which the nitrogen atom in an ammonia molecule vibrated back and forth. The rate of molecular vibration is not affected by temperature, pressure, or other external influences, and can be used to regulate an electronic clock.

A more accurate atomic clock is the **caesium clock**. Because of its internal structure, a caesium atom produces or absorbs radiation of a very precise frequency (9,192,631,770 Hz) that varies by less than one part in 10 billion. This frequency has been used to define the second, and is the basis of atomic clocks used in international timekeeping.

Hydrogen maser clocks, based on the radiation from hydrogen atoms, are the most accurate. The hydrogen maser clock at the US Naval Research Laboratory, Washington, DC, is estimated to lose one second in 1,700,000 years. Cooled hydrogen maser clocks could theoretically be accurate to within one second in 300 million years.

Atomic clocks are so accurate that minute adjustments must be made periodically to the length of the year to keep the calendar exactly synchronized with the Earth's rotation, which has a tendency to slow down. There have been 17 adjustments made since 1972 adding a total of 20 seconds to the calendar. In 1997 the northern hemisphere's summer was longer than usual - by one second. An extra second was added to the world's time at precisely 23 hours, 59 minutes, and 60 seconds on 30 June 1997. The adjustment was called for by the International Earth Rotation Service in Paris, which monitors the difference between Earth time and atomic time.

atomic clock

Atomic clocks are so accurate that if they had been set up by a dinosaur they would be less than a second out today.

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atomic energy

former name for nuclear energy.

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atomic force microscope

AFM

microscope developed in the late 1980s that produces a magnified image using a diamond probe, with a tip so fine that it may consist of a single atom, dragged over the surface of a specimen to 'feel' the contours of the surface. In effect, the tip acts like the stylus of a record player, reading the surface. The tiny up-and-down movements of the probe are converted to an image of the surface by computer and displayed on a screen. The AFM is useful for examination of biological specimens since, unlike the scanning tunnelling microscope, the specimen does not have to be electrically conducting.

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atomicity

number of atoms of an element that combine together to form a molecule. A molecule of oxygen (O_2) has atomicity 2; sulphur (S_8) has atomicity 8.

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atomic mass unit

or dalton unit; symbol amu or u

unit of mass that is used to measure the relative mass of atoms and molecules. It is equal to one-twelfth of the mass of a carbon-12 atom, which is roughly equivalent to the mass of a proton or 1.66×10^{-27} kg. The atomic weight of an atom has no units; thus oxygen-16 has an atomic mass of 16 daltons, but an atomic weight of 16.

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atomic number

or proton number; symbol Z

number of protons in the nucleus of an atom. It is equal to the positive charge on the nucleus. In a neutral atom, it is also equal to the number of electrons surrounding the nucleus. The chemical elements are arranged in the periodic table of the elements according to their atomic number. Nuclear notation is used to label an atom according to the composition of its nucleus.

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atomic radiation

energy given out by disintegrating atoms during radioactive decay. The energy may be in the form of fast-moving particles, known as alpha particles and beta particles, or in the form of high-energy electromagnetic waves known as gamma radiation. Overlong exposure to atomic radiation can lead to radiation sickness.

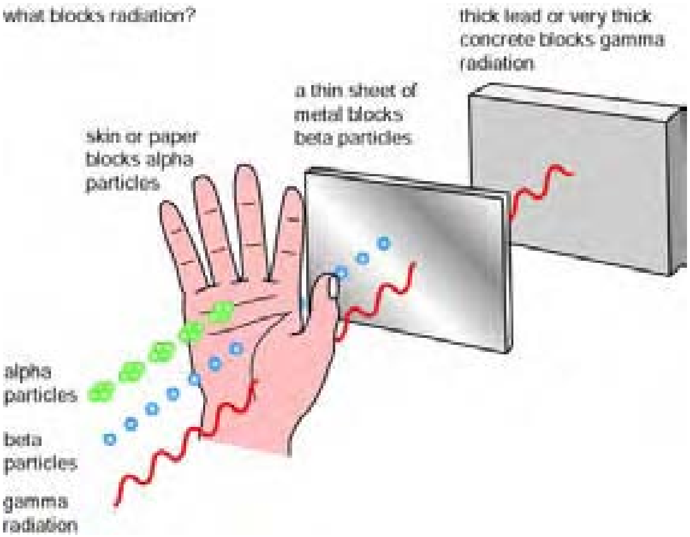
Radiation biology studies the effect of radiation on living organisms. Exposure to atomic radiation is linked to chromosomal damage, cancer, and, in laboratory animals at least, hereditary disease.

atomic radiation

(Image © Research Machines plc)

Testing for radiation, Australia. During the 1950s, the UK carried out a number of atom-bomb experiments in the Nullarbor Desert of southern Western Australia. Fallout was detected across the country while service personnel in the immediate area were exposed to high levels of radiation. Radiation levels at the test-sites are still very high.

atomic radiation


what blocks radiation?
thick lead or very thick concrete blocks gamma radiation
a thin sheet of metal blocks beta particles
skin or paper blocks alpha particles
alpha particles
beta particles
gamma radiation

(Image © Research Machines plc)

Atomic radiation may be in the form of alpha particles, beta particles, or gamma radiation. Alpha particles are fast-moving and consist of two protons and two neutrons. Because they have a relatively large mass, alpha particles have a range of up to 10 cm in air and can be stopped by skin or thin paper. Beta particles are electrons created and then instantly ejected from a radioactive atom. They have a greater range in air than alpha particles and can be stopped by a thin sheet of metal, such as aluminium. Gamma radiation is high-frequency, high-energy electromagnetic radiation. It is very penetrating and can only be blocked by thick lead or very thick concrete.

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atomic size

or atomic radius

size of an atom expressed as the radius in angstroms or other units of length.

The sodium atom has an atomic radius of 1.57 angstroms (1.57 x 10^{-8} cm). For metals, the size of the atom is always greater than the size of its ion. For non-metals the reverse is true.

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atomic structure

internal structure of an atom.

the nucleus

The core of the atom is the **nucleus**, a dense body only one ten-thousandth the diameter of the atom itself. The simplest nucleus, that of hydrogen, comprises a single stable positively charged particle, the **proton**. Nuclei of other elements contain more protons and additional particles, called **neutrons**, of about the same mass as the proton but with no electrical charge. Each element has its own characteristic nucleus with a unique number of protons, the atomic number. The number of neutrons may vary. Where atoms of a single element have different numbers of neutrons, they are called isotopes. Although some isotopes tend to be unstable and exhibit radioactivity, all those of a single element have identical chemical properties.

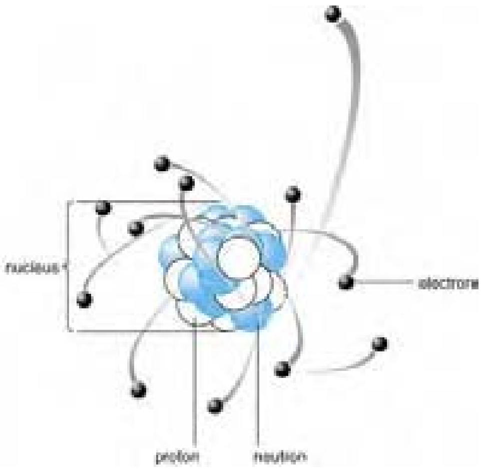
electrons

The nucleus is surrounded by a number of moving **electrons**, each of which has a negative charge equal to the positive charge on a proton, but which has a mass of only 1/1,836 times as much. In a neutral atom, the nucleus is surrounded by the same number of electrons as it contains protons. According to quantum theory, the position of an electron is uncertain; it may be found at any point. However, it is more likely to be found in some places than others. The region of space in which an electron is most likely to be found is called an atomic orbital. The chemical properties of an element are determined by the ease with which its atoms can gain or lose electrons.

attraction and repulsion

According to the theory of fundamental forces, atoms are held together by the electrical forces of attraction between each negative electron and the positive protons within the nucleus. The latter repel one another with enormous forces; a nucleus holds together only because an even stronger force, called the **strong nuclear force**, attracts the protons and neutrons to one another. The strong force acts over a very short range – the protons and neutrons must be in virtual contact with one another. If, therefore, a fragment of a complex nucleus, containing some protons, becomes only slightly loosened from the main group of neutrons and protons, the natural repulsion between the protons will cause this fragment to fly apart from the rest of the nucleus at high speed. It is by such fragmentation of atomic nuclei (nuclear fission) that nuclear energy is released.

atomic structure



(Image © Research Machines plc)

The structure of a sodium atom. The nucleus is composed of 11 protons and 12 neutrons. Eleven electrons orbit the nucleus in 3 orbits: 2 in the inner orbit, 8 in the middle, and 1 in the outer.

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atomic time

time as given by atomic clocks, which are regulated by natural resonance frequencies of particular atoms, and display a continuous count of seconds.

In 1967 a new definition of the second was adopted in the SI system of units: the duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the caesium-133 atom. The International Atomic Time Scale is based on clock data from a number of countries; it is a continuous scale in days, hours, minutes, and seconds from the origin on 1 January 1958, when the Atomic Time Scale was made 0 h 0 min 0 sec when Greenwich Mean Time was at 0 h 0 min 0 sec.

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atomic weight

or atomic mass

mass of an atom. It depends on the number of protons and neutrons in the atom, the electrons having negligible mass. It is calculated relative to one-twelfth the mass of an atom of carbon-12. If more than one isotope of the element is present, the atomic weight is calculated by taking an average that takes account of the relative proportions of each isotope, resulting in values that are not whole numbers.

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atomizer

device that produces a spray of fine droplets of liquid. A vertical tube connected with a horizontal tube dips into a bottle of liquid, and at one end of the horizontal tube is a nozzle, at the other a rubber bulb. When the bulb is squeezed, air rushes over the top of the vertical tube and out through the nozzle. Following Bernoulli's principle, the pressure at the top of the vertical tube is reduced, allowing the liquid to rise. The air stream picks up the liquid, breaks it up into tiny drops, and carries it out of the nozzle as a spray. Scent spray, paint spray guns, and carburettors all use the principle of the atomizer.

ATP

abbreviation for adenosine triphosphate

nucleotide molecule found in all cells. It can yield large amounts of energy, and is used to drive the thousands of biological processes needed to sustain life, growth, movement, and reproduction. Green plants use light energy to manufacture ATP as part of the process of photosynthesis. In animals, ATP is formed by the breakdown of glucose molecules, usually obtained from the carbohydrate component of a diet, in a series of reactions termed respiration. It is the driving force behind muscle contraction and the synthesis of complex molecules needed by individual cells.

ATP

To remember the initials of adenosine triphosphate (ATP):

Adenosine triphosphate (ATP) is crucial for **A**ctive **T**rans-**P**ort

---

atrium

either of the two upper chambers of the heart. The left atrium receives freshly oxygenated blood from the lungs via the pulmonary vein; the right atrium receives deoxygenated blood from the vena cava. Atrium walls are thin and stretch easily to allow blood into the heart. On contraction, the atria force blood into the thick-walled ventricles, which then give a second, more powerful beat.

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atrophy

in medicine, a diminution in size and function, or output, of a body tissue or organ. It is usually due to nutritional impairment, disease, or disuse (muscle).

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atropine

alkaloid derived from belladonna, a plant with toxic properties. It acts as an anticholinergic, inhibiting the passage of certain nerve impulses. It is used in premedication, to reduce bronchial and gastric secretions. It is also administered as a mild antispasmodic drug, and to dilate the pupil of the eye.

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attar of roses

perfume derived from the essential oil of roses (usually damask roses), obtained by crushing and distilling the petals of the flowers.

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attention-deficit hyperactivity disorder

ADHD

psychiatric condition occurring in young children characterized by impaired attention and hyperactivity. The disorder, associated with disruptive behaviour, learning difficulties, and underachievement, is more common in boys. It is treated with methylphenidate (Ritalin). There was a 50% increase in the use of the drug in the USA in the period 1994–96, with an estimated 5% of school-aged boys diagnosed as suffering from ADHD. In 1998, the number of children and adults in the USA taking medication for ADHD (mostly Ritalin) was approximately 4 million. In the UK, the prescription of Ritalin doubles each year.

Hyperactivity was first clinically diagnosed in 1902 and information has been gathered on the subject since then. The condition was formally called ADHD in 1994. In 1996, US researchers found that 50% of children diagnosed as ADHD sufferers carry a gene that affects brain cell response to the neurotransmitter dopamine. The same gene has also been linked to impulsiveness in adults. Diagnosis requires the presence, for at least six months, of eight behavioural problems, first developing before the age of seven. In addition to their hyperactivity, such children are found to be reckless, impulsive, and accident prone; they are often aggressive and tend to be unpopular with other children. The outlook for ADHD sufferers varies, with up to a quarter being diagnosed with an antisocial personality disorder as adults.

Attention-Deficit Hyperactivity

Go to site

Part of Internet Mental Health, this is a section from a freely available encyclopaedia of 'Mental health information'. It contains information on attention-deficit disorder, its treatment, and links to other related sites.

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attrition

in earth science, the process by which particles of rock are rounded and gradually reduced in size by hitting one another as they are transported by rivers, wind, or the sea.

The rounding of particles is a good indication of how far they have been transported. This is particularly true for particles carried by rivers, which become more rounded and smaller as the distance downstream increases. Thus the load of a river is often large and jagged in its upper course, and smaller and rounder in its lower course.

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aubrieta

any of a group of spring-flowering dwarf perennial plants native to the Middle East. All are trailing plants with showy, purple flowers. They are widely cultivated in rock gardens. (Genus *Aubrieta*, family Cruciferae.)

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audiometer

electrical apparatus used to test hearing.

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auditory canal

tube leading from the outer ear opening to the eardrum. It is found only in animals whose eardrums are located inside the skull, principally mammals and birds.

Audubon, John James (1785-1851)

US naturalist and artist. In 1827, after extensive travels and observations of birds, he published the first part of his *Birds of North America*, with a remarkable series of colour plates. Later he produced a similar work on North American quadrupeds.

The **National Audubon Society** (founded 1886) has branches throughout the USA and Canada for the study and protection of birds.

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auk

oceanic bird belonging to the family Alcidae, order Charadriiformes, consisting of 22 species of marine diving birds including razorbills, puffins, murres, and guillemots. Confined to the northern hemisphere, their range extends from well inside the Arctic Circle to the lower temperate regions. They feed on fish, and use their wings to 'fly' underwater in pursuit.

Most auks are colonial, breeding on stack tops or cliff edges, although some nest in crevices or holes. With the exception of one species they all lay a single large, very pointed egg.

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aura diagnosis

in alternative medicine, ascertaining a person's state of health from the colour and luminosity of the aura, the 'energy envelope' of the physical body commonly claimed to be seen by psychics. A study carried out by the Charing Cross Hospital Medical School in London, England, confirmed that the aura can be viewed by high frequency electrophotography techniques and is broadly indicative of states of health, but concluded that aura diagnosis cannot identify specific abnormalities.

The direct observation of aura is called the Kirlian effect, after Semion Kirlian who developed a visual technique in the 1920s to image aura using simulated electrophotonic response in a subject.

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auricula

species of primrose, a plant whose leaves are said to resemble a bear's ears. It grows wild in the Alps but is popular in cool-climate areas and often cultivated in gardens. (*Primula auricula*.)

Auriga

constellation of the northern hemisphere, represented as a charioteer. Its brightest star is the first-magnitude Capella, about 42 light years from the Sun; Epsilon Aurigae is an eclipsing binary star with a period of 27 years, the longest of its kind (last eclipse in 1983).

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aurochs

plural aurochs

extinct species of long-horned wild cattle *Bos primigenius* that formerly roamed Europe, southwestern Asia, and North Africa. It survived in Poland until 1627. Black to reddish or grey, it was up to 1.8 m/6 ft at the shoulder. It is depicted in many cave paintings, and is considered the ancestor of domestic cattle.

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aurora

coloured light in the night sky near the Earth's magnetic poles, called **aurora borealis** ('northern lights') in the northern hemisphere and **aurora australis** ('southern lights') in the southern hemisphere. Although auroras are usually restricted to the polar skies, fluctuations in the solar wind occasionally cause them to be visible at lower latitudes. An aurora is usually in the form of a luminous arch with its apex towards the magnetic pole, followed by arcs, bands, rays, curtains, and coronae, usually green but often showing shades of blue and red, and sometimes yellow or white. Auroras are caused at heights of over 100 km/60 mi by a fast stream of charged particles from solar flares and low-density 'holes' in the Sun's corona. These are guided by the Earth's magnetic field towards the north and south magnetic poles, where they enter the upper atmosphere and bombard the gases in the atmosphere, causing them to emit visible light.

Auroras: Paintings in the Sky

Go to site

Take a tour of the auroras. This page provides an in-depth explanation for the aurora phenomenon, includes a number of images taken from Earth and space, and sheds light on where they are best viewed. You can view a video clip of the aurora borealis and listen to audio clips of David Stern of NASA.

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auscultation

evaluation of internal organs by listening, usually with the aid of a stethoscope.

Australian terrier

small low-set dog with a long body and straight back. Its straight, rough coat is about 5-6.5 cm/2-2.5 in long, and blue or silver-grey, and tan or clear red or sandy in colour. It has a long head with a topknot of soft hair and ears either pricked or dropped forwards towards the front. Australian terriers are about 25 cm/10 in high and weigh 4.5-5 kg/10-11 lb.

The Australian terrier traces its ancestry to the Cairn, Norwich, and Yorkshire terriers.

Australia Telescope

system of radio telescopes in New South Wales, Australia, operated by the Australia Telescope National Facility (ATNF), part of the Commonwealth Scientific and Industrial Research Organization (CSIRO). It consists of six 22-m/72-ft antennae at Culgoora, near Narrabri, known as the Australia Telescope Compact Array; the 64-m/210-ft Parkes radio telescope; and the 22-m/75-ft Mopra radio telescope - the whole simulating a dish 300 km/186 mi across.

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autism

one of a spectrum of disorders defined by problems with communication, imagination, and social interaction. The symptoms may be present from birth or may develop in early childhood, around the third year. In rare cases, autistic individuals may show extraordinary talents in some areas, for example music, arithmetics, or drawing, but most will have learning difficulties. The causes of autisim are unknown, but it is thought to involve a number of environmental and genetic factors affecting the development of the child's brain. Special education may bring about some improvement.

First described in the 1940s by the Austrian-US psychiatrist and pediatrician Leo Kanner (1894-1981) and independently by the Austrian pediatrician Hans Asperger (1906-1980), autistic spectrum disorders (ASD) were long mistaken for a psychological or even a parenting problem. They are now established to be developmental disorders of the brain that can be investigated by brain imaging studies as well as by genetic analysis of the contributing factors.

A 2001 review of the subject commissioned by the UK government concluded that 0.6% of today's children are on the autistic spectrum. Whether the incidence has in fact increased during the 20th century (either through environmental factors or through better reproductive success of people who carry some of the genetic factors), or whether the observed increase is due to improved diagnosis remains controversial.

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autochrome

in photography, a single-plate additive colour process devised by the Lumière brothers in 1903. It was the first commercially available process, in use 1907-35.

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autoclave

pressurized vessel that uses superheated steam to sterilize materials and equipment such as surgical instruments. It is similar in principle to a pressure cooker.

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autogenics

in alternative medicine, system developed in the 1900s by German physician Johannes Schultz, designed to facilitate mental control of biological and physiological functions generally considered to be involuntary. Effective in inducing relaxation, assisting healing processes, and relieving psychosomatic disorders, autogenics is regarded as a precursor of biofeedback.

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autogiro

or autogyro

heavier-than-air craft that supports itself in the air with a rotary wing, or rotor. The Spanish aviator Juan de la Cierva designed the first successful autogiro in 1923. The autogiro's rotor provides only lift and not propulsion; it has been superseded by the helicopter, in which the rotor provides both. The autogiro is propelled by an orthodox propeller.

The three- or four-bladed rotor on an autogiro spins in a horizontal plane on top of the craft, and is not driven by the engine. The blades have an aerofoil cross section, as a plane's wings. When the autogiro moves forward, the rotor starts to rotate by itself, a state known as autorotation. When travelling fast enough, the rotor develops enough lift from its aerofoil blades to support the craft.

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autoimmunity

in medicine, condition in which the body's immune responses are mobilized not against 'foreign' matter, such as invading germs, but against the body itself. Diseases considered to be of autoimmune origin include myasthenia gravis, rheumatoid arthritis, and lupus erythematosus.

In autoimmune diseases T-lymphocytes reproduce to excess to home in on a target (properly a foreign disease-causing molecule); however, molecules of the body's own tissue that resemble the target may also be attacked, for example insulin-producing cells, resulting in insulin-dependent diabetes; if certain joint membrane cells are attacked, then rheumatoid arthritis may result; and if myelin, the basic protein of the nervous system, then multiple sclerosis results. In 1990 in Israel a T-cell vaccine was produced that arrests the excessive reproduction of T-lymphocytes attacking healthy target tissues.

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autolysis

in biology, the destruction of a cell after its death by the action of its own enzymes, which break down its structural molecules.

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automatic pilot

control device that keeps an aeroplane flying automatically on a given course at a given height and speed.

The automatic pilot contains a set of gyroscopes that provide references for the plane's course. Sensors detect when the plane deviates from this course and send signals to the control surfaces – the ailerons, elevators, and rudder – to take the appropriate action. Autopilot is also used in missiles. Most airliners cruise on automatic pilot, also called autopilot and gyropilot, for much of the time.

US business executive Lawrence Sperry first used a gyroscope in 1912 to create an artificial horizon. This entered production in 1924 and was soon linked to aircraft controls to increase stability. More gyroscopes were added later to control altitude and course. The first automatic pilot was introduced in the 1930s using pneumatic power.

Automatic Pilot: Computing in Aviation

computers with wings

An oft-repeated joke in the aviation industry runs like this: today's aircraft only require a pilot and a dog to fly them. Why? The dog is there to bite the pilot if he tries to touch the controls. The pilot's job is to feed the dog. The joke may be stale, but there is a serious point behind it. Today's aircraft are becoming increasingly computerized, making some pilots feel they are almost redundant.

The pace of aircraft automation has quickened recently. Until the 1980s, aircraft technology was based on mechanical controls and hydraulic systems to move the flight surfaces on the wing. Autopilots enabled planes to fly straight and level through dense cloud, but the pilot was still very much in charge.

the microprocessor takes over

Then came the microprocessor. Engineers incorporated the 'computer on a chip' into aircraft such as the Boeing 757 and 767, and the European Airbus A310. However, these planes still used hydraulic and mechanical control systems. In 1988, the designers of the Airbus A320 took another step towards complete automation by introducing a 'fly by wire' system in which electrical signals along a network of wire activate the flight surfaces.

The cockpit of the Airbus A320 is a product of the computer age. It is filled with computer screens and input devices, dispensing with the plethora of analogue dials and gauges of earlier aircraft. By displaying information in a more concise form, the computer screens simplify the pilot's task. A keyboard between the pilot and first officer provides the input to the flight management system. This contains several dozen microprocessors which assume many of the routine tasks once undertaken by the crew.

the pilot is no longer in control

If the pilot attempts a manoeuvre beyond the capabilities of the aircraft, it will be overridden by the control computer. This feature irritates pilots, who feel that they should have freedom of action. If a plane is heading for the side of a mountain, they argue, they should be able to pull up sharply, even if the plane is stressed beyond normal tolerances. However, aircraft makers argue that the new planes are safer. Boeing's 757 and 767 aircraft, amongst the most automated, have had only one accident in nearly 4 million flights; this compares with one accident in 200,000 flights for the Boeing 707, a 1950s model.

The Airbus A320 has an estimated design failure rate of one failure every billion flights, say the makers, Airbus Industrie. To achieve these levels of reliability, the aircraft has five separate control computers. Only one is required at any one time; the rest are held in reserve in case of failure. The odds against all five computers failing at the same time are calculated by multiplying the odds of separate failures: hence the extremely low overall failure rate estimated by the makers. However, these estimates have been criticized. Computer systems have a tendency to fail under similar conditions so that, if one fails, the others are likely to fail too.

what if the system fails?

A comparable doubt hangs over the control computer software. The chance of an error occurring in a computer program rises as the program gets longer. The average programmer can write tiny programs, say 20 lines of code long, without making mistakes, but such programs are trivial compared to the programs airline passengers entrust their lives to, which often contain hundreds of thousands of lines of code. As yet no-one has devised a way of assessing software reliability for very large programs.

Sloppy programming is sometimes found by spot checks and routine testing of programs. But errors do get through; aircraft deliveries have been delayed when cockpit displays gave incorrect readings. Two Airbuses have crashed since the aircraft took to the skies: one in 1987 at an air show at Habsheim in France, and the other at Bangalore, India, in 1990. In both cases, pilot error was blamed, but the pilot at Habsheim reported that the plane failed to respond to his commands.

Some experts feel that the aircraft industry is moving too fast. The human pilot, although fallible, has often snatched survival from near-impossible odds. If it is impossible to guarantee the reliability, and hence safety, of the computerized plane, manufacturers may have to fall back on tried and tested mechanical methods of control.

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automation

widespread use of self-regulating machines in industry. Automation involves the addition of control devices, using electronic sensing and computing techniques, which often follow the pattern of human nervous and brain functions, to already mechanized physical processes of production and distribution; for example, steel processing, mining, chemical production, and road, rail, and air control.

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automatism

performance of actions without awareness or conscious intent. It is seen in sleepwalking and in some (relatively rare) psychotic states.

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automaton

mechanical figure imitating human or animal performance. Automatons are usually designed for aesthetic appeal as opposed to purely functional robots. The writings of Ctesibius of Alexandria in the 3nd century BC show that in his time there was already a long tradition of building automata, such as model birds that sang or flapped their wings. A Chinese emperor of about 500 BC was reputed to have had a wooden horse moved by springs. Building automata has been one of the most challenging applications of advanced engineering skills up to the modern era of robots.

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automobile

or car

a small, driver-guided, passenger-carrying motor vehicle; originally the automated version of the horse-drawn carriage, meant to convey people and their goods over streets and roads.

Most are four-wheeled and have water-cooled, piston-type internal-combustion engines fuelled by gasoline or diesel. Variations have existed for decades that use ingenious and sometimes less polluting power plants, but the automobile industry has failed to improve on the current basic design for the consumer market. Experimental and sports models are streamlined, energy-efficient, and hand-built.

origins

Although it is recorded that in 1479 Gilles de Dom was paid 25 livres by the treasurer of Antwerp in the Low Countries for supplying a self-propelled vehicle, the ancestor of the automobile is generally agreed to be the cumbersome steam carriage made by Nicolas-Joseph Cugnot (1725-1804) in 1769, still preserved in Paris. Steam was an attractive form of power to the pioneering English engineers, and in 1803 Richard Trevithick built a working steam carriage. Later in the 19th century, practical steam coaches were used for public transport until stifled out of existence by the 6.4 kph/4 mph speed limit, punitive road tolls, and legislation that required someone to walk in front of the coach with a red flag by day and a red lantern by night.

the first automobiles

Although a Frenchman, Jean Etienne Lenoir, patented the first internal-combustion engine (gas-driven but immobile) in 1860, and an Austrian, Siegfried Marcus, built a vehicle which was shown at the Vienna Exhibition (1873), two Germans, Gottleib Daimler and Karl Benz, are generally regarded as the creators of the automobile. In 1885 Daimler and Benz built and ran the first gasoline-driven automobile (they worked independently with Daimler building a very efficient engine and Benz designing a vehicle but with a poor engine). The pattern for the modern automobile was set by Panhard in 1891 (front radiator, Daimler engine under bonnet, sliding-pinion gearbox, wooden ladder-chassis) and Mercedes in 1901 (honeycomb radiator, in-line four-cylinder engine, gate-change gearbox, pressed-steel chassis). Emerging with car manufacturers Haynes and Duryea in the early 1890s, US demand was so fervent that 300 manufacturers existed by 1895, although only 109 were left by 1900. In Britain, in 1896 (after the Red Flag Act had been repealed) Frederick Lanchester produced an advanced and reliable vehicle, later much copied.

automobiles as an industry

The period 1905–06 inaugurated a world automobile boom continuing to the present day. Among the legendary automobiles of the early 20th century are: the De Dion Bouton, with the first practical high-speed engines; the Mors, notable first for racing and later as a silent tourer; the Napier, the 24-hour record-holder at Brooklands in 1907, unbeaten for 17 years; the opulent Rolls-Royce Silver Ghost; the enduring Model T Ford; and the many types of Bugatti and Delage, from record-breakers to luxury tourers. After World War I popular motoring began with the era of cheap, light (baby) automobiles made by Citroën, Peugeot, and Renault (France); Austin, Morris, Clyno, and Swift (England); Fiat (Italy); Volkswagen (Germany); and the cheap though bigger Ford, Chevrolet, and Dodge in the USA. During the interwar years a great deal of racing took place, and the experience gained benefited the everyday motorist in improved efficiency, reliability, and safety. There was a divergence between the lighter, economical European automobile, with its good handling, and the heavier US automobile, cheap, rugged, and well adapted to long distances on straight roads at speed. By this time motoring had become a universal pursuit.

After World War II small European automobiles tended to fall into three categories, in about equal numbers: front engine and rear drive, the classic arrangement; front engine and front-wheel drive; rear engine and rear-wheel drive; in about equal numbers, although US automobiles became longer, lower, with more powerful (V8 engines) and 'styled' with fins. Big automobiles with soft suspensions and low gasoline mileage became the average family's ideal car until the OPEC oil crisis of 1973. Air conditioning was a new option in the 1950s. From the 1950s a creative resurgence produced automatic transmission for small automobiles, rubber suspension, transverse engine mounting, self-levelling ride, disk brakes, and safer wet-weather tires.

automobiles and pollution

Automobiles are responsible for almost a quarter of the world's carbon dioxide emissions. The drive against pollution from the 1960s and occasional fuel crises led to experiments with steam automobiles (cumbersome), diesel engines (slow and heavy, though economical), solar-powered automobiles, and hybrid automobiles using both electricity (in town centers) and gasoline (on the open road). The industry brought on the market the stratified-charge gasoline engine, using a fuel injector to achieve 20% improvement in gasoline consumption (the average US car in 1991 did only 10 km/l/27 mi/gal); weight reduction in the body by the use of aluminum and plastics; and 'slippery' body designs with low air resistance, or drag. In 1996 Daimler-Benz unveiled the world's first automobile to be powered by fuel-cell, which may become the industry's most practical pollution-free alternative. It can cover 250 km/155 mi and reach speeds of over 160 kph/100 mph.

Microprocessors were also developed to measure temperature, engine speed, pressure, and oxygen/CO_2 content of exhaust gases, and readjust the engine accordingly. In 1992, General Motors and Ford joined forces to develop a battery to propel pollution-free vehicles. $130 million were allocated for research on the project, with an equal amount to be provided by the US Department of Energy. Many developments in the fight against pollution were introduced first by the large and vigorous Japanese motor industry.

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autonomic nervous system

in mammals, the part of the nervous system that controls those functions not controlled voluntarily, including the heart rate, activity of the intestines, and the production of sweat.

There are two divisions of the autonomic nervous system. The **sympathetic** system responds to stress, when it speeds the heart rate, increases blood pressure, and generally prepares the body for action. The **parasympathetic** system is more important when the body is at rest, since it slows the heart rate, decreases blood pressure, and stimulates the digestive system.

At all times, both types of autonomic nerves carry signals that bring about adjustments in visceral organs. The actual rate of heartbeat is the net outcome of opposing signals. Today, it is known that the word 'autonomic' is misleading – the reflexes managed by this system are actually integrated by commands from the brain and spinal cord (the central nervous system).

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autopsy

or postmortem

examination of the internal organs and tissues of a dead body, performed to try to establish the cause of death.

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autoradiography

in biology, a technique for following the movement of molecules within an organism, especially a plant, by labelling with a radioactive isotope that can be traced on photographs. It is commonly used to study photosynthesis, where the pathway of radioactive carbon dioxide can be traced as it moves through the various chemical stages.

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autosome

any chromosome in the cell other than a sex chromosome. Autosomes are of the same number and kind in both males and females of a given species.

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autosuggestion

conscious or unconscious acceptance of an idea as true, without demanding rational proof, but with potential subsequent effect for good or ill. Pioneered by French psychotherapist Emile Coué in healing, it is sometimes used in modern psychotherapy to conquer nervous habits and dependence on addictive substances such as tobacco and alcohol.

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autotroph

any living organism that synthesizes organic substances from inorganic molecules by using light or chemical energy. Autotrophs are the primary producers in all food chains since the materials they synthesize and store are the energy sources of all other organisms. All green plants and many planktonic organisms are autotrophs, using sunlight to convert carbon dioxide and water into sugars by photosynthesis.

The total biomass of autotrophs is far greater than that of animals, reflecting the dependence of animals on plants, and the ultimate dependence of all life on energy from the Sun – green plants convert light energy into a form of chemical energy (food) that animals can exploit. Some bacteria use the chemical energy of sulphur compounds to synthesize organic substances. It is estimated that 10% of the energy in autotrophs can pass into the next stage of the food chain, the rest being lost as heat or indigestible matter. See also heterotroph.

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autumn crocus

any of a group of late-flowering plants belonging to the lily family. The mauve meadow saffron (*Colchicum autumnale*) yields colchicine, which is used in treating gout and in plant breeding. (Genus *Colchicum*, family Liliaceae.)

Colchicine causes plants to double the numbers of their chromosomes, forming polyploids)

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auxin

plant hormone that regulates stem and root growth in plants. Auxins influence many aspects of plant growth and development, including cell enlargement, inhibition of development of axillary buds, tropisms, and the initiation of roots. Auxin affects cell division mainly at the tip, because it is here that cell division in a stem or root mainly occurs. Just behind the tip the cells grow in size under the influence of auxins, causing the stem or root to grow longer. Auxin therefore affects the amount of elongation here too.

Synthetic auxins are used in hormone rooting powders to encourage cuttings to root. They are also used in some weedkillers, where high auxin concentrations cause such rapid growth that the plants die. Other uses include the prevention of premature fruit drop in orchards.

The most common naturally occurring auxin is known as indoleacetic acid, or IAA. It is produced in the shoot apex and transported to other parts of the plant.

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avalanche

(from French avaler 'to swallow')

fall or flow of a mass of snow and ice down a steep slope under the force of gravity. Avalanches occur because of the unstable nature of snow masses in mountain areas.

Changes of temperature, sudden sound, or earth-borne vibrations may trigger an avalanche, particularly on slopes of more than 35°. The snow compacts into ice as it moves, and rocks may be carried along, adding to the damage caused.

Avalanches leave slide tracks, long gouges down the mountainside that can be up to 1 km/0.6 mi long and 100 m/330 ft wide. These slides have a similar beneficial effect on biodiversity as do forest fires, clearing the land of snow and mature mountain forest and so enabling plants and shrubs that cannot grow in shade, to recolonize and creating wildlife corridors.

Avalanche!

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page follows an intrepid documentary team as they set out to film an avalanche. It provides information on the causes of avalanches, as well as details on how the film crew avoided getting swept away by them. There are six video clips of actual avalanches in progress and a number of still photos. You can download a transcript of the television programme.

Avalanche Awareness

Go to site

Description of avalanches, what causes them, and how to minimize dangers if caught in one. There is advice on how to determine the stability of a snowpack, what to do if caught out, and how to locate people trapped under snow. Nobody skiing off piste should set off without reading this.

Avebury

Europe's largest stone circle (diameter 412 m/1,350 ft), in Wiltshire, England. This megalithic henge monument is thought to be part of a ritual complex, and contains 650 massive blocks of stone arranged in circles and avenues. It was probably constructed around 3,500 years ago, and is linked with nearby Silbury Hill.

The henge, an earthen bank and interior ditch with entrances on opposite sides, originally rose 15 m/49 ft above the bottom of the ditch. This earthwork and an outer ring of stones surround the inner circles. The stones vary in size from 1.5 m/5 ft to 5.5 m/18 ft high and 1 m/3 ft to 3.65 m/12 ft broad. They were erected by a late Neolithic or early Bronze Age culture. The remains that can be seen today may cover an earlier site - as may be the case at a number of prehistoric sites.

Avedon, Richard (1923-2004)

US photographer. A fashion photographer with *Harper's Bazaar* magazine in New York City from the mid-1940s, he moved to *Vogue* in 1965. He later became the highest-paid fashion and advertising photographer in the world. He became associated with the *New Yorker* in 1993. Using large-format cameras, his work consists of intensely realistic images, chiefly portraits.

Avedon, Richard

Go to site

Biography and most famous work of the former merchant marine who rose to eminence in fashion photography. There is a photo of Avedon and descriptions of the stark black and white images of the great and good in the USA, many of which can be viewed at this site.

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avens

any of several low-growing plants found throughout Europe, Asia, and North Africa. (Genus *Geum*, family Rosaceae.)

Mountain avens (*Dryas octopetala*) belongs to a different genus and grows in mountain and arctic areas of Europe, Asia, and North America. A creeping perennial, it has white flowers with yellow stamens.

Avens

Go to site

Contains detailed information about avens, including an informative description of the plant and its habitat. This site also features details of the plant's constituents, as well as notes on the medicinal uses of avens, which range from curing agues to treating skin affections.

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average

in statistics, a term used inexactly to indicate the typical member of a set of data. It usually refers to the arithmetic mean. The term is also used to refer to the middle member of the set when it is sorted in ascending or descending order (the median), and the most commonly occurring item of data (the mode), as in 'the average family'.

In addition, it is useful to know the range or spread of data.

Using and Handling Data

Go to site

Description of the three main types of average: mean, median, and mode. Each section quickly explains what the term means and illustrates how to find it by using worked examples. There are links to other GCSE exam topics on the same site.

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aviation

see flight for the history of aviation and aircraft.

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avocado

tree belonging to the laurel family, native to Central America. Its dark-green, thick-skinned, pear-shaped fruit has buttery-textured flesh and is used in salads. (*Persea americana*, family Lauraceae.)

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avocet

wading bird, with a characteristic long, narrow, upturned bill, which it uses to sift water as it feeds in the shallows. It is about 45 cm/18 in long, has long legs, partly webbed feet, and black and white plumage. There are four species of avocet, genus *Recurvirostra*, family Recurvirostridae, order Charadriiformes. They are found in Europe, Africa, and central and southern Asia. Stilts belong to the same family.

Avogadro, Amedeo (1776-1856)

Conte di Quaregna

Italian physicist, one of the founders of physical chemistry, who proposed Avogadro's hypothesis on gases in 1811. His work enabled scientists to calculate Avogadro's number, and still has relevance for atomic studies.

Avogadro made it clear that the gas particles need not be individual atoms but might consist of molecules, the term he introduced to describe combinations of atoms. No previous scientist had made this fundamental distinction between the atoms of a substance and its molecules.

Avogadro's hypothesis

in chemistry, the law stating that equal volumes of all gases, when at the same temperature and pressure, have the same numbers of molecules. One mole of any gas contains 6.023×10^{23} particles and occupies 24 dm^3 at room temperature and pressure. The type of gas does not make any difference. The law was first put forward by Italian chemist Amedeo Avogadro.

Avogadro's Hypothesis

Go to site

Scientific biography of the ground-breaking 18th-century scientist Amadeo Avogadro, who hypothesized that that 'equal volumes of gases, at the same temperature and pressure, contain equal numbers of molecules'. The page opens with a discussion of the nature of scientific thought, moves on to describe Avogadro's discoveries and ends by explaining the number named in honour of Avogadro, who died in obscurity, his distinction between atoms and molecules as yet unrecognized.

Avogadro's number

or Avogadro's constant

number of carbon atoms in 12 g of the carbon-12 isotope (6.022045×10^{23}). It is named after Italian chemist Amedeo Avogadro. The relative atomic mass of any element, expressed in grams, contains this number of atoms and is called a mole. For example, one mole of any substance contains 6.022×10^{23} particles. One mole of carbon has a mass of 12 g.

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avoirdupois

system of weights based on the pound (0.45 kg), which consists of 16 ounces, each of 16 drams, with each dram equal to 27.34 grains (1.772 g).

Axel, Richard (1946-)

US neuroscientist. With US neuroscientist Linda Buck he shared the Nobel Prize for Physiology or Medicine in 2004 for his contributions in determining how the olfactory system recognizes and differentiates between different smells.

Axel's and Buck's collaborative research discovered that the sense of smell depends on a large family of around 10,000 genes that produce an equivalent number of odorant receptors in the cells lining the upper part of the nasal epithelium. They discovered that each receptor was triggered by only one specific odorant molecule. They went on to show that the chain reaction that occurred when a receptor was triggered sent signals directly to the higher brain functions that could link a smell to a particular memory or a certain emotion, allowing specific decisions to be made on the basis of smell. Axel and Buck published their fundamental scientific paper of the functioning of the olfactory system in 1991. They subsequently worked separately to expand on their initial work in helping to define the mechanisms involved in olfactory system functions.

Axelrod, Julius (1912-2004)

US neuropharmacologist who was awarded a Nobel Prize for Physiology or Medicine in 1970 for his work with the biophysicists Bernard Katz and Ulf von Euler, on neurotransmitters (the chemical messengers of the brain).

Axelrod wanted to know why the messengers, once transmitted, should stop operating. Through his studies he found a number of specific enzymes that rapidly degraded the neurotransmitters.

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axil

upper angle between a leaf (or bract) and the stem from which it grows. Organs developing in the axil, such as shoots and buds, are termed axillary, or lateral.

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axiom

in mathematics, a statement that is assumed to be true and upon which theorems are proved by using logical deduction; for example, two straight lines cannot enclose a space. The Greek mathematician Euclid used a series of axioms that he considered could not be demonstrated in terms of simpler concepts to prove his geometrical theorems.

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axis

plural axes

in geometry, one of the reference lines by which a point on a graph may be located. The horizontal axis is usually referred to as the *x*-axis, and the vertical axis as the *y*-axis. The term is also used to refer to the imaginary line about which an object may be said to be symmetrical (**axis of symmetry**) - for example, the diagonal of a square - or the line about which an object may revolve (**axis of rotation**).

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axis deer

or chital

species of deer found in India and the East Indies. It is profusely spotted with white on a fawn background, shading from almost black on the back to white on the underparts.

classification

The axis deer *Axis axis* is in family Cervidae, order Artiodactyla.

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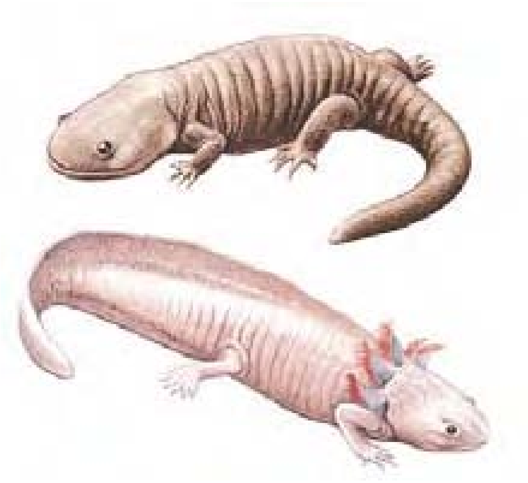
axolotl

(Aztec 'water monster')

aquatic larval form ('tadpole') of the Mexican salamander *Ambystoma mexicanum*, belonging to the family Ambystomatidae. Axolotls may be up to 30 cm/12 in long. They are remarkable because they can breed without changing to the adult form, and will metamorphose into adults only in response to the drying-up of their ponds. The adults then migrate to another pond.

Axolotls resemble a newt in shape, having a powerful tail, two pairs of weak limbs, and three pairs of simple external gills. They lay eggs like a frog's in strings attached to water plants by a viscous substance, and the young, hatched in two to three weeks, resemble the parents. See also neoteny.

axolotl



(Image © Research Machines plc)

The rare axolotl *Ambystoma mexicanum* lives in mountain lakes in Mexico. The capture of specimens as pets and the introduction of predatory fish has led to a decline in numbers.

Axolotls

Go to site

Attractively illustrated guide to the Mexican 'Walking Fish', or axolotl, aimed at the prospective pet owner. Complete with information on the salamander's native habitats, answers to frequently asked questions, requirements for housing and feeding, and suggestions for further reading. There are also linked guides of a similar nature for related species such as the Tiger Salamander.

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axon

long threadlike extension of a nerve cell that conducts electrochemical impulses away from the cell body towards other nerve cells, or towards an effector organ such as a muscle. Axons terminate in synapses, junctions with other nerve cells, muscles, or glands.

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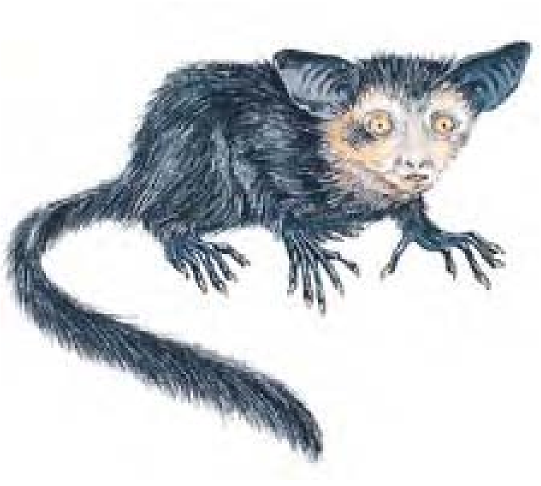
aye-aye

nocturnal tree-climbing prosimian *Daubentonia madagascariensis* of Madagascar, related to the lemurs. It is just over 1 m/3 ft long, including a tail 50 cm/20 in long.

It has an exceptionally long middle finger with which it probes for insects and their larvae under the bark of trees, and gnawing, rodentlike front teeth, with which it tears off the bark to get at its prey. The aye-aye has become rare through loss of its forest habitat, and is now classified as an endangered species.

aye-aye



(Image © Research Machines plc)

The aye-aye is a nocturnal animal that lives in the dense forests of Madagascar. Closely related to the lemur, the aye-aye has large forward-looking eyes, powerful rodentlike teeth, large ears, and a particularly long middle finger which is used to dig insects out of tree trunks.

Ayurveda

basically naturopathic system of medicine widely practised in India and based on principles derived from the ancient Hindu scriptures, the Vedas. Hospital treatments and remedial prescriptions tend to be nonspecific and to coordinate holistic therapies for body, mind, and spirit.

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azalea

any of a group of deciduous flowering shrubs belonging to the heath family. Several species are native to Asia and North America, and many cultivated varieties have been derived from these. Azaleas are closely related to the mostly evergreen rhododendrons. (Genus *Rhododendron*, family Ericaceae.)

Azaleas, particularly the Japanese varieties, make fine ornamental shrubs. Several species are highly poisonous.

Azilian

archaeological period following the close of the Old Stone (Palaeolithic) Age and regarded as the earliest culture of the Mesolithic Age in Western Europe. It was first recognized at Le Mas d'Azil, a cave in Ariège, France.

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azimuth

in astronomy, angular distance of an object eastwards along the horizon, measured from due north, between the astronomical meridian (the vertical circle passing through the centre of the sky and the north and south points on the horizon) and the vertical circle containing the celestial body whose position is to be measured.

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azo dye

synthetic dye containing the azo group of two nitrogen atoms ($N{=}N$) connecting aromatic ring compounds. Azo dyes are usually red, brown, or yellow, and make up about half the dyes produced. They are manufactured from aromatic amines.

AZT

or **retrovir** or **zidovudine** trademark for azidothymidine, an antiviral drug used in the treatment of AIDS.

Developed in the mid-1980s and approved for use by 1987, it is not a cure for AIDS but is effective in suppressing the causative virus (HIV) for as long as it is administered; it does not, however, delay the onset of AIDS in people carrying the virus. Taken every four hours, night and day, it reduces the risk of opportunistic infection and relieves many neurological complications. However, frequent blood monitoring is required to control anemia, a potentially life-threatening side-effect of AZT. Blood transfusions are often necessary, and the drug must be withdrawn if liver damage occurs or bone-marrow function is severely affected.

Baade, (Wilhelm Heinrich) Walter (1893-1960)

German-born US astronomer who made observations that doubled the distance, scale, and age of the universe. He discovered that stars are in two distinct populations according to their age, known as Population I (the younger) and Population II (the older). Later, he found that Cepheid variable stars of Population I are brighter than had been supposed and that distances calculated from them were wrong.

Babbage, Charles (1792-1871)

English mathematician who devised a precursor of the computer. He designed an analytical engine, a general-purpose mechanical computing device for performing different calculations according to a program input on punched cards (an idea borrowed from the Jacquard loom). This device was never built, but it embodied many of the principles on which digital computers are based.

Babbage was born in Totnes, Devon. As a student at Cambridge, he assisted John Herschel with his astronomical calculations and thought they could be better done by machines. His mechanical calculator, or difference engine, begun in 1822, which could compute squares to six places of decimals, got him a commission from the British Admiralty for an expanded version. But this project was abandoned in favour of the analytical engine, on which he worked for the rest of his life. The difference engine could perform only one function, once it was set up. The analytical engine was intended to perform many functions; it was to store numbers and be capable of working to a program. The first computer printer, also designed but never built by Charles Babbage, was completed and put on show at London's Science Museum in April 2000.

Babbage, Charles

Charles Babbage, who was perhaps the first person to conceive the idea of a mechanical computer, was a stickler for accuracy. He once wrote to the poet Tennyson to object to the poet's lines 'Every moment dies a man, every moment one is born'. According to Babbage, Tennyson's recipe gave zero population growth, and should be corrected to: 'Every moment one and one-sixteenth is born'.

Babbit metal

soft, white metal, an alloy of tin, lead, copper, and antimony, used to reduce friction in bearings, developed by the US inventor Isaac Babbit in 1839.

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babbler

bird of the thrush family Muscicapidae with a loud babbling cry. Babblers, subfamily Timaliinae, are found in the Old World, and there are some 250 species in the group.

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babirusa

wild pig *Babirousa babyrussa*, becoming increasingly rare, found in the moist forests and by the water of Sulawesi, Buru, and nearby Indonesian islands. The male has large upper tusks which grow upwards through the skin of the snout and curve back towards the forehead. The babirusa is up to 80 cm/2.5 ft at the shoulder. It is nocturnal, and swims well.

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baboon

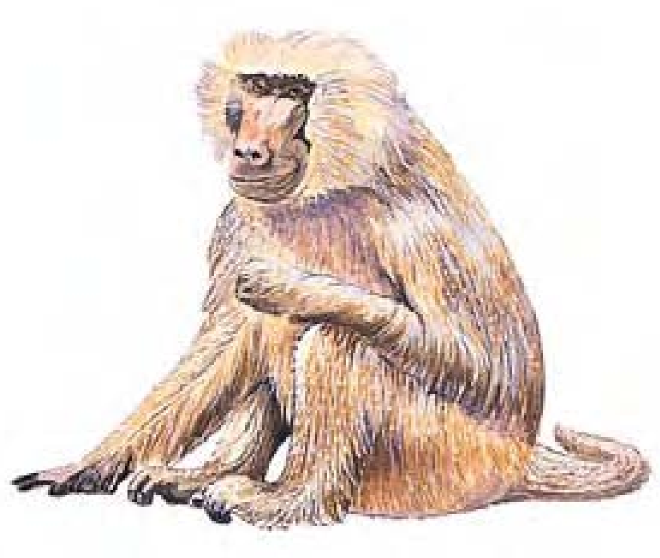
large monkey of the genus *Papio*, with a long doglike muzzle and large canine teeth, spending much of its time on the ground in open country. Males, with head and body up to 1.1 m/3.5 ft long, are larger than females, and dominant males rule the 'troops' in which baboons live. They inhabit Africa and southwestern Arabia.

Species include the **olive baboon** *P. anubis* from West Africa to Kenya, the **chacma** *P. ursinus* from South Africa, and the **sacred baboon** *P. hamadryas* from northeastern Africa and southwestern Arabia. The male sacred baboon has a 'cape' of long hair.

baboon

In baboons, 60% of all infant deaths are infanticides by males to hasten the sexual receptivity of the female.

baboon



(Image © Research Machines plc)

Hamadryas baboon of Ethiopia, Somalia, and southern Saudi Arabia. Like all baboons, this species has a doglike muzzle and a sloping back. They live in family groups consisting of an old male, several females, and their young, sleeping in trees or among rocks at night and wandering in search of food during the day.

Bach flower healing

a homeopathic system of medical therapy developed in the 1920s by the English physician Edward Bach. Based on the healing properties of wild flowers, it seeks to alleviate mental and emotional causes of disease rather than their physical symptoms.

bacille Calmette-Guérin

tuberculosis vaccine BCG.

bacillus

genus of rod-shaped bacteria that occur everywhere in the soil and air. Some are responsible for diseases such as anthrax, or for causing food spoilage.

backcross

cross between an offspring and one of its parents, or an individual that is genetically identical to one of its parents. It is a breeding technique used to determine the genetic makeup of an individual organism.

background radiation

radiation that is always present in the environment. By far the greater proportion (87%) of it is emitted from natural sources. Alpha particles, beta particles, and gamma radiation are emitted by the traces of radioactive minerals that occur naturally in the environment and even in the human body (for example, by breathing in ^{14}C). Radioactive gases such as radon and thoron are found in soil and may seep upwards into buildings. Radiation from space (cosmic radiation) also contributes to the background level.

The **background count** is the count registered on a Geiger counter when no other radioactive source is nearby.

backing storage

in computing, memory outside the central processing unit (CPU) used to store programs and data that are not in current use. Backing storage must be nonvolatile – that is, its contents must not be lost when the power supply to the computer system is disconnected.

Backing storage uses either **direct** or **serial** access methods. Direct access means that particular files can be found without the need to read through all of the data, as with serial access. Data may be stored on (or **written** to) CD-ROM, floppy disk (both direct access), magnetic tape, or memory stick (serial access).

back pain

aches in the region of the spine. Low back pain can be caused by a very wide range of medical conditions. About half of all episodes of back pain will resolve within a week, but severe back pain can be chronic and disabling. The causes include muscle sprain, a prolapsed intervertebral disc, and vertebral collapse due to osteoporosis or cancer. Treatment methods include rest, analgesics, physiotherapy, osteopathy, and exercises.

backswimmer

or water boatman

aquatic predatory bug living mostly in fresh water. The adults are about 15 mm/0.5 in long and rest upside down at the water surface to breathe. When disturbed they dive, carrying with them a supply of air trapped under the wings. They have piercing beaks, used in feeding on tadpoles and small fish.

classification

Backswimmers belong to the genus *Notonecta*, family Notonectidae in suborder Heteroptera, order Hemiptera (true bugs), class Insecta, phylum Arthropoda.

Females have a sharp ovipositor to pierce the stems of aquatic plants. In each notch one egg is laid; each female lays a total of approximately 60 eggs over a period of a few weeks. Backswimmers fly readily from pond to pond.

back-up system

in computing, duplicate computer system that can take over the operation of a main computer system in the event of equipment failure. A large interactive system, such as an airline's ticket-booking system, cannot be out of action for even a few hours without causing considerable disruption. In such cases a complete duplicate computer system may be provided to take over and run the system should the main computer develop a fault or need maintenance.

Back-up systems include **incremental back-up** and **full back-up**.

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bacteria

singular bacterium

microscopic single-celled organisms lacking a membrane-bound nucleus. Bacteria, like fungi and viruses, are micro-organisms – organisms that are so small they can only be seen using a microscope. They are organisms that are more simple than the cells of animals, plants, and fungi in that they lack a nucleus. Bacteria are widespread, being present in soil, air, and water, and as parasites on and in other living things. In fact, they occur anywhere life can exist. Some parasitic bacteria cause disease by producing toxins, but others are harmless and can even benefit their hosts. Bacteria usually reproduce by binary fission (dividing into two equal parts), and, on average, this occurs every 20 minutes. Only 4,000 species of bacteria are known (1998), although bacteriologists believe that around 3 million species may actually exist. Certain types of bacteria are vital in many food and industrial processes, while others play an essential role in the nitrogen cycle, which maintains soil fertility. They can be the first organism of a food chain, by acting as decomposers of dead plant and animal remains. This helps to recycle nutrients.

Bacteria can be grown on the surface of agar jelly in dishes in the laboratory and have been studied in detail. This has led to the development of antibiotics, chemicals that kill or inhibit other micro-organisms such as bacteria. Sometimes the chemical is not harmful to humans and so can be used to treat disease. Some antibiotics work against a range of bacteria and in many situations, such as penicillins. Others are quite specific. For example, neomycin sulphate is especially active against bacteria that cause infections of the middle ear. Unfortunately, there are increasing numbers of bacteria that are resistant to antibiotics. New antibiotics need to be discovered so that antibiotic-resistant bacteria can be destroyed, but this is only occurring very slowly.

bacteria

The bacterium *Deinococcus radiourans* can survive at gamma radiation levels of up to 50,000 grays – thousands of times greater than that needed to kill a human.

bacteria: navigation

The freshwater bacterium *Aquaspirillium magnetotacticum* uses the Earth's magnetic field to navigate. The bacteria in the northern hemisphere travel north (downwards) if dislodged from the mud at the bottom of rivers and lakes; those in the southern hemisphere head south.

bacteria: quanitity

Bacteria on and in the human body outnumber the number of cells that constitute the body.

bacteria: simplest organism

The simplest known free-living organism is the bacterium *Mycoplasma genitalium*, which has 468 genes.

Drug: Drug-resistant Bacteria

drugs sought against super-infections

The recent flurry of deaths from antibiotic-resistant bacteria has pointed up the need for new drugs to fight infection. For the harsh fact is that, after half a century of widespread, often inappropriate use, antibiotics are beginning to lose their power. Microbiologists cite a growing number of bacterial strains – including some responsible for pneumonia, tuberculosis, and blood-poisoning – which defy all existing treatments. Most at risk from these so-called super-bugs are people whose immune systems are in some way impaired – the frail elderly, AIDS patients, transplant recipients, and patients receiving chemotherapy for cancer.

the search for new remedies

The phenomenon of super-resistance gives fresh urgency to the search for new remedies. Traditionally, researchers have mostly looked for antibiotics from organisms in the soil, and one promising new contender, rapamycin, has been isolated from bacteria and microscopic fungi contained in soil samples from Easter Island. Synthesized by workers in California, this experimental compound is thought also to have potential as an anti-cancer agent and immunosuppressant. Meanwhile the hunt has been widened to other sources in the natural world – for instance the African clawed frog. In the late 1980s its nerve endings were found to contain a small peptide which not only kills bacteria but seems effective also against fungi, parasites, and some cancer cells. This compound, since named magainin (from the Hebrew word for a shield), is believed to have a similar mode of action to that of another new antibiotic substance, squalamine, discovered in tissue from the dogfish shark.

a new strategy

Other researchers have adopted a whole new strategy in the battle against infectious disease. Instead of targeting bacteria, as conventional antibiotics do, they are developing compounds to boost the body's natural defences. Among these is a genetically engineered carbohydrate that causes proliferation and increased bacterial activity of some white blood cells. One attraction of the immunological approach is that there is no likelihood of meeting the resistance seen with antibiotics since these new drugs – all still at the experimental stage – are merely stimulating a natural mechanism.

Antibiotics: How Do Antibiotics Work?

Go to site

Introduction to the use and importance of antibiotics, in easy-to-understand language. The site includes a full list of all antibacterial drugs, a discussion of the growing problem of bacterial resistance, and links to other sites providing additional information on these topics.

Bacteria in Sickness and in Health

Go to site

Guide to the goodies of the microbial world, the bacteria that work to keep the human body healthy. The site looks at various parts of the body, such as the gut, mouth, nose, and throat, the bacteria that they normally contain, and explains how to tell when bacteria are acting as pathogens. Each page deals with a different location of bacteria within the human body and is navigable through the arrows provided at the bottom of the page.

Bacterial Evolution: Score one for Punk Eek

Go to site

Part of a larger site maintained by *Scientific American*, this page reports on research conducted at Michigan State University in which scientists speeded up the evolution of bacteria in order to study the theory of 'punctuated equilibrium', which seeks to explain why evolutionary changes sometimes take place with relative suddenness after aeons of general stasis. The text includes hypertext links to further information, and there is also a list of links to critical analysis of punctuated equilibrium and related sites on the Web.

Bad Bug Book - Hepatitis A Virus

Go to site

Concise fact sheet about hepatitis A. The site includes basic information on the nature and diagnosis of the disease, as well as brief discussions of its frequency and of foods associated with it.

Bad Bug Book - Streptococcus

Go to site

Fact sheet with background information on streptococcus. It includes discussions of the nature and diagnosis of the bacteria, the foods normally associated with it, and the frequency, course, and complications of the infection.

Bugs in the News!

Go to site

Lively articles fill you in not just on the micro-organisms in the news, but also on immunity, antibiotics, and molecular biology issues in the real world. The articles are divided into three different levels to give a brief and simple overview or more detailed information as required.

Kingdom Monera: The Prokaryotes

Go to site

Clearly written guide to Kingdom Monera, otherwise known as bacteria, the most numerous organisms on Earth. The site describes the basic types of bacteria - archaebacteria, eubacteria, and the mycoplasms - and shows how to identify them. It also covers bacterial reproduction and movement, and the economic importance of these micro-organisms.

Microbe Zoo

Go to site

Colourful and interactive zoo of some of the microbes that surround us. It includes sections on the 'domestic' microbes; the vampire ones that suck the life from other bacteria; the killers that destroy stone buildings; those in aquatic environments; and those that are to be found in foods such as beer, bread, chocolate, and wine.

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bacteriology

study of bacteria.

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bacteriophage

virus that attacks bacteria, commonly called a phage. Such viruses are now useful vectors in genetic engineering for introducing modified DNA.

Phages

introduction

Phages, or bacteriophages (literally 'bacteria eaters'), are viruses that infect bacteria. They were first identified by F W Twort in 1905 and, independently, by F d'Herelle in 1917 as filterable infectious agents that caused the lysis (disintegration) of *Shigella dynsenteriae*, the bacterium that causes dysentery. They were initially of interest for their specificity, they would not infect other bacteria, and potential therapeutic use, and have become some of the best characterized viruses.

life cycle of phages

Phages, like other viruses, are obligate intracellular parasites. They cannot reproduce independently and must instead infect a host bacterium within which they replicate, usually resulting in the lysis of the bacteria and release of progeny phage particles. The phage particle is a metabolically inert entity consisting of a protein coat (capsid) surrounding the genome which consists of single- or double-stranded DNA or RNA. Two distinct replication patterns exist; lytic, in which genome replication, transcription and translation of phage genes and the subsequent assembly of progeny phage particles occurs immediately (so called virulent phages) and lysogenic, in which the phage genome becomes integrated into the host chromosome (the temperate phages). In the latter case the phage genome is replicated as part of the bacterial chromosome, remaining latent as a prophage until induction at which point the phage enters a normal lytic cycle.

phage structure and classification

The diverse range of phages are primarily classified according to their capsid structure (filamentous - e.g. M13, tailless icosahedral - e.g. ϕX174, phages with noncontractile tails - e.g. λ and phages with contractile tails - e.g. T2) and the type of genetic material. The T-even phages of *Escherichia coli* (T2, T4, T6) possess large double-stranded DNA genomes within an icosahedral capsid bearing a contractile tail, and are some of the most complex of all viruses.

phages in research

The short replication cycle (as little as 15 min) and ease of manipulation in the laboratory have meant that phages have been used for some of the most significant biological, and in particular genetic, experiments of the last 50 years. The identification of DNA as the genetic material was based on a study of phage T2 infection of *E. coli* by Alfred Hershey and Martha Chase in 1952. Phage ϕX174, a single-stranded DNA phage was the first complete genome to be sequenced (1977), leading to the discovery of overlapping genes, and the switch between lytic and lysogenic life cycles by phage lambda (λ) is the paradigm for a 'genetic switch', which has broad similarities with similar controlling events in many other organisms (including humans). The natural ability of phages to exchange genetic material between bacteria has led to them being exploited for experiments in molecular genetics - both phage M13 and λ are widely used DNA cloning vectors.

phages and human disease

The specificity of bacterial infection by phages means that they can be used to distinguish between different strains of bacteria (particularly *Salmonella* sp.), a technique called 'phage typing' widely used in reference laboratories. Furthermore, phages may have a role in causing human disease as well as diagnosing it. *Vibrio cholerae*, the bacterium that causes cholera, requires two factors for full virulence; the cholera toxin (CT) and a toxin-coregulated pili (TCP) required for intestinal colonization. Recent research has shown that the genes encoding both CT and TCP are carried by the filamentous phage CTXϕ, which can transfer them to apathogenic strains of *V. cholerae* and so lead to the formation of novel virulent strains capable of causing cholera.

d'Herelle suggested that the specific lysis of bacteria by phages could be exploited in the development of therapeutic treatments for bacterial infections. The intervening 80 years have seen the discovery and widespread use of antibiotics for treating bacterial infection. Although very effective, there are an increasing number of multiply drug-resistant bacteria, e.g. *Mycobacterium tuberculosis* (TB) and *Staphylococcus aureus* (septicaemia) as a direct consequence of the widespread use of antibiotics, and there has been a resurgence in the interest in the use of phages for treating bacterial infection.

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bactrian

species of camel, *Camelus bactrianus*, found in the Gobi Desert in central Asia. Body fat is stored in two humps on the back. It has very long winter fur which is shed in ragged lumps. The bactrian has a head and body length of about 3 m/10 ft, and is about 2.1 m/6.8 ft tall at the shoulder. Most bactrian camels are domesticated and are used as beasts of burden in central Asia.

In 1995 there were only about 730-880 bactrian camels remaining in the wild.

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badger

large mammal of the weasel family with molar teeth of a crushing type adapted to a partly vegetable diet, and short strong legs with long claws suitable for digging. The Eurasian **common badger** *Meles meles* is about 1 m/3 ft long, with long, coarse, greyish hair on the back, and a white face with a broad black stripe along each side. Mainly a woodland animal, it is harmless and nocturnal, and spends the day in a system of burrows called a 'sett'. Earthworms make up 90% of the badger's diet but it also feeds on roots, a variety of fruits and nuts, insects, mice, and young rabbits.

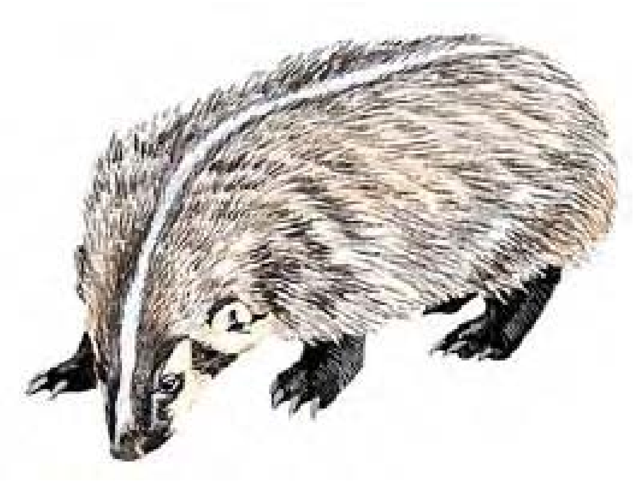
The Eurasian badger lives for up to 15 years. It mates February to March, and again July to September if the earlier mating has not resulted in fertilization. Implantation of the blastocyst (early embryo) is however delayed until December. Cubs are born January to March, and remain below ground for eight weeks. They remain with the sow at least until autumn.

The **American badger** *Taxidea taxus* is slightly smaller than the Eurasian badger, and lives in open country in North America. Various species of hog badger, ferret badger, and stink badger occur in South and East Asia, the last having the well-developed anal scent glands characteristic of the weasel family.

badger

More than 25,000 badgers have been killed in Britain since 1975 in a government campaign. The British Ministry of Agriculture, Fisheries, and Food (MAFF) has spent more than £15 million on this attempt to eliminate tuberculosis (TB) in cattle. Nobody has yet established how badgers transmit TB to cattle and, despite the slaughter, the incidence of TB in cattle shows no signs of decline.

badger



(Image © Research Machines plc)

The American badger is slightly smaller than its Eurasian cousin. Unlike the Eurasian badger, it is a solitary creature, and lives mainly on small rodents. It usually spends the day in its burrow or sett, emerging at night to hunt for mice, eggs, and reptiles. It is an excellent digger and can rapidly dig out burrowing rodents.

Badgers.org.uk

Go to site

Complete resource for anyone interested in badgers. There are detailed pages about the conservation of the animals, accompanied by many photos. You can also send a virtual badger postcard, or sign up for your own badger e-mail account.

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badlands

barren landscape cut by erosion into a maze of ravines, pinnacles, gullies, and sharp-edged ridges. Areas in South Dakota and Nebraska, USA, are examples.

Baekeland, Leo Hendrik (1863-1944)

Belgian-born US chemist. He invented Bakelite, the first commercial plastic, made from formaldehyde (methanal) and phenol. He also made a photographic paper, Velox, which could be developed in artificial light.

Baikonur

or Baykonur; formerly Tyuratam and Leninsk

site of the Baikonur Cosmodrome in Kazakhstan.

Officially known as Tyuratam until the mid-1990s, the town has been known by several names, including Zarya, Leninsk, and Zvezdograd, to add to the confusion of the location of the Baikonur Cosmodrome. However, it was renamed Baikonur by Russian president Boris Yeltsin in 1996, ending decades of confusion.

Baikonur Cosmodrome

or Baykonur Cosmodrome

launch site for spacecraft, located near Baikonur (formerly Tyuratam and Leninsk), Kazakhstan, near the Aral Sea. It was built in 1955. The first Soviet satellites and all Soviet (later Russian) space probes, as well as crewed *Soyuz* missions, were launched from here. In July 2000 the *Zvezda* module for the *International*

Space Station (*ISS*) was sent into orbit from Baikonur. Following NASA's suspension of shuttle flights after the 2003 *Columbia* space shuttle disaster, later flights to the *ISS* have been launched from Baikonur. The cosmodrome, which Russia now rents from Kazakhstan, is the world's largest space launching facility. It covers an area of 12,200 sq km/4,700 sq mi, much larger than its US equivalent, the Kennedy Space Center in Florida. This includes dozens of launching pads, five tracking control centres, nine tracking stations, and a rocket test range. On 11 May 2002, a hangar used to assemble and test space vehicles collapsed, killing eight people.

Baikonur Cosmodrome

Go to site

In-depth and illustrated accounts of the history of the Baikonur launch centre, with detailed information on the Energiya-*Buran* and *Soyuz* facilities, launch sites, and control station at Baikonur. There is also information on, as well as photographs of, the town of Baikonur (formerly Tyuratam).

Bailey, David (1938-)

English fashion photographer. His work for *Vogue* magazine in the 1960s and his black-and-white portraits of fashionable celebrities did much to define the image of 'swinging London'. He has also directed documentaries and commercials for television. His books include *Box of Pin-ups* (1965) and *Goodbye Baby and Amen* (1969).

Bailey began directing and producing television commercials in the mid-1960s, and turned to producing television documentaries in the late 1960s. His documentaries include *Beaton by Bailey* (1971), *Andy Warhol* (1973), and *Who Dealt?* (1993). A major show of Bailey's work was held in London's Barbican Art Gallery in 1999.

Baily's beads

bright spots of sunlight seen around the edge of the Moon for a few seconds immediately before and after a total eclipse of the Sun, caused by sunlight shining between mountains at the Moon's edge. Sometimes one bead is much brighter than the others, producing the so-called **diamond ring** effect. The effect was described in 1836 by the English astronomer Francis Baily, a wealthy stockbroker who retired in 1825 to devote himself to astronomy.

Baird, John Logie (1888-1946)

Scottish electrical engineer who pioneered television. In 1925 he gave the first public demonstration of television, transmitting an image of a recognizable human face. The following year, he gave the world's first demonstration of true television before an audience of about 50 scientists at the Royal Institution, London. By 1928 Baird had succeeded in demonstrating colour television.

Baird used a mechanical scanner which temporarily changed an image into a sequence of electronic signals that could then be reconstructed on a screen as a pattern of half-tones. The neon discharge lamp Baird used offered a simple means for the electrical modulation of light at the receiver. His first pictures were formed of only 30 lines repeated approximately 10 times a second. The results were crude but it was the start of television as a practical technology.

By 1927, Baird had transmitted television over 700 km/435 mi of telephone line between London and Glasgow and soon after made the first television broadcast using radio, between London and the SS *Berengaria* , halfway across the Atlantic Ocean. He also made the first transatlantic television broadcast between Britain and the USA when signals transmitted from the Baird station in Coulson, Kent, were picked up by a receiver in Hartsdale, New York.

Baird's black-and-white system was used by the BBC in an experimental television service in 1929. In 1936, when the public television service was started, his system was threatened by one promoted by Marconi-EMI. The following year the Baird system was dropped in favour of the Marconi electronic system, which gave a better definition.

Bakelite

first synthetic plastic, created by Belgian-born US chemist Leo Baekeland in 1909. Bakelite is hard, tough, and heatproof, and is used as an electrical insulator. It is made by the reaction of phenol with methanal (formaldehyde), producing a powdery resin that sets solid when heated. Objects are made by subjecting the resin to compression moulding (simultaneous heat and pressure in a mould).

It is one of the thermosetting plastics, which do not remelt when heated, and is often used for electrical fittings.

baking powder

mixture of bicarbonate of soda, an acidic compound, and a nonreactive filler (usually starch or calcium sulphate), used in baking as a raising agent. It gives a light open texture to cakes and scones, and is used as a substitute for yeast in making soda bread.

Several different acidic compounds (for example, tartaric acid, cream of tartar, sodium or calcium acid phosphates, and glucono-delta-lactone) may be used, any of which will react with the sodium hydrogencarbonate, in the presence of water and heat, to release the carbon dioxide that causes the cake mix or dough to rise.

balance

apparatus for weighing or measuring mass. The various types include the **beam balance**, consisting of a centrally pivoted lever with pans hanging from each end, and the **spring balance**, in which the object to be weighed stretches (or compresses) a vertical coil spring fitted with a pointer that indicates the weight on a scale. Kitchen and bathroom scales are balances.

balance of nature

in ecology, the idea that there is an inherent equilibrium in most ecosystems, with plants and animals interacting so as to produce a stable, continuing system of life on Earth. The activities of human beings can, and frequently do, disrupt the balance of nature.

In general, organisms in the ecosystem are adapted to each other – for example, waste products produced by one species are used by another, and resources used by some are replenished by others; the oxygen needed by animals is produced by plants while the waste product of animal respiration, carbon dioxide, is used by plants as a raw material in photosynthesis. The nitrogen cycle, the water cycle, and the control of animal populations by natural predators are other examples.

baldness

loss of hair from the scalp, common in older men. Its onset and extent are influenced by genetic make-up and the level of male sex hormones. There is no cure, and expedients such as hair implants may have no lasting effect. Hair loss in both sexes may also occur as a result of ill health or radiation treatment, such as for cancer. Alopecia, a condition in which the hair falls out in patches, is different from the 'male-pattern baldness' described above.

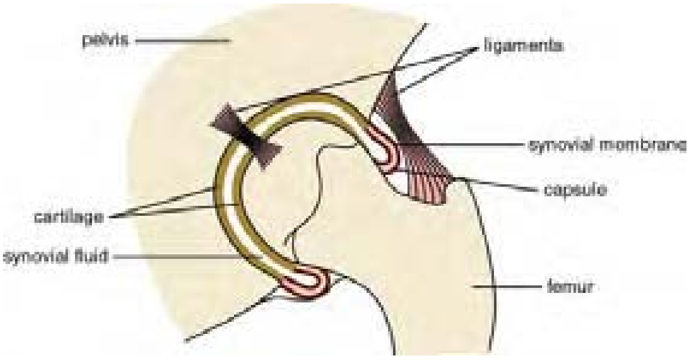
baldness

The best way for a man to know whether he will go bald is to look at his mother's father. Baldness is hereditary, but the gene controlling it is on the sex-linked chromosome and skips one generation.

ball-and-socket joint

joint between bones that allows considerable movement in three dimensions, for instance the joint between the pelvis and the femur (hip joint). To facilitate movement, such joints are rimmed with cartilage and lubricated by synovial fluid. The bones are kept in place by ligaments and moved by muscles.

ball-and-socket joint



(Image © Research Machines plc)

The hip joint is an example of a ball-and-socket joint.

ballistics

study of the motion and impact of projectiles such as bullets, bombs, and missiles. For projectiles from a gun, relevant exterior factors include temperature, barometric pressure, and wind strength; and for nuclear missiles these extend to such factors as the speed at which the Earth turns.

balloon

lighter-than-air craft that consists of a gasbag filled with gas lighter than the surrounding air and an attached basket, or gondola, for carrying passengers and/or instruments. In 1783, the first successful human ascent was in Paris, in a hot-air balloon designed by the Montgolfier brothers Joseph Michel and Jacques Etienne. In 1785, a hydrogen-filled balloon designed by French physicist Jacques Charles travelled across the English Channel.

During the French Revolution balloons were used for observation; in World War I they were used by all sides as aerial observation posts for artillery spotters and as a form of air defence; in World War II they were used to defend London, England, against low-flying aircraft. They are now used for recreation and advertising, and as a means of meteorological, infrared, gamma-ray, and ultraviolet observation. The first transatlantic crossing by balloon was made in 1978 by a US team. In the late 1990s, NASA developed an Ultra-Long Duration Balloon to circle the Earth at the edge of space, but initial test flights in 2001 were unsuccessful.

balloon

(Image © Research Machines plc)

Hot air ballooning is a sport enjoyed by tens of thousands of people worldwide. The safest times to fly are early in the morning or in the evening just before sunset, when the sun is low in the sky and the wind is calm.

Balloon Development Overview

Go to site

Balloon research at the Jet Propulsion Laboratory, including background material on balloons and how they work. There are pages dedicated to the exploration of Mars, Venus, and the outer planets with sensors suspended from balloons.

ball valve

valve that works by the action of external pressure raising a ball and thereby opening a hole.

balm, lemon

garden herb, see lemon balm.

balsam

any of various garden plants belonging to the balsam family. They are usually annuals with spurred red or white flowers and pods that burst and scatter their seeds when ripe. (Genus *Impatiens*, family Balsaminaceae.)

In medicine and perfumery, balsam refers to various oily or gummy aromatic plant resins, such as balsam of Peru from the Central American tree *Myroxylon pereirae*.

bamboo

any of a large group of giant grass plants, found mainly in tropical and subtropical regions. Some species grow as tall as 36 m/120 ft. The stems are hollow and jointed and can be used in furniture, house, and boat construction. The young shoots are edible; paper is made from the stems. (Genus *Bambusa*, family Gramineae.)

Bamboos flower and seed only once before the plant dies, sometimes after growing for as long as 120 years.

American Bamboo Society World Wide Web Page

Go to site

Good central source of information about bamboo. There is much information about different giant grasses, their decorative and practical uses, how to grow them, and keep them healthy. Though the site provider is primarily a horticultural organization, the contents also include information on how to make a variety of objects from bamboo, news of conservation projects, and further written and online sources of information about bamboo.

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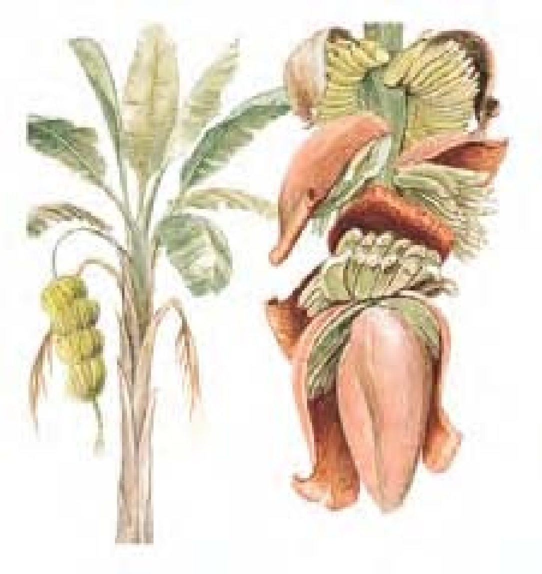
banana

any of several treelike tropical plants which grow up to 8 m/25 ft high. The edible banana is the fruit of a sterile hybrid form. (Genus *Musa*, family Musaceae.)

The curved yellow fruits of the commercial banana, arranged in clusters known as 'hands', form cylindrical masses of a hundred or more fruits.

They are picked and exported green and ripened aboard refrigerated ships. The plant is destroyed after cropping. The **plantain**, a larger, coarser hybrid variety that is used green as a cooked vegetable, is a dietary staple in many countries. In the wild, bananas depend on bats for pollination.

banana



(Image © Research Machines plc)

The banana plant grows as a series of suckers from a rhizome. Each stem gradually droops downwards and produces at its tip the male flowers, which are sterile. The female flowers, which produce the edible fruit without fertilization, are found further along the stem. After a stem has produced a crop of fruit, it dies and is replaced by a new stem from a bud further along the rhizome. A banana plant may live for over 60 years.

bananas

(Image © Corel)

Bananas ripening in the sun, Jamaica. Bananas were first imported to Jamaica from the Canary Islands by the Spanish. The industry flourished from the late 19th century until the 1930s, when the crops were struck by banana blight, which all but destroyed the Jamaican economy.

banana

(Image © Research Machines plc)

Bananas grown for export, such as these ones in the Seychelles, are cut when still green and ripened during the voyage. Although it resembles a tree, the banana is in fact a giant perennial herb. Cultivated bananas are grown in all the tropical regions of the world. They produce a higher crop yield per acre than potatoes.

Exotic Varieties Add to Popularity of America's Favourite Fruit

Go to site

Comprehensive article on the banana, with more- or less-known facts about this tropical and most popular fruit. It includes exhaustive nutritional information, and extended presentation of the properties and cooking of several 'Boutique bananas', that is, a series of uncommon kinds of bananas from all over the world.

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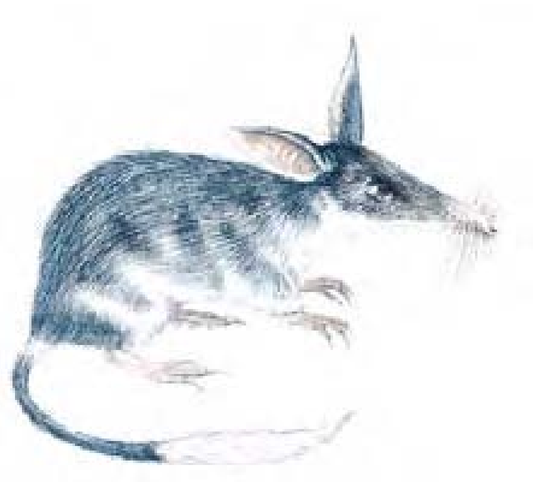
bandicoot

small marsupial mammal inhabiting Australia and New Guinea. There are about 11 species, family Peramelidae. Bandicoots are rat- or rabbit-sized and live in burrows. They have long snouts, eat insects, and are nocturnal. A related group, the rabbit bandicoots or bilbies, is reduced to a single species that is now endangered and protected by law.

bandicoot



(Image © Research Machines plc)

The rabbit bandicoot or bilby is the single surviving species of its family, Thylacomyidae. It lives in the arid scrubland of central and NW Australia. Sleeping in its burrow during the heat of the day, it emerges at night to feed on termites and beetle larvae.

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bandy-bandy

venomous Australian snake *Vermicella annulata* of the cobra family, which grows to about 75 cm/2.5 ft. It is banded in black and white. It is not aggressive toward humans.

Banks, Joseph (1743-1820)

English naturalist and explorer. In the position of naturalist, he accompanied Captain James Cook on an expedition from 1768 to 1771 to the southern hemisphere in the *Endeavour*, and brought back 3,600 plants, a large proportion of which had not been classified previously. The *Banksia* genus of shrubs is named after him.

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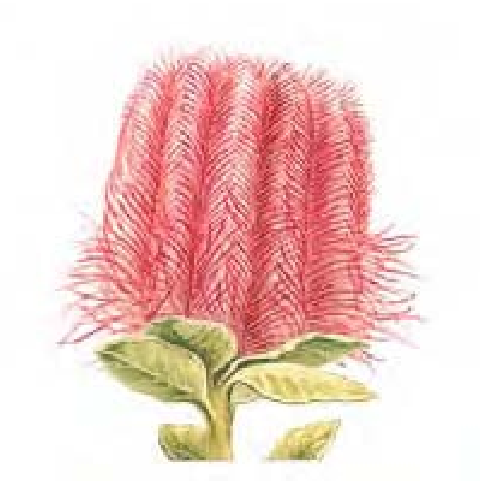
banksia

any shrub or tree of a group native to Australia, including the honeysuckle tree. They are named after the English naturalist and explorer Joseph Banks. (Genus *Banksia*, family Proteaceae.)

Banksias have spiny evergreen leaves and large flower spikes, made up of about 1,000 individual flowers formed around a central axis. The colours of the flower spikes can be gold, red, brown, purple, greenish-yellow, and grey.

banksia



(Image © Research Machines plc)

Banksias vary from prostrate shrubs to large trees, but have in common a large flower spike made up of about 1,000 individual flowers formed around a central axis.

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bantam

small ornamental variety of domestic chicken weighing about 0.5-1 kg/1-2 lb. Bantams can either be a small version of one of the larger breeds, or a separate type. Some are prolific egg layers. Bantam cocks have a reputation as spirited fighters.

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banteng

wild species of cattle *Bos banteng*, now scarce, but formerly ranging from Myanmar (Burma) through Southeast Asia to Malaysia and Java, inhabiting hilly forests. Its colour varies from pale brown to blue-black, usually with white stockings and rump patch, and it is up to 1.5 m/5 ft at the shoulder.

Banting, Frederick Grant (1891-1941)

Canadian physician who was awarded a Nobel Prize for Physiology or Medicine in 1923 for his discovery, in 1921, of a technique for isolating the hormone insulin. Banting and his colleague Charles Best tied off the ducts of the pancreas to determine the function of the cells known as the islets of Langerhans and thus made possible the treatment of diabetes. John J R Macleod, Banting's mentor, shared the prize, and Banting divided his prize with Best.

Banting, Sir Frederick Grant

Go to site

Profile of the life and career of the Nobel laureate. It traces his childhood, early interest in divinity, developing interest in diabetes, and his death in a plane crash. There is also a picture of Banting.

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banyan

tropical Asian fig tree. It produces aerial roots that grow down from its spreading branches, forming supporting pillars that look like separate trunks. (*Ficus benghalensis*, family Moraceae.)

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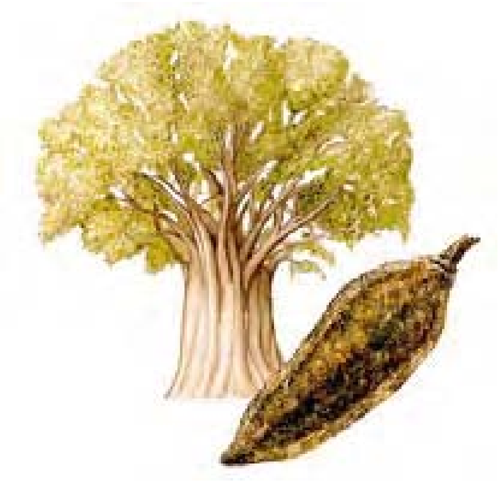
baobab

tree with rootlike branches, hence the nickname 'upside-down tree', and a disproportionately thick girth, up to 9 m/30 ft in diameter. The pulp of its fruit is edible and is known as monkey bread. (Genus *Adansonia*, family Bombacaceae.)

baobab



(Image © Research Machines plc)

The Australian baobab, or gourd tree, grows in NW Australia. It has edible seeds, and the massive trunk is used as a source of water by animals and Aborigines.

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bar

in physics, unit of pressure equal to 10^5 pascals or 10^6 dynes/cm^2, approximately 750 mmHg or 0.987 atm. Its diminutive, the **millibar** (one-thousandth of a bar), is commonly used by meteorologists.

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barb

general name for fish of the genus *Barbus* and some related genera of the family Cyprinidae. As well as the barbel, barbs include many small tropical Old World species, some of which are familiar aquarium species. They are active egg-laying species, usually of 'typical' fish shape and with barbels at the corner of the mouth.

Barbary ape

tailless, yellowish-brown macaque monkey *Macaca sylvanus*, 55–75 cm/20–30 in long. Barbary apes are found in the mountains and wilds of Algeria and Morocco, especially in the forests of the Atlas Mountains. They were introduced to Gibraltar, where legend has it that the British will leave if the ape colony dies out.

The macaque is threatened by illegal logging, which is devastating some of the ancient forests in the area. Although it is breeding well in captivity, forest loss may confound attempts to reintroduce this species into the wild.

Barbary sheep

or aoudad or udad

species of bovid related to the goat and sheep. It has powerful horns and a goatlike odour, but is distinguished from goats by its longer tail and the mane of long hair on the throat and upper parts of the forelegs. It is found in North Africa and parts of the Sudan.

classification

The Barbary sheep *Ammotragus lervia* is in family Bovidae, order Artiodactyla.

barbastelle

insect-eating bat *Barbastella barbastellus* with hairy cheeks and lips, 'frosted' black fur, and a wingspan of about 25 cm/10 in. It lives in hollow trees and under roofs, and is occasionally found in the UK but more commonly in Europe.

barberry

any spiny shrub belonging to the barberry family, with sour red berries and yellow flowers. These shrubs are often used as hedges. (Genus *Berberis*, family Berberidaceae.)

Barberry, Common

Go to site

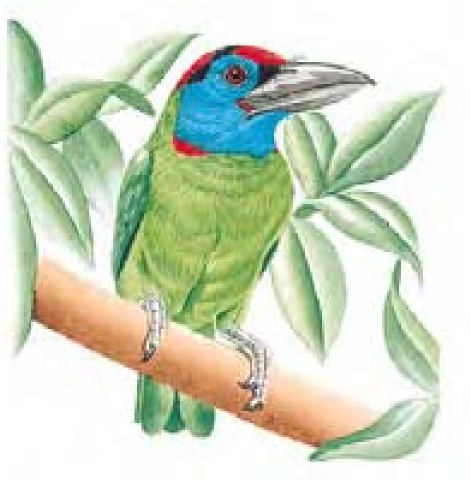
Large amount of information about the common barberry, including a detailed description of the plant and its habitat. There is an account of the history of the plant, as well as details of its constituents and cultivation. This site also features notes on the plant's medicinal uses, which include treating jaundice and diarrhoea. There are even a number of recipes which include barberries as a main ingredient.

barbet

(Latin barbatus, 'bearded')

small, tropical bird, often brightly coloured. There are about 78 species of barbet in the family Capitonidae, order Piciformes, common to tropical Africa, Asia, and America. Barbets eat insects and fruit and, being distant relations of woodpeckers, drill nest holes with their beaks. The name comes from the 'little beard' of bristles about the mouth that assists them in catching insects.

barbet



(Image © Research Machines plc)

The barbet digs nest holes in termite mounds and rotten tree-stumps with its large and often sharp-toothed beak. It may also take up residence in old woodpecker holes.

barbiturate

hypnosedative drug, commonly known as a 'sleeping pill', consisting of any salt or ester of barbituric acid $C_4H_4O_3N_2$. It works by depressing brain activity. Most barbiturates, being highly addictive, are no longer prescribed and are listed as controlled substances.

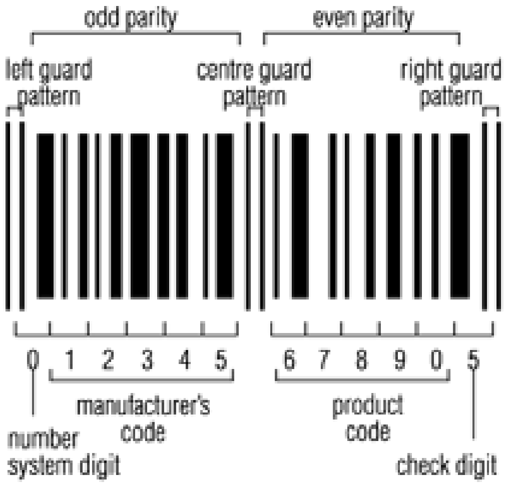
Tolerance develops quickly in the user so that increasingly large doses are required to induce sleep. A barbiturate's action persists for hours or days, and can cause confused, aggressive behaviour or disorientation. Overdosing causes death by inhibiting the breathing centre in the brain. Short-acting barbiturates are used as anaesthetics to induce general anaesthesia; slow-acting ones may be prescribed for epilepsy.

bar code

pattern of bars and spaces that can be read by a computer. Bar codes are widely used in retailing, industrial distribution, and libraries. The code is read by a scanning device; the computer determines the code from the widths of the bars and spaces.

The technique was patented in 1949 but became popular only in 1973, when the food industry in North America adopted the Universal Product Code system.

bar code



(Image © Research Machines plc)

The bars of varying thicknesses and spacings represent two series of numbers, identifying the manufacturer and the product. Two longer, thinner bars mark the beginning and end of the manufacturer and product codes. The bar code is used on most articles for sale in shops.

BarCode 1: A Web Of Information About Bar Code

Go to site

Everything you could want to know about bar codes. Among the many attractions are a comprehensive bar code 'Frequently Asked Questions' list, software directory, user forum, and a searchable database of bar code Web sites.

Bardeen, John (1908-1991)

US physicist. He was awarded the Nobel Prize for Physics in 1956, with Walter Brattain and William Shockley, for the development of the transistor in 1948 and he became the first double winner of the Nobel Prize for Physics in 1972 (with Leon Cooper and Robert Schrieffer) for his work on superconductivity.

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barium

chemical symbol Ba

(Greek barytes 'heavy')

soft, silver-white, metallic element, atomic number 56, relative atomic mass 137.33. It is one of the alkaline-earth metals, found in nature as barium carbonate and barium sulphate. As the sulphate it is used in medicine: taken as a suspension (a 'barium meal'), its movement along the gut is followed using X-rays. The barium sulphate, which is opaque to X-rays, shows the shape of the gut, revealing any abnormalities of the alimentary canal. Barium is also used in alloys, pigments, and safety matches and, with strontium, forms the emissive surface in cathode-ray tubes. It was first discovered in baryte or heavy spar.

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bark

protective outer layer on the stems and roots of woody plants, composed mainly of dead cells. To allow for expansion of the stem, the bark is continually added to from within, and the outer surface often becomes cracked or is shed as scales. Trees deposit a variety of chemicals in their bark, including poisons. Many of these chemical substances have economic value because they can be used in the manufacture of drugs. Quinine, derived from the bark of the *Cinchona* tree, is used to fight malarial infections; curare, an anaesthetic used in medicine, comes from the *Strychnus toxifera* tree in the Amazonian rainforest.

Bark technically includes all the tissues external to the vascular cambium (the phloem, cortex, and periderm), and its thickness may vary from 2.5 mm/0.1 in to 30 cm/12 in or more, as in the giant redwood *Sequoia* where it forms a thick, spongy layer.

---

bark beetle

any one of a number of species of mainly wood-boring beetles. Bark beetles are cylindrical, brown or black, and 1-9 mm/0.04-0.4 in long. Some live just under the bark and others bore deeper into the hardwood. The detailed tunnelling pattern that they make within the trunk varies with the species concerned, and is used for identification.

Most bark beetles live in forest trees; some, however, attack fruit trees. Generally, but not always, dead or dying timber is attacked. Some species transmit pathogens, for example, the fungus that causes Dutch elm disease.

Examples include the **birch bark beetle** *Scolytus ratzeburgi* and the **greater fruit-tree bark beetle** *S. meli*.

classification

Bark beetles are in the families Curculionidae or Scolytidae, order Coleoptera, class Insecta, phylum Arthropoda.

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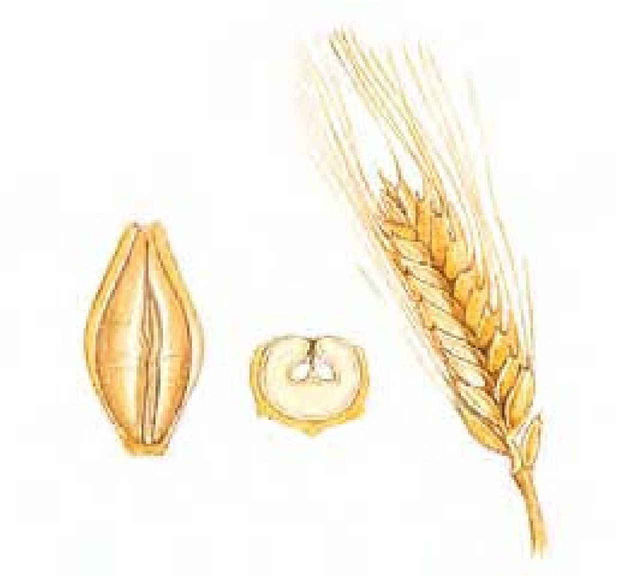
barley

cereal belonging to a family of grasses. It resembles wheat but is more tolerant of cold and draughts. Cultivated barley (*Hordeum vulgare*) comes in three main varieties – six-rowed, four-rowed, and two-rowed. (Family Gramineae.)

Barley was one of the earliest cereals to be cultivated, about 5000 BC in Egypt, and no other cereal can thrive in so wide a range of climatic conditions; polar barley is sown and reaped well within the Arctic Circle in Europe. Barley is no longer much used in bread making, but it is used in soups and stews and as a starch. Its high-protein form is widely used as animal feed, and its low-protein form is used in brewing and distilling alcoholic drinks.

barley



(Image © Research Machines plc)

Barley was first cultivated in Egypt about 5000 BC. The raw grain is enclosed in a tough husk. Pearl barley is produced in a revolving drum where the cereal is ground until the hull and germ are removed from the grains, leaving starchy balls or 'pearls'.

barley

(Image © Corel)

Ears of barley. Both hardy and versatile, barley can be grown successfully in temperate, subtropical, and subarctic climates. Barley was first cultivated in Egypt about 5000 BC. The raw grain is enclosed in a tough husk.

barley

(Image © Research Machines plc)

Barley can tolerate a greater range of climate conditions than any other cereal crop. It was first grown thousands of years ago in the temperate regions of the Middle East and is now an important crop in northern Europe. Malt obtained from the germinated grains is used in brewing beer and making whisky.

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barn

farm building traditionally used for the storage and processing of cereal crops and hay. On older farmsteads, the barn is usually the largest building. It is often characterized by ventilation openings rather than windows and has at least one set of big double doors for access. Before mechanization, wheat was threshed by hand on a specially prepared floor inside these doors.

Tithe barns were used in feudal England to store the produce paid as a tax to the parish priest by the local occupants of the land. In the Middle Ages, monasteries often controlled the collection of tithes over a wide area and, as a result, constructed some enormous tithe barns.

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barnacle

marine crustacean of the subclass Cirripedia. The larval form is free-swimming, but when mature, it fixes itself by the head to rock or floating wood. The animal then remains attached, enclosed in a shell through which the cirri (modified legs) protrude to sweep food into the mouth. Barnacles include the stalked **goose barnacle** *Lepas anatifera* found on ships' bottoms, and the **acorn barnacles**, such as *Balanus balanoides*, common on rocks.

barnacle

The parasitic barnacle *Loxothylacus panopaei* uses a crab as its host. The barnacle larva attaches itself to a crab and injects it with a squirming worm-shaped bag of cells. One of these cells develops into the adult barnacle that spends its life as a lump on the crab's carapace.

Barnard, Christiaan Neethling (1922-2001)

South African surgeon who performed the first human heart transplant in 1967 at Groote Schuur Hospital in Cape Town. The 54-year-old patient lived for 18 days.

Barnard also discovered that intestinal artresia – a congenital deformity in the form of a hole in the small intestine – is the result of an insufficient supply of blood to the fetus during pregnancy. It was a fatal defect before he developed the corrective surgery.

Barnard's star

star, 6 light years away from the Sun, in the constellation Ophiuchus. It is the second-closest star to the Sun, after Alpha Centauri, a triple star, the closest component of which, Proxima Centauri, is 4.2 light years away from the Sun. It is a faint red dwarf of 10th magnitude, visible only through a telescope. It is named after the US astronomer Edward E Barnard (1857-1923), who discovered in 1916 that it has the fastest proper motion (apparent angular motion across the sky) of any star, 10.3 arc seconds per year.

Some observations have suggested that Barnard's star may be accompanied by planets, but those observations are now doubted.

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barograph

device for recording variations in atmospheric pressure. A pen, governed by the movements of an aneroid barometer, makes a continuous line on a paper strip on a cylinder that rotates over a day or week to create a **barogram**, or permanent record of variations in atmospheric pressure. Some instruments record the measurements in the form of electronic data that can be readily processed by a computer.

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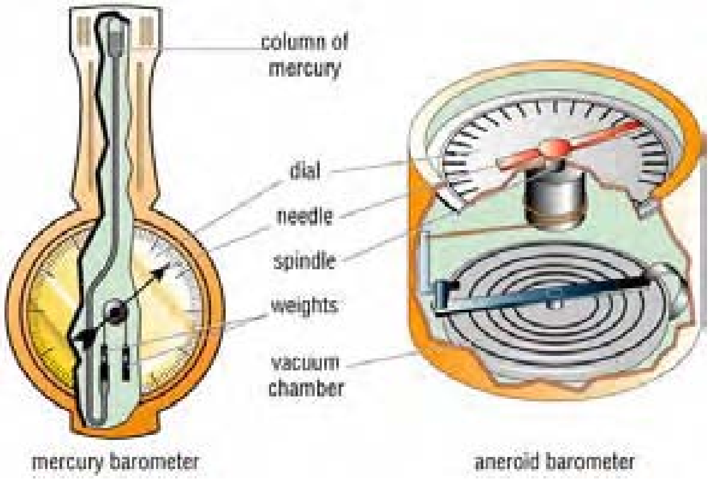
barometer

instrument that measures atmospheric pressure as an indication of weather. Most often used are the mercury barometer and the aneroid barometer.

In a mercury barometer a column of mercury in a glass tube, roughly 0.75 m/2.5 ft high (closed at one end, curved upwards at the other), is balanced by the pressure of the atmosphere on the open end; any change in the height of the column reflects a change in pressure. In an aneroid barometer, a shallow cylindrical metal box containing a partial vacuum expands or contracts in response to changes in pressure.

barometer



(Image © Research Machines plc)

The mercury barometer (left) and the aneroid barometer (right). In the mercury barometer, the weight of the column of mercury is balanced by the pressure of the atmosphere on the lower end. A change in height of the column indicates a change in atmospheric pressure. In the aneroid barometer, any change of atmospheric pressure causes the metal box which contains the vacuum to be squeezed or to expand slightly. The movements of the box sides are transferred to a pointer and scale via a chain of levers.

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baroreceptor

in biology, a specialized nerve ending that is sensitive to pressure. There are baroreceptors in various regions of the heart and circulatory system (carotid sinus, aortic arch, atria, pulmonary veins, and left ventricle). Increased pressure in these structures stimulates the baroreceptors, which relay information to the medulla providing an important mechanism in the control of blood pressure.

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barracuda

large predatory fish *Sphyraena barracuda* found in the warmer seas of the world. It can grow over 2 m/6 ft long and has a superficial resemblance to a pike. Young fish shoal, but the older ones are solitary. The barracuda has very sharp shearing teeth and may attack people.

barracuda

Barracudas are mysteriously attracted to all things yellow. This means that they may be caught by the use of yellow-feathered lines.

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barrel

a unit of liquid capacity, the value of which depends on the liquid being measured. It is used for petroleum, a barrel of which contains 159 litres/42 gallons; a barrel of alcohol contains 189 litres/49.9 gallons.

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barrier island

long island of sand, lying offshore and parallel to the coast.

Some are over 100 km/60 mi in length. Most barrier islands are derived from marine sands piled up by shallow longshore currents that sweep sand parallel to the seashore. Others are derived from former spits, connected to land and built up by drifted sand, that were later severed from the mainland.

Often several islands lie in a continuous row offshore. Coney Island and Jones Beach near New York City are well-known examples, as is Padre Island, Texas. The Frisian Islands are barrier islands along the coast of the Netherlands.

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barrier reef

coral reef that lies offshore, separated from the mainland by a shallow lagoon.

Barringer Crater

or Arizona Meteor Crater or Coon Butte

impact crater near Winslow in Arizona, caused by the impact of a 50-m/165-ft iron meteorite about 50,000 years ago. It is 1.2 km/0.7 mi in diameter and 200 m/660 ft deep, and the walls are raised 50–60 m/165–198 ft above the surrounding desert.

It is named after the US mining engineer Daniel Barringer who proposed in 1902 that it was an impact crater rather than a volcanic feature, an idea confirmed in the 1960s by US astronomer Eugene Shoemaker, who studied the crater for his doctoral research at the California Institute of Technology.

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barrow

(Old English beorgh 'hill or mound')

burial mound, usually composed of earth but sometimes of stones. Examples are found in many parts of the world. The two main types are **long**, dating from the Neolithic period (New Stone Age), and **round**, dating from the Mesolithic period (early Bronze Age). Barrows made entirely of stones are known as cairns.

long barrow

Long barrows may be mere mounds, typically higher and wider at one end. They usually contain a chamber of wood or stone slabs, or a turf-lined cavity, in which the body or bodies of the deceased were placed. Secondary chambers may be added in the sides of the mound. They are common in southern England from Sussex to Dorset. Earthen (or unchambered) long barrows belong to the early and middle Neolithic, whereas others, such as the Neolithic West Kennet barrow near Avebury, Wiltshire, were constructed over megalithic (great stone) tombs which generally served as collective burial chambers. The stones are arranged to form one, often large, chamber with a single entrance, and are buried under a mound of earth. The remains of these stone chambers, once their earth covering has disappeared, are known as **dolmens**, and in Wales as **cromlechs**.

round barrow

Round barrows belong mainly to the Bronze Age, although in historic times there are examples from the Roman period, and some of the Saxon and most of the Danish invaders were barrow-builders. In northern Europe, round barrows were sometimes built above a tree-trunk coffin in which waterlogged conditions have preserved nonskeletal material, such as those found in Denmark dating from around 1000 BC.

In Britain the most common type is the bell barrow, consisting of a circular mound enclosed by a ditch and an outside bank of earth. Other types include the bowl barrow, pond barrow, saucer barrow, ring barrow, and disc barrow, all of which are associated with the Wessex culture (early Bronze Age culture of southern England dating from approximately 2000–1500 BC). Many barrows dot the Wiltshire Downs in England.

Barrows from the Roman era, such as the Six Hills at Stevenage, Hertfordshire, and the Bartlow Hills at Ashdon, Essex, have a distinctive steep and conical outline, and in southeast Britain usually cover the graves of wealthy merchant traders. They are also found in Belgic Gaul, where the traders had commercial links. Not all burials in the Roman era were in barrows; cemeteries were also used.

The Saxons buried the remains of important chieftains in large conical barrows, such as Taeppa's law which gives its name to Taplow, Buckinghamshire, but clusters of small burial mounds are more commonly found. Many examples of these graves of ordinary people are found in east Kent.

In eastern European and Asiatic areas where mobility was afforded by the horse and wagon, a new culture developed of pit graves marked by a *kurgan*, or round mound, in which a single body lay, often accompanied by grave goods which might include a wagon. These date from around 3000 BC.

boat burial

The placing of a great person's body in a ship is seen in Viking burials, such as the Oseberg ship in Norway, which was buried and sealed around AD 800. Barrows were erected over boat burials during the Saxon period, and the Sutton Hoo boat burial excavated in Suffolk during 1938–39 was that of an East Anglian king of Saxon times.

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baryon

in nuclear physics, a heavy subatomic particle made up of three indivisible elementary particles called quarks. The baryons form a subclass of the hadrons and comprise the nucleons (protons and neutrons) and hyperons.

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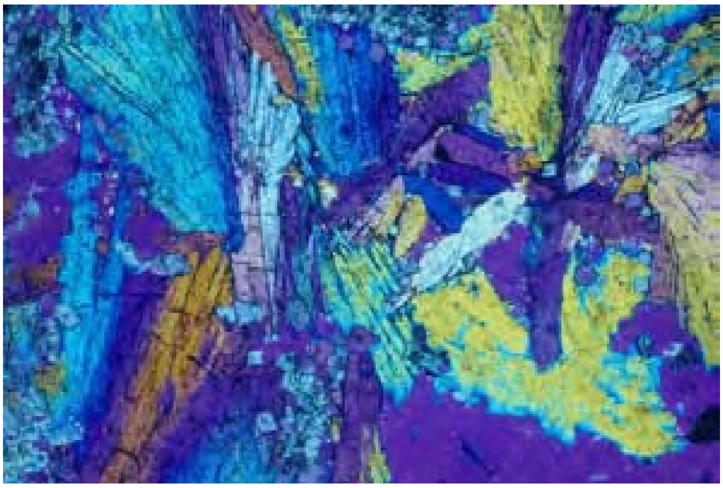
baryte

barium sulphate, $BaSO_4$, the most common mineral of barium. It is white or light-coloured, and has a comparatively high density (specific gravity 4.6); the latter property makes it useful in the production of high-density drilling muds (muds used to cool and lubricate drilling equipment). Baryte occurs mainly in ore veins, where it is often found with calcite and with lead and zinc minerals. It crystallizes in the orthorhombic system and can form tabular crystals or radiating fibrous masses.

baryte



(Image © Corel)

The mineral baryte through a polarized microscope. Baryte forms in hydrothermal veins and in the vicinity of hot springs.

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basal metabolic rate

BMR

minimum amount of energy needed by the body to maintain life. It is measured when the subject is awake but resting, and includes the energy required to keep the heart beating, sustain breathing, repair tissues, and keep the brain and nerves functioning. The rate varies depending on the height, weight, age, and activity of the person. Measuring the subject's consumption of oxygen gives an accurate value for BMR, because oxygen is needed to release energy from food.

A cruder measure of BMR estimates the amount of heat given off, some heat being released when food is used up. BMR varies from one species to another, and from males to females. In humans, it is highest in children and declines with age. Disease, including mental illness, can make it rise or fall. Hormones from the thyroid gland control the BMR.

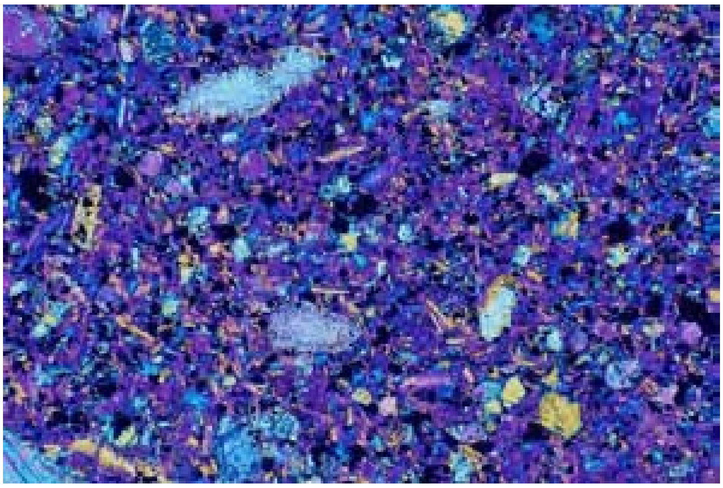
basalt

commonest volcanic igneous rock in the Solar System. Basalt is an extrusive rock, created by the outpouring of volcanic magma. The magma cools quickly, allowing only small crystals to form. Much of the surfaces of the terrestrial planets Mercury, Venus, Earth, and Mars, as well as the Moon, are composed of basalt. Earth's ocean floor is virtually entirely made of basalt. Basalt is mafic, that is, it contains relatively little silica: about 50% by weight. It is usually dark grey but can also be green, brown, or black. Its essential constituent minerals are calcium-rich feldspar, and calcium- and magnesium-rich pyroxene.

The groundmass may be glassy or finely crystalline, sometimes with large crystals embedded. Basaltic lava tends to be runny and flows for great distances before solidifying. Successive eruptions of basalt have formed the great plateaus of Colorado and the Deccan plateau region of southwest India. In some places, such as Fingal's Cave in the Inner Hebrides of Scotland and the Giant's Causeway in Antrim, Northern Ireland, shrinkage during the solidification of the molten lava caused the formation of hexagonal columns.

The dark-coloured lowland maria regions of the Moon are underlain by basalt. Lunar mare basalts have higher concentrations of titanium and zirconium and lower concentrations of volatile elements like potassium and sodium relative to terrestrial basalts. Martian basalts are characterized by low ratios of iron to manganese relative to terrestrial basalts, as judged from some Martian meteorites (shergottites, a class of the **SNC** meteorites) and spacecraft analyses of rocks and soils on the Martian surface.

basalt



(Image © Corel)

Basalt rock through a polarized microscope. Basalt is formed from solidified lava.

basalt

(Image © Garret Nagle)

Basalt formations by the beach at Vik, in southern Iceland. Basalt is a hard, igneous rock, formed by the rapid cooling of magma as it comes in contact with air. These hexagonal columns are typical of basalt.

basalt

(Image © Garret Nagle)

Columns of basalt at the coastal resort of Vik, in southern Iceland. These angular formations of igneous rock are created during cooling when contraction of the material produces joints which form a hexagonal pattern. Another example of such basalt formations is the Giant's Causeway in Northern Ireland.

bascule bridge

type of drawbridge in which one or two counterweighted deck members pivot upwards to allow shipping to pass underneath. One example is the double bascule Tower Bridge, London.

base

in chemistry, a substance that accepts hydrogen ions, or protons. A base reacts with an acid, neutralizing it to form a salt: acid + base → salt + water. Metal oxides and metal hydroxides are bases; examples include copper oxide and sodium hydroxide. Bases can contain negative ions such as the hydroxide ion (OH^-), which is the strongest base, or be molecules such as ammonia (NH_3). Ammonia is a weak base, as only some of its molecules accept protons.

$OH^- + H^+_{(aq)} \rightarrow H_2O_{(l)}$

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

Bases that dissolve in water are called alkalis.

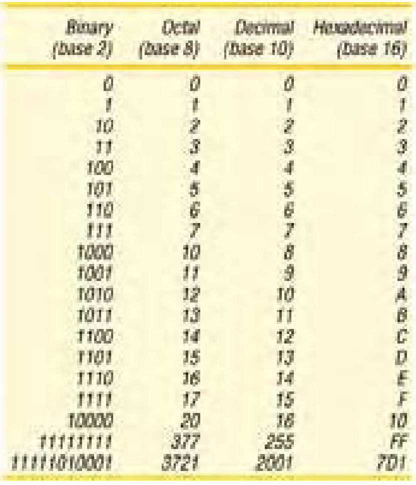
Inorganic bases are usually oxides or hydroxides of metals, which react with dilute acids to form a salt and water. Many carbonates also react with dilute acids, additionally giving off carbon dioxide.

base

in mathematics, the number of different single-digit symbols used in a particular number system. In our usual (decimal) counting system of numbers (with symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, 9) the base is 10. In the binary number system, which has only the symbols 1 and 0, the base is two. A base is also a number that, when raised to a particular power (that is, when multiplied by itself a particular number of times as in $10^2 = 10 \times 10 = 100$), has a logarithm equal to the power. For example, the logarithm of 100 to the base ten is 2.

In geometry, the term is used to denote the line or area on which a polygon or solid stands.

base



Binary (base 2)	Octal (base 8)	Decimal (base 10)	Hexadecimal (base 16)
0	0	0	0
1	1	1	1
10	2	2	2
11	3	3	3
100	4	4	4
101	5	5	5
110	6	6	6
111	7	7	7
1000	10	8	8
1001	11	9	9
1010	12	10	A
1011	13	11	B
1100	14	12	C
1101	15	13	D
1110	16	14	E
1111	17	15	F
10000	20	16	10
11111111	377	255	FF
11111010001	3721	2001	7D1

(Image © Research Machines plc)

Four different numerical systems showing the numbers 1-16, with so, some examples of greater numbers. In the hexadecimal (base 16) system, all numbers up to 15 must be represented by a single character. To achieve this the decimal values 10-15 are represented by the letters A-F.

Number systems

Binary (Base 2)	Octal (Base 8)	Decimal (Base 10)	Hexadecimal (Base 16)
0	0	0	0
1	1	1	1
10	2	2	2
11	3	3	3
100	4	4	4
101	5	5	5
110	6	6	6
111	7	7	7
1000	10	8	8
1001	11	9	9
1010	12	10	A
1011	13	11	B
1100	14	12	C
1101	15	13	D
1110	16	14	E
1111	17	15	F
10000	20	16	10
11111111	377	255	FF
11111010001	3721	2001	7D1

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basenji

breed of dog originating in Central Africa, where it is used for hunting. About 41 cm/16 in tall, it has pointed ears, curled tail, and short glossy coat of black or red, often with white markings. It is remarkable because it has no true bark.

---

base pair

in biochemistry, the linkage of two base (purine or pyrimidine) molecules that join the complementary strands of DNA. Adenine forms a base pair with thymine (or uracil in RNA) and cytosine pairs with guanine in a double-stranded nucleic acid molecule.

One base lies on one strand of the DNA double helix and one on the other, so that the base pairs link the two strands like the rungs of a ladder. In DNA, there are four bases: adenine and guanine (purines) and cytosine and thymine (pyrimidines). Adenine always pairs with thymine and cytosine with guanine.

The sizes of genes and genomes are commonly cited in base pairs, for example the human genome consists of around 3 billion base pairs.

BASIC

acronym for Beginner's All-purpose Symbolic Instruction Code

high-level computer-programming language, developed in 1964, originally designed to take advantage of multiuser systems (which can be used by many people at the same time). The language is relatively easy to learn and is popular among microcomputer users.

Most versions make use of an interpreter, which translates BASIC into machine code and allows programs to be entered and run with no intermediate translation. Some more recent versions of BASIC allow a compiler to be used for this process.

BASIC Archives

Go to site

Detailed guide to this computer-programming language. This site includes an informative 'Frequently Asked Questions', giving tips on such topics as 'how to print graphics with BASIC', 'how to display a BMP or GIF file', and 'how to make an EXE file'. There is also a brief history of the development of BASIC and a number of links to related sites.

basicity

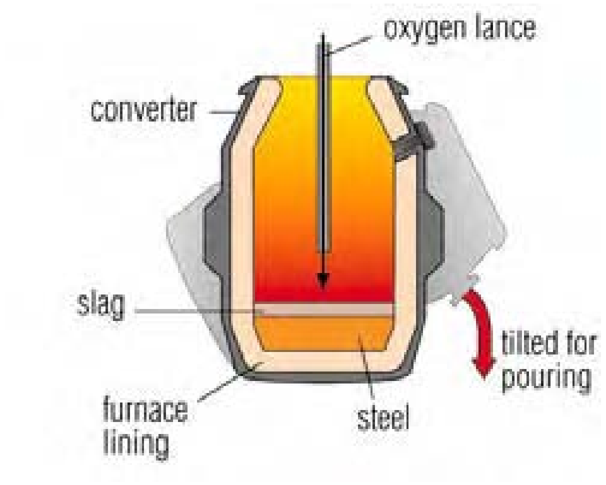
number of replaceable hydrogen atoms in an acid. Nitric acid (HNO_3) is monobasic, sulphuric acid (H_2SO_4) is dibasic, and phosphoric acid (H_3PO_4) is tribasic.

basic-oxygen process

most widely used method of steelmaking, involving the blasting of oxygen at high pressure into molten pig iron.

Pig iron from a blast furnace, together with steel scrap, is poured into a converter, and a jet of oxygen is then projected into the mixture. The excess carbon in the mix and other impurities quickly burn out or form a slag, and the converter is emptied by tilting. It takes only about 45 minutes to refine 350 tonnes/400 tons of steel. The basic-oxygen process was developed 1948 at a steelworks near the Austrian towns of Linz and Donawitz. It is a version of the Bessemer process.

basic-oxygen process



(Image © Research Machines plc)

In the basic-oxygen process oxygen is blown at high pressure through molten pig iron and scrap steel in a converter lined with basic refractory materials. The impurities, principally carbon, quickly burn out, producing steel.

basidiocarp

spore-bearing body, or 'fruiting body', of all basidiomycete fungi (see fungus), except the rusts and smuts. A well known example is the edible mushroom *Agaricus brunnescens*. Other types include globular basidiocarps (puffballs) or flat ones that project from tree trunks (brackets). They are made up of a mass of tightly packed, intermeshed hyphae.

The tips of these hyphae develop into the reproductive cells, or **basidia**, that form a fertile layer known as the hymenium, or **gills**, of the basidiocarp. Four spores are budded off from the surface of each basidium.

basil

or sweet basil

plant with aromatic leaves, belonging to the mint family. A native of the tropics, it is cultivated in Europe as a herb and used to flavour food. Its small white flowers appear on spikes. (Genus *Ocimum basilicum*, family Labiatae.)

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basilisk

Central and South American lizard, genus *Basiliscus*. It is about 50 cm/20 in long and weighs about 90 g/0.2 lb. Its rapid speed (more than 2 m/6.6 ft per second) and the formation of air pockets around the feet enable it to run short distances across the surface of water. The male has a well-developed crest on the head, body, and tail.

---

bass

long-bodied scaly sea fish *Morone labrax* found in the North Atlantic and Mediterranean. They grow to 1 m/3 ft, and are often seen in shoals.

Other fish of the same family (Serranidae) are also called bass, as are North American freshwater fishes of the family Centrarchidae, such as black bass and small-mouthed bass.

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basset

any of several breeds of hound with a long low body and long pendulous ears, of a type originally bred in France for hunting hares by scent.

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bat

any mammal of the order Chiroptera, related to the Insectivora (hedgehogs and shrews), but differing from them in being able to fly. Bats are the only true flying mammals. Their forelimbs are developed as wings capable of rapid and sustained flight. There are two main groups of bats: **megabats**, which eat fruit, and **microbats**, which mainly eat insects. Bats are nocturnal, and those native to temperate countries hibernate in winter. There are about 977 species forming the order Chiroptera, making this the second-largest mammalian order; bats make up nearly one-quarter of the world's mammals. Although bats are widely distributed, populations have declined alarmingly and many species are now endangered.

megabats

The Megachiroptera live in the tropical regions of the Old World, Australia, and the Pacific, and feed on fruit, nectar, and pollen. The hind feet have five toes with sharp hooked claws from which the animal suspends, head downwards, when resting. There are 162 species of Megachiroptera. Relatively large, weighing up to 900 g/2 lb and with a wingspan as great as 1.5 m/5 ft, they have large eyes and a long face, earning them the name 'flying fox'. Most navigate by sight.

microbats

Most bats are Microchiroptera: small and insect-eating. Some eat fish as well as insects; others consume small rodents, frogs, lizards, or birds; a few, vampire bats, feed on the blood of mammals. A single bat may eat 3,000 insects in one night. There are about 750 species. They roost in caves, crevices, and hollow trees. The bumblebee bat, inhabiting Southeast Asian rainforests, is the smallest mammal in the world. A new species of bat, *Rhinolophus convexus*, was discovered in Malaysia, at an altitude of 1,600 m in the Cameron Highlands, in 1997. It is related to the tropical horsehoe bats. In December 2001, a new bat species was discovered in Greece. It is a whiskered bat, species *Myotis*, and is the smallest of the species.

Many microbats have poor sight and orientation and hunt their prey principally by echolocation. They have relatively large ears and many have nose-leaves, fleshy appendages around the nose and mouth, that probably help in sending or receiving the signals, which are squeaks pitched so high as to be inaudible to the human ear.

bat

The pipistrelle, which weighs about as much as a two pence piece, can eat up to 3,000 midges in a night.

Bat Conservation International

Go to site

Articles, photographs, and miscellaneous bat trivia, plus sound files of bat echolocation signals. As well as promoting membership of their bat society, this page contains plenty of bat-related information, including US and European species' lists and tips on photographing these elusive animals.

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batch processing

in computing, system for processing data with little or no operator intervention. Batches of data are prepared in advance to be processed during regular 'runs' (for example, each night). This allows efficient use of the computer and is well suited to applications of a repetitive nature, such bulk file format conversion, as a company payroll, or the production of utility bills.

In **interactive computing**, by contrast, data and instructions are entered while the processing program is running.

Bates, H(enry) W(alter) (1825-1892)

English naturalist and explorer. He spent 11 years collecting animals and plants in South America and identified 8,000 new species of insects. He made a special study of camouflage in animals, and his observation of insect imitation of species that are unpleasant to predators is known as 'Batesian mimicry'.

Bates eyesight training

method developed by US ophthalmologist William Bates (1860-1931) to enable people to correct problems of vision without wearing glasses. The method is of proven effectiveness in relieving all refractive conditions, correcting squints, lazy eyes, and similar problems, but does not claim to treat eye disease.

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batholith

large, irregular, deep-seated mass of intrusive igneous rock, usually granite, with an exposed surface of more than 100 sq km/40 sq mi. The mass forms by the intrusion or upswelling of magma (molten rock) through the surrounding rock. Batholiths form the core of some large mountain ranges like the Sierra Nevada of western North America.

According to plate tectonic theory, magma rises in subduction zones along continental margins where one plate sinks beneath another. The solidified magma becomes the central axis of a rising mountain range, resulting in the deformation (folding and overthrusting) of rocks on either side. Gravity measurements indicate that the downward extent or thickness of many batholiths is some 10-15 km/6-9 mi.

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bathyal zone

upper part of the ocean, which lies on the continental shelf at a depth of between 200 m/650 ft and 2,000 m/6,500 ft.

Bathyal zones (both temperate and tropical) have greater biodiversity than coral reefs, according to a 1995 study by the Natural History Museum in London. Maximum biodiversity occurs between 1,000 m/3,280 ft and 3,000 m/9,800 ft.

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bathyscaph

or bathyscaphe or bathyscape

deep-sea diving apparatus used for exploration at great depths in the ocean. In 1960, Jacques Piccard and Don Walsh took the bathyscaph *Trieste* to a depth of 10,917 m/35,820 ft in the Challenger Deep in the Mariana Trench off the island of Guam in the Pacific Ocean.

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battery

any chemical energy-storage device allowing release of electricity on demand. It is made up of one or more electrical cells. Electricity is produced by a chemical reaction in the cells. There are two types of battery: primary-cell batteries, which are disposable; and secondary-cell batteries, or accumulators, which are rechargeable. Primary-cell batteries are an extremely uneconomical form of energy, since they produce only 2% of the power used in their manufacture. It is dangerous to try to recharge a primary-cell battery.

primary cell

The **dry cell** is the most common type of primary-cell battery, based on the Leclanché cell. Dry cells are used in batteries to power, for example, torches, electronic toys, and compact stereo systems. Dry cells consist of a zinc case used as a negative electrode, and a carbon rod as a positive electrode suspended in the centre of the case and immersed in a paste of manganese dioxide and ammonium chloride acting as an electrolyte.

The cell depends on the difference in electronegativity between the zinc and carbon to produce electricity. Carbon strongly holds onto its electrons; it is more electronegative. Zinc weakly holds onto its electrons; it is less electronegative. Zinc dissolves in the ammonium chloride and loses two electrons for each atom of zinc. The electrons move towards the carbon electrode:

$Zn \rightarrow Zn^{2+} + 2e^-$

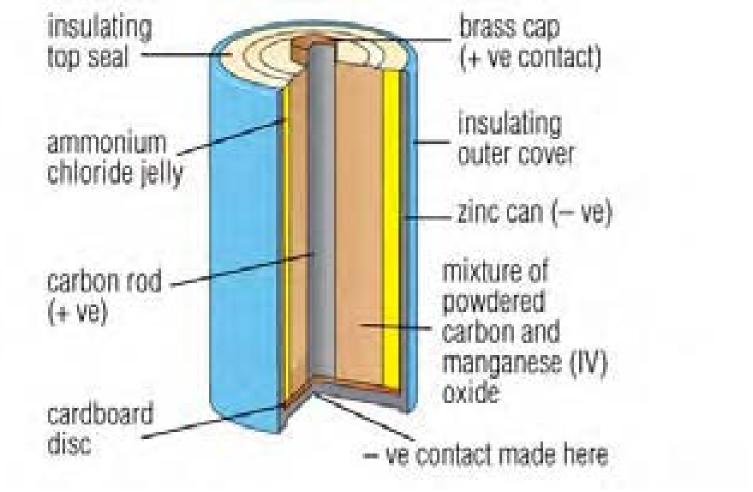
A small amount of charge is produced and zinc becomes negatively charged and carbon becomes positively charged. When a connection is made externally between the positive carbon terminal and the negative zinc terminal, electrons flow to the carbon from the zinc. The charge is neutralized on both electrodes and more of the zinc metal dissolves in the electrolyte to produce more electrons. A dry cell provides a current until the zinc electrode is completely used up.

secondary cell

A storage battery of secondary cells gives large amounts of power for a short time and can be recharged. The lead-acid car battery is a secondary-cell battery. The electrolyte is sulphuric acid (battery acid), the positive electrode is lead peroxide, and the negative electrode is lead. A typical lead-acid battery consists of six lead-acid cells in a case. Each cell produces 2 volts, so the whole battery produces a total of 12 volts.

Hydrogen cells and sodium-sulphur batteries were developed in 1996 to allow cars to run entirely on battery power. The introduction of rechargeable nickel-cadmium batteries has revolutionized portable electronic news gathering (sound recording, video) and information processing (computing). These batteries offer a stable, short-term source of power free of noise and other electrical hazards.

battery



(Image © Research Machines plc)

The common dry cell relies on chemical changes occurring between the electrodes - the central carbon rod and the outer zinc casing - and the ammonium chloride electrolyte to produce electricity. The mixture of carbon and manganese is used to increase the life of the cell.

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battery acid

sulphuric acid of approximately 70% concentration used in lead-acid cells (as found in car batteries).

The chemical reaction within the battery that is responsible for generating electricity also causes a change in the acid's composition. This can be detected as a change in its specific gravity: in a fully charged battery the acid's specific gravity is 1.270-1.290; in a half-charged battery it is 1.190-1.210; in a flat battery it is 1.110-1.130.

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baud

in engineering, a unit of electrical signalling speed equal to one pulse per second, measuring the rate at which signals are sent between electronic devices such as telegraphs and computers.

Bauds were used as a measure to identify the speed of modems until the early 1990s because at the lower modem speeds available then the baud rate generally equalled the rate of transmission measured in bps (bits per second). At higher speeds, this is not the case, and modem speeds now are generally quoted in Kbps or Mbps.

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bauxite

principal ore of aluminium, consisting of a mixture of hydrated aluminium oxides and hydroxides, generally contaminated with compounds of iron, which give it a red colour. It is formed by the chemical weathering of rocks in tropical climates. Chief producers of bauxite are Australia, Guinea, Jamaica, Russia, Kazakhstan, Suriname, and Brazil.

To extract aluminium from bauxite, high temperatures (about 800°C/1,470°F) are needed to make the ore molten. Electric currents are then passed through the molten ore. The process is economical only if cheap electricity is readily available, usually from a hydroelectric plant.

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bay

any of various species of laurel tree. The aromatic evergreen leaves are used for flavouring in cookery. There is also a golden-leaved variety. (Genus *Laurus*, family Lauraceae.)

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bay

in earth science, a wide-curving indentation of the sea into the land. Bays are often eroded in beds of rocks that are weaker than the adjacent headlands. Deposition is most intense in bays due to wave refraction.

A bay is larger than a cove, but smaller than a gulf. A **bay-head beach** is a small beach of sand or shingle found between two peninsulas or headlands as seen along the coastlines of Cornwall, England, and south Wales.

Bayesian statistics

form of statistics that uses the knowledge of prior probability together with the probability of actual data to determine posterior probabilities, using Bayes' theorem.

Bayes' theorem

in statistics, a theorem relating the probability of particular events taking place to the probability that events conditional upon them have occurred.

For example, the probability of picking an ace at random out of a pack of cards is 4/52. If two cards are picked out, the probability of the second card being an ace is conditional on the first card: if the first card is an ace the probability of drawing a second ace will be 3/51; if not it will be 4/51. Bayes' theorem gives the probability that given that the second card is an ace, the first card is also.

Baykonur

alternative spelling of Baikonur, a former mining town in central Kazakhstan. It is also the alternative name of Baikonur, a town near the Baikonur Cosmodrome, also in Kazakhstan.

Bayliss, William Maddock (1860-1924)

English physiologist who discovered the digestive hormone secretin, the first hormone to be found, with Ernest Starling in 1902. During World War I, Bayliss introduced the use of saline (salt water) injections to help the injured recover from shock. Knighted in 1922.

BCE

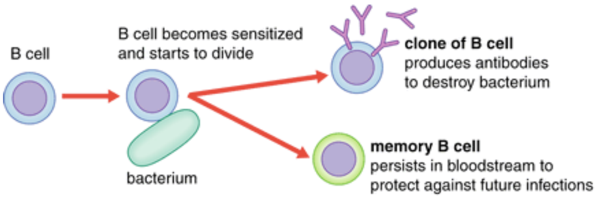
abbreviation for **before the Common Era**, used with dates instead of BC.

B cell

or B lymphocyte

type of lymphocyte (white blood cell) that develops in the bone marrow and aids the immune system by producing antibodies. Each B cell produces just one type of antibody, specific to a single antigen. Lymphocytes are related to T cells.

B cell


B cell
B cell becomes sensitized and starts to divide
clone of B cell
produces antibodies to destroy bacterium
bacterium
memory B cell
persists in bloodstream to protect against future infections

(Image © Research Machines plc)

B cells, a type of lymphocyte (white blood cell), have an important role in the body's immune system. When a B cell encounters an invading bacterium it starts to divide, forming two different types of cell. One type is a clone of itself that begins to produce antibodies to fight the infection; the other is a memory cell that will persist in the bloodstream, ready to produce antibodies should re-infection occur.

BCG

abbreviation for **bacille Calmette-Guérin**, bacillus injected as a vaccine to confer active immunity to tuberculosis (TB).

BCG was developed by Albert Calmette and Camille Guérin in France in 1921 from live bovine TB bacilli. These bacteria were bred in the laboratory over many generations until they became attenuated (weakened). Each inoculation contains just enough live, attenuated bacilli to provoke an immune response: the formation of specific antibodies. The vaccine provides protection for 50–80% of infants vaccinated. It is effective for a decade but then wears off; booster shots are ineffective.

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beach

strip of land bordering the sea, normally consisting of boulders and pebbles on exposed coasts, or sand on sheltered coasts. Beaches lie between the high- and low-water marks (high and low tides). A berm, a ridge of sand and pebbles, may be found at the farthest point that the water reaches, generally at high tide.

The material of the beach consists of a rocky debris eroded from exposed rocks and headlands by the processes of coastal erosion, or material carried in by rivers. The material is transported to the beach, and along the beach, by longshore drift.

When the energy of the waves decreases, more sand is deposited than is transported, building depositional features such as spits, bars, and **tombolos**.

beach

(Image © Research Machines plc)

Blackpool Sands, at Dartmouth in Devon, was voted the best kept beach and resort in the United Kingdom in 1999. It has also been granted a prestigious European Blue Flag Award. Mentioned in the Domesday Book, Blackpool Sands was also the site of the last highwayman's coach hold-up in England.

beach

(Image © Garret Nagle)

Track marks from vehicles are clearly visible on the sand dunes at Studland Beach, Dorset, England. Sand dunes are vulnerable ecosystems. They are easily disrupted by activities such as trampling, camping, and driving. The concentration of people and vehicles at particular places can cause great ecological damage.

beach

(Image © Garret Nagle)

Wide sandy beaches, such as this one at Formby in Lancashire, England, are formed along parts of the coast where there is a large supply of sand, strong offshore winds, and a large tidal range. These areas are very attractive for tourism and recreation; the holiday camp in the background dominates the area behind the beach.

beach

(Image © Garret Nagle)

The shingle beach at Lulworth Cove, Dorset, England. Wave action wears down rugged, sharp stones into smaller rounded pebbles. As the process of attrition continues, the pebbles become progressively smaller and smoother.

Beadle, George Wells (1903-1989)

US biologist who was awarded the Nobel Prize for Physiology or Medicine in 1958 with Edward L Tatum and Joshua Lederberg for work in biochemical genetics, forming the 'one-gene-one-enzyme' hypothesis (a single gene codes for a single kind of enzyme).

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beagle

short-haired hound with pendant ears, sickle tail, and a bell-like voice for hunting hares on foot ('beagling').

Beagle

Go to site

Profile of the beagle from the American Kennel Club. There is a history of the breed, description of the ideal breed standard, a note on the dog's temperament, and some quirky facts about beagles. There is also a high-resolution photo of this tenacious hunter.

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beak

horn-covered projecting jaws of a bird (see bill), or other horny jaws such as those of the octopus, platypus, or tortoise.

Beaker people

prehistoric people thought to have been of Iberian origin, who spread out over Europe from the 3rd millennium BC. They were skilled in metalworking, and are associated with distinctive earthenware drinking vessels with various designs, in particular, a type of beaker with a bell-shaped profile, widely distributed throughout Europe.

The Beaker people favoured individual inhumation (burial of the intact body), often in round barrows, or secondary burials in some form of chamber tomb. A beaker typically accompanied male burials, possibly to hold a drink for the deceased on their final journey.

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bean

seed of a large number of leguminous plants (see legume). Beans are rich in nitrogen compounds and proteins and are grown both for human consumption and as food for cattle and horses. Varieties of bean are grown throughout Europe, the USA, South America, China, Japan, Southeast Asia, and Australia.

The broad bean (*Vicia faba*) has been cultivated in Europe since prehistoric times. The French bean, kidney bean, or haricot (*Phaseolus vulgaris*) is probably of South American origin; the runner bean (*P. coccineus*) is closely allied to it, but differs in its climbing habit. Among beans of warmer countries are the lima or butter bean (*P. lunatus*) of South America; the soybean (*Glycine max*), extensively used in China and Japan; and the winged bean (*Psophocarpus tetragonolobus*) of Southeast Asia. The tuberous root of the winged bean has potential as a main crop in tropical areas where protein deficiency is common. The Asian mung bean (*Phaseolus mungo*) yields the bean sprouts used in Chinese cookery. Canned baked beans are usually a variety of (*P. vulgaris*), which grows well in the USA.

Beans

Go to site

Informative guide to beans from the Virginia Cooperative Extension. There is a guide to planting beans, as well as the types of soil and sunlight that yield best results. This site also features solutions to common problems and information about harvesting and storage. There are also extensive notes on the different types of beans, such as soybeans, dry beans, and lima beans.

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bear

large mammal with a heavily built body, short powerful limbs, and a very short tail. Bears breed once a year, producing one to four cubs. In northern regions they hibernate, and the young are born in the winter den. They are found mainly in North America and northern Asia. Bears walk on the soles of the feet and have long, nonretractable claws. The bear family, Ursidae, is related to carnivores such as dogs and weasels, and all bears are capable of killing prey.

species

There are seven species of bear. The **brown bear** *Ursus arctos* formerly ranged across most of Europe, northern Asia, and North America, but is now reduced in number. It varies in size from under 2 m/7 ft long in parts of the Old World to 2.8 m/9 ft long and 780 kg/1,700 lb in Alaska. The **grizzly bear** is a North American variety of this species, and another subspecies, the **Kodiak bear** of Alaska, is the largest living land carnivore. The white-furred **polar bear** *Thalarctos maritimus* is up to 2.5 m/8 ft long, has furry undersides to the feet, and feeds mainly on seals. Its skin is black to conserve 80-90% of the solar energy trapped and channelled down the hollow hairs of its fur. It is found in the north polar region. The North American **black bear** *Euarctos americanus* and the **Asian black bear** *Selenarctos thibetanus* are smaller, only about 1.6 m/5 ft long. The latter has a white V-mark on its chest. The **spectacled bear** *Tremarctos ornatus* of the Andes is similarly sized, as is the **sloth bear** *Melursus ursinus* of India and Sri Lanka, which has a shaggy coat and uses its claws and protrusile lips to obtain termites, one of its preferred foods. The smallest bear is the Malaysian **sun bear** *Helarctos malayanus*, rarely more than 1.2 m/4 ft long, a good climber, whose favourite food is honey.

threat of extinction

Of the seven species of bear, five are reckoned to be endangered and all apart from the polar bear and the American black bear are in decline. In April 2001, there were estimated to be fewer than 1,000 grizzly bears in the wild. The population of brown bears in the Pyrenees was estimated at eight in 1994. Despite the intoduction of two female bears in 1996, the bear population in the Pyrenees had declined to six by 1998.

bear

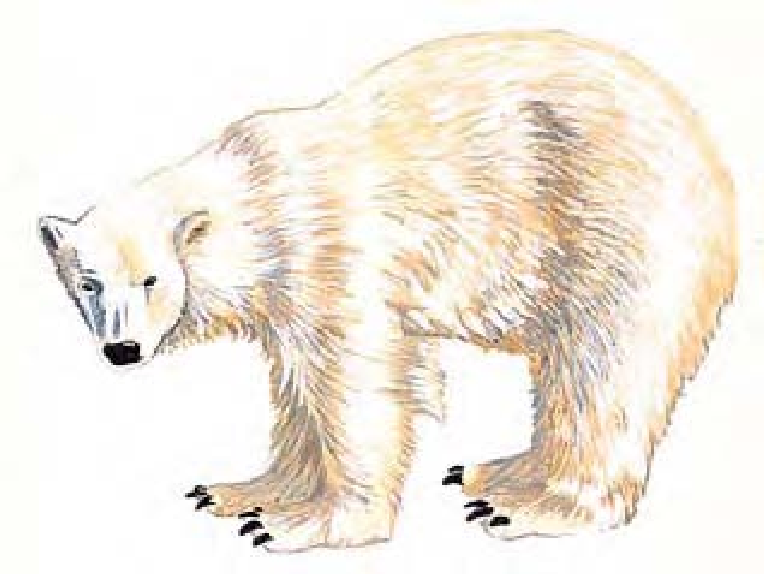
Polar bear's forepaws have a 30-cm/12-in diameter and their toes are partially webbed. They can swim up to 95 km/59 mi without resting. Polar bears stomachs can hold 70 kg/154 lb of food. During the summer they lose up to half their body weight - the most extreme period of starvation for any mammal, as they may not eat for as long as a month.

grizzly bear

(Image © Corel)

Grizzly bears *Ursus arctos* will hunt for fish in rivers or lakes. Their diet may include fruit, nuts, and roots, as well as insects, fish, and small vertebrates. Grizzly bears can grow up to 2.5 m/8.3 ft in length. They have no tail.

polar bear



(Image © Research Machines plc)

The polar bear ranges over the coasts and ice floes of the Arctic Ocean, to the southern limit of the ice. It is a swift runner, outpacing a reindeer over short distances; it is also an excellent swimmer. Its main prey are seals, fish, birds, hares, reindeer, and musk oxen; in summer it also eats berries and leaves.

bear

(Image © Canadian Tourist Office)

The polar bear ranges over the coasts and ice floes of the Arctic Ocean, to the southern limits of the ice. It is a swift runner, able to outpace a reindeer over short distances, and an excellent swimmer. It eats seals, fish, birds, hares, reindeer, and musk ox, and in summer also eats berries and leaves. It has a good sense of smell and better eyesight than most bears.

Bear Den

Go to site

Invaluable resource for information on all types of bears. As well as general information on the evolution and history of bears in general, there are more specific details on each of the eight species of bear, including habitat, reproduction, food, and much more. The site also has photographs and sound effects.

bearberry

any of a group of evergreen trailing shrubs belonging to the heath family, found in high and rocky places. Most bearberries are North American but *Arctostaphylos uva-ursi* is also found in Asia and Europe in northern mountainous regions. It has small pink flowers in spring, followed by red berries that are dry but edible. (Genus *Arctostaphylos*, family Ericaceae.)

Bearberry

Go to site

Describes this shrub in detail. There are notes on the parts of the plant that can be used medicinally, as well as the details of the plant's constituents. There are also notes on the other uses of the plant: from tanning leather to feeding grouse.

Bear, Great and Little

common names (and translations of the Latin) for the constellations Ursa Major and Ursa Minor respectively.

bearing

device used in a machine to allow free movement between two parts, typically the rotation of a shaft in a housing.
Ball bearings consist of two rings, one fixed to a housing, one to the rotating shaft. Between them is a set, or race, of steel balls. They are widely used to support shafts, as in the spindle in the hub of a bicycle wheel.

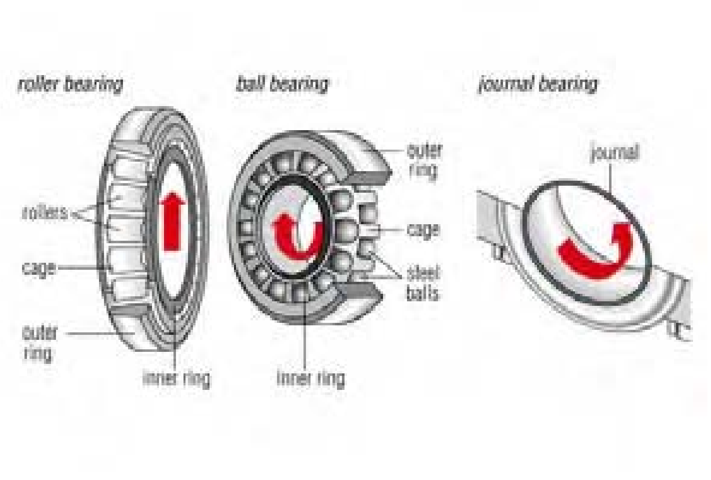
The **sleeve**, or **journal bearing**, is the simplest bearing. It is a hollow cylinder, split into two halves. It is used for the big-end and main bearings on a car crankshaft.

In some machinery the balls of ball bearings are replaced by cylindrical rollers or thinner **needle bearings**.

In precision equipment such as watches and aircraft instruments, bearings may be made from material such as ruby and are known as **jewel bearings**.

For some applications bearings made from nylon and other plastics are used. They need no lubrication because their surfaces are naturally waxy.

bearing



(Image © Research Machines plc)

Three types of bearing. The roller and the ball bearing are similar, differing only in the shape of the parts that roll when the middle shaft turns. The simpler journal bearing consists of a sleeve, or journal, lining the surface of the rotating shaft. The bearing is lubricated to reduce friction and wear.

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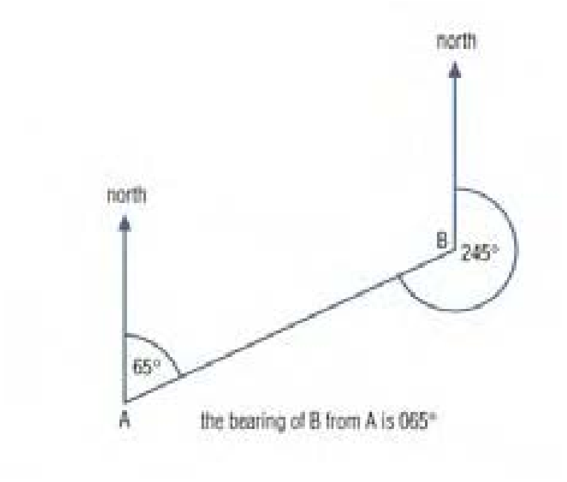
bearing

direction of a fixed point, or the path of a moving object, from a point of observation. Bearings are angles measured in degrees (°) from the north line in a clockwise direction. A bearing must always have three figures. For instance, north is 000°, northeast is 045°, south is 180°, and southwest is 225°.

True north differs slightly from magnetic north (the direction in which a compass needle points), hence northeast may be denoted as 045M or 045T, depending on whether the reference line is magnetic (M) or true (T) north. True north also differs slightly from grid north since it is impossible to show a sphere on a flat map.

bearing



(Image © Research Machines plc)

A bearing is the direction of a fixed point, or the path of a moving object, from a point of observation on the Earth's surface, expressed as an angle from the north. In the diagram, the bearing of a point A from an observer at B is the angle between the line BA and the north line through B, measured in a clockwise direction from the north line.

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beat frequency

in musical acoustics, fluctuation produced when two notes of nearly equal pitch or frequency are heard together. Beats result from the interference between the sound waves of the notes. The frequency of the beats equals the difference in frequency of the notes.

Beaton, Cecil Walter Hardy (1904-1980)

English photographer. His elegant and sophisticated fashion pictures and society portraits often employed exotic props and settings. He adopted a more simple style for his wartime photographs of bomb-damaged London. He also worked as a stage and film designer, notably for the musicals *Gigi* (1959) and *My Fair Lady* (1965). He was knighted in 1972.

Beaufort, Francis (1774-1857)

British admiral, hydrographer to the Royal Navy from 1829; the Beaufort scale and the Beaufort Sea in the Arctic Ocean are named after him. Made Knight Commander of the Bath (KCB) in 1848.

Beaufort scale

system of recording wind velocity, devised by Francis Beaufort in 1806. It is a numerical scale ranging from 0 to 17, calm being indicated by 0 and a hurricane by 12; 13-17 indicate degrees of hurricane force.

In 1874 the scale received international recognition; it was modified in 1926. Measurements are made at 10 m/33 ft above ground level.

The Beaufort scale

The Beaufort scale is a system of recording wind velocity (speed) devised in 1806 by Francis Beaufort (1774-1857). It is a numerical scale ranging from 0 to 12, calm being indicated by 0 and a hurricane by 12. The scale received international recognition in 1874. Measurements are made at 10 metres/33 feet above ground level.

Force	Description	Features	Air speed	
			kph	mph
0	calm	smoke rises vertically; water smooth	0-2	0-1
1	light air	smoke shows wind direction; water ruffled	2-5	1-3
2	light breeze	leaves rustle; wind felt on face	6-11	4-7
3	gentle breeze	loose paper blows around	12-19	8-12
4	moderate breeze	branches sway	20-29	13-18
5	fresh breeze	small trees sway, leaves blown off	30-39	19-24
6	strong breeze	whistling in telephone wires; sea spray from waves	40-50	25-31
7	near gale	large trees sway	51-61	32-38
8	gale	twigs break from trees	62-74	39-46
9	strong gale	branches break from trees	75-87	47-54
10	storm	trees uprooted; weak buildings collapse	88-101	55-63
11	violent storm	widespread damage	102-117	64-73
12	hurricane	widespread structural damage	above 118	above 74

Beaumont, William (1785-1853)

US surgeon who conducted pioneering experiments on the digestive system. In 1822 he saved the life of a Canadian trapper wounded in the side by a gun blast; the wound only partially healed, and through an opening in the stomach wall, Beaumont was able to observe the workings of the stomach. His *Experiments and Observations on the Gastric Juice and the Physiology of Digestion* was published in 1833.

beaver

aquatic rodent with webbed hind feet, a broad flat scaly tail, and thick waterproof fur. It has very large incisor teeth and fells trees to feed on the bark and to use the logs to construct the 'lodge', in which the young are reared, food is stored, and much of the winter is spent. There are two species, the Canadian *Castor canadensis* and the European *C. fiber*. They grow up to 1.4 m/4.6 ft in length and weigh about 20 kg/44 lb.

Beavers are monogamous and a pair will produce a litter of twins each year. Their territory consists of about 3 km/2 mi of river. Beavers can construct dams on streams, and thus modify the environment considerably; beaver ponds act as traps for minerals and provide fertile living conditions for other species - zooplankton biomass may be 1,000 times greater within a beaver pond than elsewhere. Beavers once ranged across Europe, northern Asia, and North America, but in Europe now only survive where they are protected, and are reduced elsewhere, partly through trapping for their fur.

beaver

By building dams, beavers create extremely fertile living conditions for other animals. The ponds formed by the dams trap a wealth of nourishing minerals. They are also full of zooplankton, the combined mass of which is a thousand times greater than that found elsewhere.

becquerel

symbol Bq

SI unit of radioactivity, equal to one radioactive disintegration (change in the nucleus of an atom when a particle or ray is given off) per second.

The becquerel is much smaller than the previous standard unit, the curie (3.7×10^{10} Bq). It is named after French physicist Henri Becquerel.

Becquerel, (Antoine) Henri (1852-1908)

French physicist. He was awarded the Nobel Prize for Physics in 1903 for his discovery of penetrating radiation coming from uranium salts, the first indication of spontaneous radioactivity. He shared the award with Marie and Pierre Curie.

Biography of A H Becquerel

Go to site

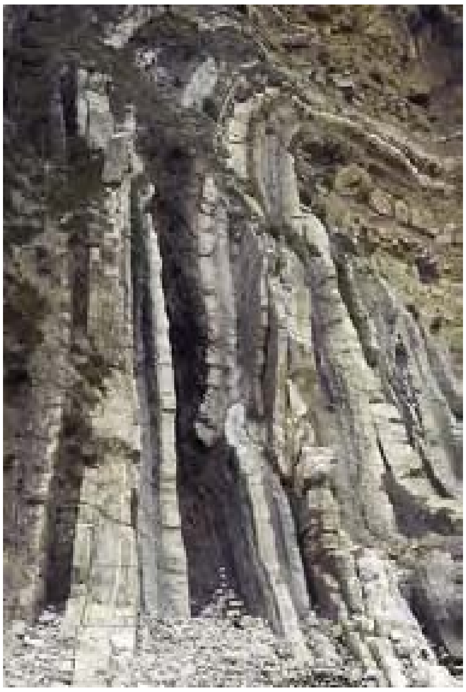
Presentation of the life and discoveries of A H Becquerel, a distinguished scientist who was awarded the Nobel Prize for Physics jointly with Marie and Pierre Curie. This essay mainly focuses on Becquerel's contribution to the understanding of spontaneous radioactivity.

bed

in geology, a single sedimentary rock unit with a distinct set of physical characteristics or contained fossils, readily distinguishable from those of beds above and below. Well-defined partings called **bedding planes** separate successive beds or strata.

The depth of a bed can vary from a fraction of a centimetre to several metres, and can extend over any area. The term is also used to indicate the floor beneath a body of water (lake bed), and a layer formed by a fall of particles (ash bed). Beds of Portland and Purbeck limestone are clearly shown at Stair Hole, next to Lulworth Cove, Dorset, England.

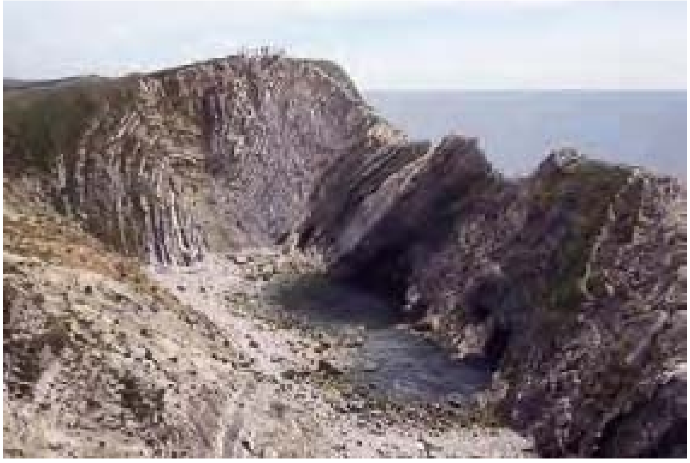
bed



(Image © Garret Nagle)

At Stair Hole, on the Durdle Promontory in Dorset, England, the sedimentary beds of Portland and Purbeck limestone have been folded into a step- or stair-like shape. This was the result of tectonic movements during the Alpine mountain-building period, 30 million years ago. The folding has also fractured the limestone, and the lines of weakness thus created were later exploited by marine erosion to form small arches in the limestone.

bed



(Image © Garret Nagle)

At Stair Hole in Dorset, England, the sedimentary beds of Portland and Purbeck limestone have been folded into a step- or stair-like shape, by tectonic movements during the Alpine mountain-building period, 30 million years ago. The folding has also fractured the limestone, and the lines of weakness thus created were later exploited by marine erosion, forming small arches in the limestone.

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bedbug

flattened wingless red-brown insect *Cimex lectularius* with piercing mouthparts. Bed bugs live in bedlinen crevices during the day and feed on human blood at night. They lay their eggs in the crevices and these hatch in a few days into nymphs (miniature versions of the adults) that take ten weeks and five skin moults to reach adult size. Adults can live for several years if undisturbed.

Bedlington

breed of terrier with a short body, long legs, and curly hair, usually grey, named after a district of Northumberland, England.

---

bedwetting

or nocturnal enuresis

in medicine, the involuntary passing of urine during sleep. It occurs most commonly in children and it is usually due to inadequate bladder training or a psychological disorder.

Most children gain full control of bladder function by the age of three years but this can occur much later in a few children. Treatment should consist of ensuring the condition is not due to an organic cause, such as a urinary tract infection. The child should be given reassurance and further bladder training. An alarm system which wakes the child if urine is being passed may also be useful. Drugs can be used if these measures fail but their long-term use is not recommended due to the occurrence of adverse effects.

---

bee

four-winged insect of the superfamily Apoidea in the order Hymenoptera, usually with a sting. There are over 12,000 species, of which fewer than 1 in 20 are social in habit. The **hive bee** or **honeybee** *Apis mellifera* establishes perennial colonies of about 80,000, the majority being infertile females (workers), with a few larger fertile males (drones), and a single very large fertile female (the queen). Worker bees live for no more than a few weeks, while a drone may live a few months, and a queen several years. Queen honeybees lay two kinds of eggs: fertilized, female eggs, which have two sets of chromosomes and develop into workers or queens, and unfertilized, male eggs, which have only one set of chromosomes and develop into drones.

Bees transmit information to each other about food sources by 'dances', each movement giving rise to sound impulses which are picked up by tiny hairs on the back of the bee's head, the orientation of the dance also having significance. They use the Sun in navigation (see migration). Besides their use in crop pollination and production of honey and wax, bees (by a measure of contaminants brought back to their hives) can provide an inexpensive and effective monitor of industrial and other pollution of the atmosphere and soil.

The most familiar species is the bumblebee, genus *Bombus*, which is larger and stronger than the hive bee and so is adapted to fertilize plants in which the pollen and nectar lie deep, as in red clover; they can work in colder weather than the hive bee.

Social bees, apart from the bumblebee and the hive bee, include the stingless South American **vulture bee *Trigona hypogea***, discovered in 1982, which is solely carnivorous.

Solitary bees include species useful in pollinating orchards in spring, and may make their nests in tunnels under the ground or in hollow plant stems; 'cuckoo' bees lay their eggs in the nests of bumblebees, which they closely resemble.

The killer bees of South America are a hybrid type, created when an African subspecies of honeybee escaped from a research establishment in Brazil in 1957. They mated with, and supplanted, the honeybees of European origin in most of South and Central America, and by 1990 had spread as far north as Texas, USA. As well as being more productive and resistant to disease than European honeybees, they also defend their hives more aggressively, in larger numbers, and for a greater length of time than other honeybees. However, their stings are no more venomous, and although they have killed hundreds of thousands of animals and probably more than 1,000 people, most individuals survive an attack, and almost all deaths have occurred where the victim has somehow been prevented from fleeing.

Most bees are passive unless disturbed, but some species are aggressive. One bee sting may be fatal to a person who is allergic to them, but this is comparatively rare (about 1.5% of the population), and most adults can survive 300-500 stings without treatment. A vaccine treatment against bee stings, which uses concentrated venom, has been developed.

bee

Bees exposed to the electrical fields of high-voltage power cables produce their honey in an erratic manner. As a consequence, bee-keepers have learned not to place their hives under power cables.

Carl Hayden Bee Research Center

Go to site

Site dedicated to bees. Features include the 'Atlas of a Honey Bee', with microscopic images; a selection of recent research papers on the subject; and online activites such as a honey bee population growth simulation.

---

beech

genus of trees *Fagus*, of the family Fagaceae. Of the ten species in this genus only one is native to North America; others grow in Europe. The American beech *F. grandifolia* grows to 30 m/100 ft, with blue-gray bark; a broad, rounded crown; and leaves that are lanceolate, serrate, triangular, and edible.

Beeching Report

official report, published in 1963, on the railway network of Britain, which recommended the closure of loss-making lines and the improvement of money-making routes. Hundreds of lines and several thousand stations were closed as a result.

These closures were not evenly spread throughout the country. Networks in East Anglia, south Wales, and the West Country fared worst, whereas the densely populated southeast retained more of its routes. Richard Beeching was chair of the British Railways Board 1963–65.

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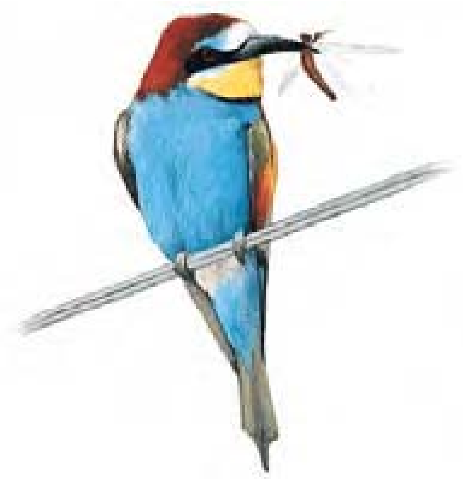
bee-eater

brightly-coloured bird *Merops apiaster*, family Meropidae, order Coraciiformes, found in Africa, southern Europe, and Asia. Bee-eaters are slender, with chestnut, yellow, and blue-green plumage, a long bill and pointed wings, and a flight like that of the swallow, which they resemble in shape. They feed on bees, wasps, and other insects, and nest in colonies in holes dug out with their long bills in sandy river banks.

bee-eater



(Image © Research Machines plc)

The bee-eater is one of the most colourful birds found in Europe. Bee-eaters live in colonies, feeding on a variety of insects, chiefly wasps and bees. They catch their prey in mid-flight and rub it on the ground or on a branch before eating it, either to kill it or to remove its sting.

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beet

any of several plants belonging to the goosefoot family, used as food crops. One variety of the common beet (*Beta vulgaris*) is used to produce sugar and another, the mangelwurzel, is grown as a cattle feed. The beetroot, or red beet (*B. rubra*), is a salad plant. (Genus *Beta*, family Chenopodiaceae.)

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beetle

common name of insects in the order Coleoptera (Greek 'sheath-winged') with leathery forewings folding down in a protective sheath over the membranous hindwings, which are those used for flight. They pass through a complete metamorphosis. They include some of the largest and smallest of all insects: the largest is the **Hercules beetle** *Dynastes hercules* of the South American rainforests, 15 cm/6 in long; the smallest is only 0.05 cm/0.02 in long. Comprising more than 50% of the animal kingdom, beetles number some 370,000 named species, with many not yet described.

Beetles are found in almost every land and freshwater habitat, and feed on almost anything edible. Examples include **click beetle** or **skipjack** species of the family Elateridae, so called because if they fall on their backs they right themselves with a jump and a loud click; the larvae, known as **wireworms**, feed on the roots of crops. In some tropical species of Elateridae the beetles have luminous organs between the head and abdomen and are known as **fireflies**. The potato pest **Colorado beetle** *Leptinotarsa decemlineata* is striped in black and yellow. The **blister beetle** *Lytta vesicatoriaf*, a shiny green species from southern Europe, was once sold pulverized as an aphrodisiac and contains the toxin cantharidin. The larvae of the **furniture beetle** *Anobium punctatum* and the **deathwatch beetle** *Xestobium rufovillosum* and their relatives are serious pests of structural timbers and furniture (see woodworm).

beetle: bombardier beetle

If alarmed, the bombardier beetle releases a boiling toxic chemical spray at 500-1,000 pulses per second. The chemicals are stored separately and only reach boiling point (100 °C) when they mix. Pulsing prevents the beetle's abdomen from exploding.

beetle: darkling beetle

Darkling beetles living in the Namib desert in Africa drink by standing on their heads at the crests of sand dunes at dawn. Mists rolling in from the coast condense to form water on their bodies; the water then trickles down into their mouths.

beetle: flea beetle

When it jumps, the flea beetle accelerates at 260 times more than gravity while spinning head over heels about 70 times per second. Flea beetles always land the right way up.

beetle: Florida leaf beetle

The Florida leaf beetle *Hemisphaerota cyanen* has 60,000 adhesive pads on its feet. These enable it to resist the pull of a 2 g/0.07 oz weight (the equivalent of a human hanging on to 200 grand pianos). Ant predators are unable to move the beetle.

beetle: ground beetle

Once the female ground beetle *Pterostichus lucublandus* has mated, she releases a chemical that not only deters other males but stops them almost dead in their tracks. If a male receives a squirt of this methacrylic acid, he remains in a death-like coma for up to three hours.

beetle: spider beetle

A colony of spider beetles (*Gibbium psylloides*) was found in 1996 living 780 m/853 yd underground. The beetles had made their home in a disused mine shaft.

Beetles

Go to site

Colour photographs of numerous beetle species from Iowa State University's Entomology Image Gallery. They include bean beetles, Colorado potato beetles, ladybirds, scarab beetles, and weevils. Click on a link to view each insect and the damage that some of them cause. There is a search engine at the top of the page to look for other species of insect.

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begonia

any of a group of tropical and subtropical plants. They have fleshy and succulent leaves, and some have large, brilliant flowers. There are numerous species in the tropics, especially in South America and India. (Genus *Begonia*, family Begoniaceae.)

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behaviourism

school of psychology originating in the USA, of which the leading exponent was John B Watson.

Behaviourists maintain that all human activity can ultimately be explained in terms of conditioned reactions or reflexes and habits formed in consequence. Leading behaviourists include Ivan Pavlov and B F Skinner.

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behaviour therapy

in psychology, the application of behavioural principles, derived from learning theories, to the treatment of clinical conditions such as phobias, obsessions, and sexual and interpersonal problems.

The symptoms of these disorders are regarded as learned patterns of behaviour that therapy can enable the patient to unlearn. For example, in treating a phobia, the patient is taken gradually into the feared situation in about 20 sessions until the fear noticeably reduces.

Behring, Emil (Adolph von) (1854-1917)

German physician who was awarded the first Nobel Prize for Physiology or Medicine, in 1901, for his discovery that the body produces antitoxins, substances able to counteract poisons released by bacteria. Using this knowledge, he developed new treatments for diseases such as diphtheria.

Behring discovered the diphtheria antitoxin and developed serum therapy together with Japanese bacteriologist Shibasaburo Kitasato, and they went on to apply the technique to tetanus. Behring also introduced early vaccination techniques against diphtheria and tuberculosis.

Biography of Emil Adolf Behring

Go to site

Informative biography of the German physician from the Nobel Foundation. Included in the biography are details of his childhood and university education, as well as information on his scientific research.

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bel

unit of sound measurement equal to ten decibels. It is named after Scottish-born US scientist and inventor Alexander Graham Bell.

Bell, Alexander Graham (1847-1922)

Scottish-born US scientist and inventor. He was the first person ever to transmit speech from one point to another by electrical means. This invention – the telephone – was made in 1876, when Bell transmitted speech from Paris, Ontario, to Brantford, Ontario (a distance of 13 km/8 mi). Later Bell experimented with a type of phonograph and, in aeronautics, invented the tricycle undercarriage.

Bell also invented a photophone, which used selenium crystals to apply the telephone principle to transmitting words in a beam of light. He thus achieved the first wireless transmission of speech.

Bell, Alexander Graham

Alexander Graham Bell's invention of the telephone stemmed from his interest in hearing defects. His wife was profoundly deaf. On the day that Bell was buried in 1922, the entire telephone network in the USA was closed down for one minute in tribute.

Alexander Graham Bell's Path to the Telephone

Go to site

Impressive attempt to reconstruct the path towards the invention of the telephone. The presentation aims to communicate the thoughts of Alexander Graham Bell, placing him within the context of other relevant inventions and related ideas. This is achieved mainly through a wealth of graphics retrieved from Bell's experimental notebooks, patents, and other papers accompanied by detailed analysis. An especially worthwhile site for those who are interested in the thought processes behind invention in general, as well as in this particular one.

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belladonna

or deadly nightshade

poisonous plant belonging to the nightshade family, found in Europe and Asia. It grows to 1.5 m/5 ft in height, with dull green leaves growing in unequal pairs, up to 20 cm/8 in long, and single purplish flowers that produce deadly black berries. Drugs are made from the leaves. (*Atropa belladonna*, family Solanaceae.)

The dried powdered leaves are used to produce the drugs atropine and hyoscine. Belladonna extract acts medicinally as an anticholinergic (blocking the passage of certain nerve impulses), and is highly poisonous in large doses.

Nightshade, Deadly

Go to site

Extensive resource of information about deadly nightshade, or belladonna. Included here are detailed descriptions of this poisonous plant and its habitat. There is information about the cultivation of belladonna, and even notes on the possible medicinal uses of the plant, which range from treating eye diseases to acting as an antispasmodic.

Bell Burnell, (Susan) Jocelyn (1943-)

Northern Irish astronomer. In 1967 she discovered the first pulsar (rapidly flashing star) with British radio astronomer Antony Hewish and colleagues at the Mullard Radio Astronomy Observatory, Cambridge, England.

Little Green Men, White Dwarfs, or Pulsars?

Go to site

Entertaining first-hand history of the discovery of pulsars. This is the text of an after-dinner speech given by Bell Burnell. It gives an intimate account of the excitement and challenges of gamma and X-ray astronomy. There is also a brief biography of the pioneering astronomer.

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bellflower

general name for many plants of the family Campanulaceae, especially those of the genus *Campanula*. The white, pink, or blue flowers are bell-shaped and showy. The varied leaf bluebell *C. rotundifolia* grows in northern North America and Europe.

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bells

nautical term applied to half-hours of watch. A day is divided into seven watches, five of four hours each and two, called dogwatches, of two hours. Each half-hour of each watch is indicated by the striking of a bell, eight bells signalling the end of the watch.

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benchmark

in computing, measure of the performance of a piece of equipment or software, usually consisting of a standard program or suite of programs. Benchmarks can indicate whether a computer is powerful enough to perform a particular task, and so enable machines to be compared. However, they provide only a very rough guide to practical performance, and may lead manufacturers to design systems that get high scores with the artificial benchmark programs but do not necessarily perform well with day-to-day programs or data.

---

bends

or compressed-air sickness or caisson disease

popular name for a syndrome seen in deep-sea divers, arising from too rapid a release of nitrogen from solution in their blood. If a diver surfaces too quickly, nitrogen that had dissolved in the blood under increasing water pressure is suddenly released, forming bubbles in the bloodstream and causing pain (the 'bends') and paralysis. Immediate treatment is gradual decompression in a decompression chamber, whilst breathing pure oxygen.

bends

Even fish can sometimes get a fish equivalent of the bends. If fish are swimming in a river near to a dam spillway they will 'drown' because the falling water is supersaturated with dissolved air.

Benioff zone

seismically active zone inclined from a deep sea trench. Earthquakes along Benioff zones apparently define a lithospheric plate that descends into the mantle beneath another, overlying plate. The zone is named after Hugo Benioff, a US seismologist who first described this feature.

---

bent

or bent grass

any of a group of grasses. Creeping bent grass (*Agrostis stolonifera*), also known as fiorin, is common in northern North America, Europe, and Asia, including lowland Britain. It spreads by runners and has large attractive clusters (panicles) of yellow or purple flowers on thin stalks, like oats. It is often used on lawns and golf courses. (Genus *Agrostris*, family Gramineae.)

Benz, Karl (Friedrich) (1844-1929)

German automobile engineer. He produced the world's first petrol-driven motor vehicle. He built his first model engine in 1878 and the petrol-driven car in 1885.

Benz made his first four-wheeled prototype in 1891 and by 1895 he was building a range of four-wheeled vehicles that were light, strong, inexpensive, and simple to operate. These vehicles ran at speeds of about 24 kph/15 mph. In 1926, the thriving company merged with the German firm of Daimler to form Daimler-Benz.

Benz, Karl

Go to site

Biography of the German mechanical engineer Karl Benz.

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benzaldehyde

C_6H_5CHO

colourless liquid with the characteristic odour of almonds. It is used as a solvent and in the making of perfumes and dyes. It occurs in certain leaves, such as the cherry, laurel, and peach, and in a combined form in certain nuts and kernels. It can be extracted from such natural sources, but is usually made from toluene.

Benzedrine

trade name for amphetamine, a stimulant drug.

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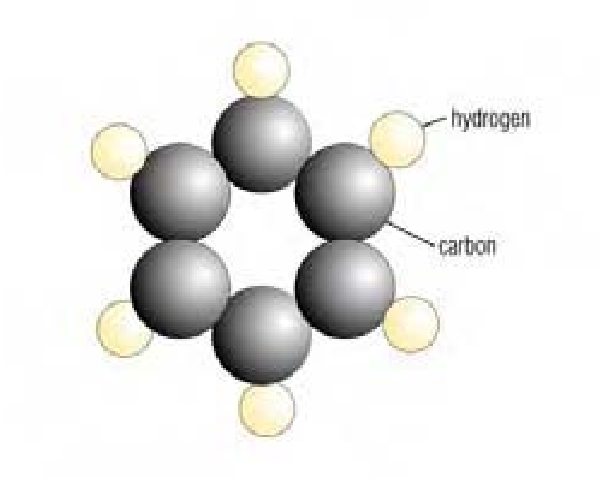
benzene

C_6H_6

clear liquid hydrocarbon of characteristic odour, occurring in coal tar. It is used as a solvent and in the synthesis of many chemicals.

The benzene molecule consists of a ring of six carbon atoms, all of which are in a single plane, and it is one of the simplest cyclic compounds. Benzene is the simplest of a class of compounds collectively known as **aromatic compounds**. Some are considered carcinogenic (cancer-inducing).

benzene



(Image © Research Machines plc)

The molecule of benzene consists of six carbon atoms arranged in a ring, with six hydrogen atoms attached. The benzene ring structure is found in many naturally occurring organic compounds.

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benzodiazepine

any of a group of mood-altering drugs (tranquillizers), for example Librium and Valium. They are addictive and interfere with the process by which information is transmitted between brain cells, and various side effects arise from continued use. They were originally developed as muscle relaxants, and then excessively prescribed in the West as anxiety-relieving drugs.

Today the benzodiazepines are recommended only for short-term use in alleviating severe anxiety or insomnia.

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benzoic acid

C_6H_5COOH

white crystalline solid, sparingly soluble in water, that is used as a preservative for certain foods and as an antiseptic. It is obtained chemically by the direct oxidation of benzaldehyde and occurs in certain natural resins, some essential oils, and as hippuric acid.

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benzoin

resin (thick liquid that hardens in the air) obtained by making cuts in the bark of the tree *Styrax benzoin*, which grows in the East Indies. Benzoin is used in cosmetics, perfumes, and incense.

Benzoin

Go to site

Detailed information about this resin. There is an informative description of the resin itself, including a detailed analysis of the resin's constituents. It also features notes on the uses of the resin, which include making antiseptic and preserving fats, as well as details of the preparation of a tincture made from the resin.

benzpyrene

one of a number of organic compounds associated with a particular polycyclic ring structure. Benzpyrenes are present in coal tar at low levels and are considered carcinogenic (cancer-inducing). Traces of benzpyrenes are present in wood smoke, and this has given rise to some concern about the safety of naturally smoked foods.

Berg, Paul (1926-)

US molecular biologist who, in 1972, spliced and combined into a single hybrid the DNA from an animal tumour virus (SV40) and the DNA from a bacterial virus, using gene-splicing techniques developed by others. He shared the Nobel Prize for Chemistry in 1980 for his work on the biochemistry of nucleic acids, especially recombinant DNA.

bergamot

small evergreen tree belonging to the rue family. A fragrant citrus-scented essence is obtained from the rind of its fruit and used as a perfume and food flavouring, for example in Earl Grey tea. The sole source of supply is southern Calabria, Italy, but the name comes from the town of Bergamo, in Lombardy. (*Citrus bergamia*, family Rutaceae.)

Bergius, Friedrich Karl Rudolf (1884-1949)

German chemist who invented processes for converting coal into oil and wood into sugar. He shared the Nobel Prize for Chemistry in 1931 with Carl Bosch for his part in inventing and developing high-pressure industrial methods.

beriberi

nutritional disorder occurring mostly in the tropics and resulting from a deficiency of vitamin B_1 (thiamine). The disease takes two forms: in one oedema (waterlogging of the tissues) occurs; in the other there is severe emaciation. There is nerve degeneration in both forms and many victims succumb to heart failure.

Beringia

or Bering Land Bridge

former land bridge 1,600 km/1,000 mi wide between Asia and North America; it existed during the ice ages that occurred before 35,000 BC and during the period 24,000-9000 BC. As the climate warmed and the ice sheets melted, Beringia flooded. It is now covered by the Bering Strait and Chukchi Sea.

berkelium

chemical symbol Bk

synthesized, radioactive, metallic element of the actinide series, atomic number 97, relative atomic mass 247. It was first produced in 1949 by US nuclear chemist Glenn Seaborg and his team, at the University of California at Berkeley, California, after which it is named.

Bernard, Claude (1813-1878)

French physiologist and founder of experimental medicine. Bernard first demonstrated that digestion is not restricted to the stomach, but takes place throughout the small intestine. He discovered the digestive input of the pancreas, several functions of the liver, and the vasomotor nerves which dilate and contract the blood vessels and thus regulate body temperature. This led him to the concept of the *milieu intérieur* ('internal environment') whose stability is essential to good health.

Bernoulli, Daniel (1700-1782)

Swiss mathematical physicist. He made important contributions to trigonometry and differential equations (differentiation). In hydrodynamics he proposed Bernoulli's principle, an early formulation of the idea of conservation of energy.

Bernoulli, Daniel

Go to site

Biography of the Swiss physicist famous for his work on fluid flows. Along with a picture of Bernoulli, there is a family tree detailing the achievements of the remarkable Bernoulli family of scientists and mathematicians. The site also includes links to many of Bernoulli's colleagues and contemporaries.

Bernoulli, Jakob (1654-1705)

Swiss mathematician who with his brother Johann pioneered German mathematician Gottfried Leibniz's calculus. Jakob used calculus to study the forms of many curves arising in practical situations, and studied mathematical probability; **Bernoulli numbers** are named after him.

Jakob Bernoulli's papers on transcendental curves (1696) and isoperimetry (1700, 1701) contain the first principles of the calculus of variations. It is probable that these papers owed something to collaboration with Johann. His other great achievement was his treatise on probability, *Ars Conjectandi* (1713), which contained both the Bernoulli numbers (a series of complex fractions) and the Bernoulli theorem.

Bernoulli, Johann (1667-1748)

Swiss mathematician who with his brother Jakob Bernoulli pioneered German mathematician Gottfried Leibniz's calculus. He was the father of Daniel Bernoulli. Johann also contributed to many areas of applied mathematics, including the problem of a particle moving in a gravitational field. He found the equation of the catenary in 1690 and developed exponential calculus in 1691.

Bernoulli's principle

law stating that the pressure of a fluid varies inversely with speed, an increase in speed producing a decrease in pressure (such as a drop in hydraulic pressure as the fluid speeds up flowing through a constriction in a pipe) and vice versa. The principle also explains the pressure differences on each surface of an aerofoil, which gives lift to the wing of an aircraft. The principle is named after Swiss mathematician and physicist Daniel Bernoulli.

Bernoulli's Equation

Go to site

Features a detailed description of Bernoulli's principle, together with an illustration to accompany the text. There are also related articles on propulsion and aerodynamics.

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berry

fleshy, many-seeded fruit that does not split open to release the seeds. The outer layer of tissue, the exocarp, forms an outer skin that is often brightly coloured to attract birds to eat the fruit and thus disperse the seeds. Examples of berries are the tomato and the grape.

A **pepo** is a type of berry that has developed a hard exterior, such as the cucumber fruit. Another is the **hesperidium**, which has a thick, leathery outer layer, such as that found in citrus fruits, and fluid-containing vesicles within, which form the segments.

Berthollet, Claude Louis (1748-1822)

Count

French chemist who carried out research into dyes and bleaches (introducing the use of chlorine as a bleach) and determined the composition of ammonia. Modern chemical nomenclature is based on a system worked out by Berthollet and Antoine Lavoisier.

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beryl

in full beryllium aluminium silicate, $3BeO.Al_2O_3.6SiO_2$

mineral that forms crystals chiefly in granite. It is the chief ore of beryllium. Two of its gem forms are aquamarine (light-blue crystals) and emerald (dark-green crystals).

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beryllium

chemical symbol Be

hard, lightweight, silver-white, metallic element, atomic number 4, relative atomic mass 9.012. It is one of the alkaline-earth metals, with chemical properties similar to those of magnesium. In nature it is found only in combination with other elements and occurs mainly as beryl ($3BeO.Al_2O_3.6SiO_2$). It is used to make sturdy, light alloys and to control the speed of neutrons in nuclear reactors. Beryllium oxide was discovered in 1798 by French chemist Louis-Nicolas Vauquelin (1763–1829), but the element was not isolated until 1828, by Friedrich Wöhler and Antoine-Alexandre-Brutus Bussy independently.

In 1992 large amounts of beryllium were unexpectedly discovered in six old stars in the Milky Way.

Berzelius, Jöns Jakob (1779-1848)

Swedish chemist. He accurately determined more than 2,000 relative atomic and molecular masses. In 1813–14, he devised the system of chemical symbols and formulae now in use and proposed oxygen as a reference standard for atomic masses. His discoveries include the elements cerium in 1804, selenium in 1817, and thorium in 1828; he was the first to prepare silicon in its amorphous form and to isolate zirconium. The words 'isomerism', 'allotropy', and 'protein' were coined by him.

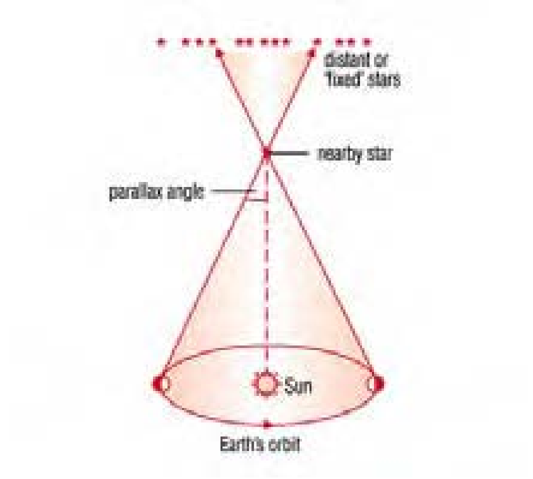
Berzelius noted that some reactions appeared to work faster in the presence of another substance which itself did not appear to change, and postulated that such a substance contained a **catalytic force**. Platinum, for example, was capable of speeding up reactions between gases. Although he appreciated the nature of catalysis, he was unable to give any real explanation of the mechanism.

Bessel, Friedrich Wilhelm (1784-1846)

German astronomer and mathematician. He was the first person to find the approximate distance to a star by direct methods when he measured the parallax (annual displacement) of the star 61 Cygni in 1838. In mathematics, he introduced the series of functions now known as Bessel functions.

Bessel's work laid the foundations for a more accurate calculation of the scale of the universe and the sizes of stars, galaxies, and clusters of galaxies. He was a pioneer of very precise observation and reduction in astronomy, and published a catalogue of 3,222 star positions under the title *Fundamenta Astronomiae* (1818). From the gravitational disturbance of the motions of Sirius and Procyon he deduced the existence of invisible companions of these stars. In 1840 he predicted the existence of Neptune.

Bessel



(Image © Research Machines plc)

The parallax of a star, the apparent change of its position during the year, can be used to find the star's distance from the Earth. The star appears to change its position because it is viewed at a different angle in July and January. By measuring the angle of parallax, and knowing the diameter of the Earth's orbit, simple geometry can be used to calculate the distance to the star. The technique was developed by the German astronomer Friedrich Bessel.

Bessel, Friedrich Wilhelm

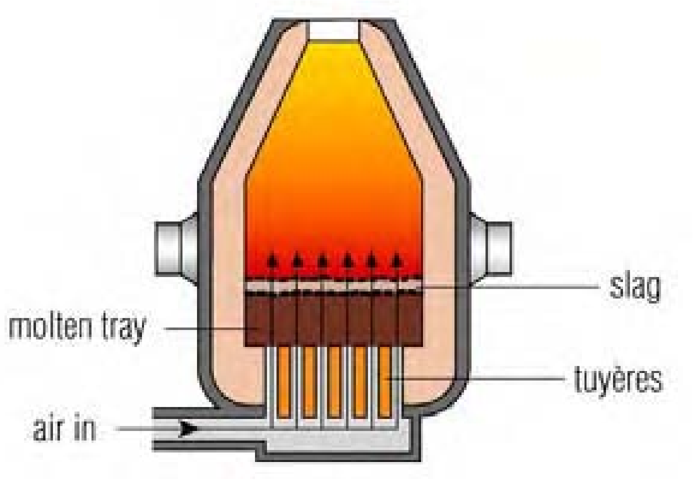
Go to site

Extensive biography of the German astronomer and mathematician. The Web site contains a clear description of the work of Bessel, and also describes his working relationships with his contemporaries. Also included are several literature references for further reading on the mathematician and a portrait of Bessel.

Bessemer process

first cheap method of making steel, invented by Henry Bessemer in England in 1856. It has since been superseded by more efficient steel-making processes, such as the basic-oxygen process. In the Bessemer process compressed air is blown into the bottom of a converter, a furnace shaped like a cement mixer, containing molten pig iron. The excess carbon in the iron burns out, other impurities form a slag, and the furnace is emptied by tilting.

Bessemer process



(Image © Research Machines plc)

In a Bessemer converter, a blast of high-pressure air oxidizes impurities in molten iron and converts it to steel.

Best, Charles H(erbert) (1899-1978)

Canadian physiologist. He was one of the team of Canadian scientists including Frederick Banting whose research resulted in 1922 in the discovery of insulin as a treatment for diabetes.

Best also discovered the vitamin choline and the enzyme histaminase, and introduced the use of the anticoagulant heparin.

beta-blocker

any of a class of drugs that block impulses that stimulate certain nerve endings (beta receptors) serving the heart muscle. This reduces the heart rate and the force of contraction, which in turn reduces the amount of oxygen (and therefore the blood supply) required by the heart. Beta-blockers may be useful in the treatment of angina, arrhythmia (abnormal heart rhythms), and raised blood pressure, and following heart attacks. They must be withdrawn from use gradually.

beta decay

the spontaneous alteration of the nucleus of a radioactive atom, which transmutes the atom from one atomic number to another through the emission of either an electron (beta-minus decay) or a positron (beta-plus decay). In the more commonly occurring of the two, beta-minus decay, the atomic number increases by one (through the decay of a neutron, which converts to a proton emitting an electron and an antineutrino); in the less commonly occurring beta-plus decay, the atomic number decreases by one (the proton converts to a neutron, emitting a positron and a neutrino). The symbol used for the electron in beta-minus decay is β^-; the symbol for the positron in beta-plus decay is β^+.

beta index

mathematical measurement of the connectivity of a transport network. If the network is represented as a simplified topological map, made up of nodes (junctions or places) and edges (links), the beta index may be calculated by dividing the number of nodes by the number of edges. If the number of nodes is n and the number of edges is e, then the beta index β is given by the formula:

$$\beta = n/e$$

The higher the index number, the better connected the network is. If β is greater than 1, then a complete circuit exists.

beta particle

or beta ray

electron ejected with great velocity from a radioactive atom that is undergoing spontaneous disintegration. Beta particles are created in the nucleus on disintegration, beta decay, when a neutron converts to a proton (the atomic number increases by one while the atomic mass stays the same) by emitting an electron. The mass lost in the change is converted into kinetic energy of the beta particle. Strontium-90 (^{90}Sr) is an example of a material that emits beta particles.

Beta particles are more penetrating than alpha particles, but less so than gamma radiation; they can travel several metres in air, but are stopped by 2-3 mm/0.08-0.1 in of aluminium. They are less strongly ionizing than alpha particles. Owing to their low mass, beta particles, like cathode rays, are easily deflected by magnetic and electric fields. Beta decay is caused by the weak nuclear force.

Betelgeuse

or Alpha Orionis

red supergiant star in the constellation of Orion. It is the tenth-brightest star in the night sky, although its brightness varies. It is 1,100 million km/700 million mi across, about 800 times larger than the Sun, roughly the same size as the orbit of Mars. It is over 10,000 times as luminous as the Sun, and lies 310 light years from the Sun. Light takes 60 minutes to travel across the giant star. The name is a corruption of the Arabic word meaning 'armpit'.

It was the first star whose angular diameter was measured with the Mount Wilson interferometer in 1920.

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betel nut

fruit of the areca palm (*Areca catechu*), which is chewed together with lime and betel pepper as a stimulant by peoples of the East and Papua New Guinea. Chewing it blackens the teeth and stains the mouth deep red.

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betony

plant belonging to the mint family, formerly used in medicine and dyeing. It has a hairy stem and leaves, and dense heads of reddish-purple flowers. (*Stachys* (formerly *Betonica*) *officinalis*, family Labiatae.)

Betony, Wood

Go to site

Detailed information about this plant, including an informative description of the plant, its history, and its habitat. It also features notes on the medicinal uses of the plant, which range from relieving headaches to treating rheumatism.

Bettelheim, Bruno (1903-1990)

Austrian-born US child psychologist. At the University of Chicago he founded a treatment centre for emotionally disturbed children based on the principle of a supportive home environment. Among his books are *Love Is Not Enough* (1950) and *The Uses of Enchantment: The Meaning and Importance of Fairy Tales* (1976).

Since his death, Bettelheim has been criticized for his autocratic and sometimes violent methods used in the Orthogenic School, Chicago.

Bézier curve

curved line invented by Pierre Bézier that connects a series of points (or 'nodes') in the smoothest possible way. The shape of the curve is governed by a series of complex mathematical formulae. They are used in computer graphics and CAD (computer-aided design).

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bhp

abbreviation for **brake horsepower**.

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bicarbonate

common name for hydrogencarbonate.

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bicarbonate of soda

or baking soda; technical name sodium hydrogencarbonate, $NaHCO_3$

white crystalline solid that neutralizes acids and is used in medicine to treat acid indigestion. It is also used in baking powders and effervescent drinks.

Bichat, Marie François Xavier (1771-1802)

French physician and founder of histology, the study of tissues. He studied the organs of the body, their structure, and the ways in which they are affected by disease.

This led to his discovery and naming of 'tissue', a basic biological and medical concept; he identified 21 types. He argued that disease does not affect the whole organ but only certain of its constituent tissues.

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bichir

African fish, genus *Polypterus*, found in tropical swamps and rivers. Cylindrical in shape, some species grow to 70 cm/2.3 ft or more. They show many 'primitive' features, such as breathing air by using the swimbladder, having a spiral valve in the intestine, having heavy bony scales, and having larvae with external gills. These, and the fleshy fins, lead some scientists to think they are related to lungfish and coelacanths.

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bicuspid

in biology, a structure with two cusps. Examples include the premolars (bicuspid teeth) and the mitral (bicuspid) valve of the heart.

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bicuspid valve

or mitral valve

in the left side of the heart, a flap of tissue that prevents blood flowing back into the atrium when the ventricle contracts.

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bicycle

pedal-driven two-wheeled vehicle used in cycling. It consists of a metal frame mounted on two large wire-spoked wheels, with handlebars in front and a seat between the front and back wheels. The bicycle is an energy-efficient, nonpolluting form of transport, and it is estimated that 800 million bicycles are in use throughout the world – outnumbering cars three to one. China, India, Denmark, and the Netherlands are countries with a high use of bicycles. More than 10% of road spending in the Netherlands is on cycleways and bicycle parking.

history

The first bicycle was probably created by the German Baron Karl de Drais de Sauerbrun, and exhibited in Paris *c.* 1818. It was a form of hobby-horse (though there are versions of the hobby-horse that date back even earlier) that had to be propelled by pushing the feet against the ground. The first treadle-propelled cycle was designed by the Scottish blacksmith Kirkpatrick Macmillan in around 1839. The Rover 'safety bike' of 1885 may be considered the forerunner of the modern bicycle, with a chain and sprocket drive on the rear wheel. By the end of the 19th century wire wheels, metal frames (replacing wood), and pneumatic tyres (invented by the Scottish veterinary surgeon John B Dunlop in 1888) had been added. Among the bicycles of that time was the front-wheel-driven penny farthing with a large front wheel.

technology

Recent technological developments have been related to reducing wind resistance caused by the frontal area and the turbulent drag of the bicycle. Most of an Olympic cyclist's energy is taken up in fighting wind resistance in a sprint. The first major innovation was the solid wheel, first used in competitive cycling 1984, but originally patented as long ago as 1878. Further developments include handlebars that allow the cyclist to crouch and use the shape of the hands and forearms to divert air away from the chest. Modern racing bicycles now have a monocoque structure produced by laying carbon fibre around an internal mould and then baking them in an oven. Using all these developments, Chris Boardman set a speed record of 54.4 kph (34 mph) on his way to winning a gold medal at the 1992 Barcelona Olympics. To manufacture a bicycle requires only 1% of the energy and materials used to build a car.

mountain bikes

Special bicycles with fat tyres, a strong frame, and more gears than conventional bicycles, designed to be ridden on rough terrain, have become popular since the 1970s; the first purpose-built mountain bikes went on sale in 1979. Mountain biking became an Olympic sport in 1996; there are also annual world championships.

bicycle

The world manufacture of bicycles was three times that for cars in 1997; the production rate of bicycles has increased fivefold since the 1960s.

biennial plant

plant that completes its life cycle in two years. During the first year it grows vegetatively and the surplus food produced is stored in its perennating organ, usually the root. In the following year these food reserves are used for the production of leaves, flowers, and seeds, after which the plant dies. Many root vegetables are biennials, including the carrot *Daucus carota* and parsnip *Pastinaca sativa*. Some garden plants that are grown as biennials are actually perennials, for example, the wallflower *Cheiranthus cheiri*.

bifocal lens

in medicine, lenses consisting of an upper section that improves distant vision and a lower section that facilitates reading. They are used most commonly to correct defects in vision that occur as part of the natural ageing process. Similar improvements in vision may be obtained using varifocal lenses.

Big Bang

in astronomy, the explosive event that marked the origin of the universe as we know it. At the time of the Big Bang, the entire universe was squeezed into a hot, superdense state. The Big Bang explosion threw this compact material outwards, producing the expanding universe seen today (see red shift). The cause of the Big Bang is unknown; observations of the current rate of expansion of the universe suggest that it took place about 10–20 billion years ago. The Big Bang theory began modern cosmology.

According to the modern modified version of the Big Bang theory, called the **inflationary theory**, the universe underwent a rapid period of expansion shortly after the Big Bang, which accounts for its current large size and uniform nature. The inflationary theory is supported by the most recent observations of the cosmic background radiation.

Present quantum theory and relativity theory break down when pushed back to earlier than 10^{-43} seconds, which is known as the Planck time. (10^{-43} is equal to $1 \div 10^{43}$; and 10^{43} is equal to 1 followed by 43 zeroes.) The present-day observable universe was then smaller than a proton and the temperature was 10^{32} K (kelvins – equal in size to degrees Celsius). Inflation began now or an instant later, and ended when 10^{-33} seconds had passed. The universe observable today was then a metre across.

One ten-thousandth of a second after the Big Bang, the temperature had decreased enormously, but was still 10 billion K (10^{10} K). Subatomic particles had formed by the collision of quarks. After 10 seconds, neutrons had combined with protons to form nuclei of deuterium (an isotope of hydrogen). The nuclei of deuterium then joined together to form helium nuclei. As the universe continued to expand for the next 300,000 years, the temperature cooled to 10,000 K. Under these conditions helium nuclei were able to join with electrons to form helium atoms. Some hydrogen nuclei joined to form lithium nuclei and thence lithium atoms. After millions of years, at lower temperature and pressure, the force of gravity was able to draw particles together. After millions more years, matter clumped together to form galaxies, stars, planets, and moons.

The first detailed images of the universe as it existed 300,000 years after the Big Bang were released by the US National Aeronautics and Space Administration (NASA) in April 2000. The images were created by mapping cosmic background radiation.

Big Crunch

in cosmology, possible fate of the universe in which it ultimately collapses to a point following the halting and reversal of the present expansion. See also Big Bang and critical density.

Big Dipper

American name for the Plough, the seven brightest and most prominent stars in the constellation Ursa Major, which in outline resemble a large dipper.

bight

coastal indentation, crescent-shaped or gently curving, such as the Bight of Biafra in West Africa and the Great Australian Bight.

bilberry

any of several shrubs belonging to the heath family, closely related to North American blueberries. Bilberries are sometimes referred to as blaeberries, whortleberries, or huckleberries. They have blue or black edible berries. (Genus *Vaccinium*, family Ericaceae.)

Bilberry

Go to site

Contains detailed information about the bilberry, including an informative description of the plant, its constituents, and its habitat. It also features notes on the uses of the plant, which include treating scurvy and diabetes. There is also information about making bilberry jam – one of the other better known uses.

bilby

rabbit-eared bandicoot *Macrotis lagotis*, a lightly built marsupial with big ears and long nose. This burrowing animal is mainly carnivorous, and its pouch opens backwards.

Bilby

Go to site

Profile of the Australian rabbit-eared bandicoot. This is one of a selection of fact sheets researched and compiled by the National Heritage Trust's Endangered Species Program. The profile, which is located in the Information and Resources section of the site, includes a description of the animal, details of its habitat, and reasons why it has become an endangered species.

bile

brownish alkaline fluid produced by the liver. Bile is stored in the gall bladder and is intermittently released into the small intestine (the duodenum), which is part of the gut, in order to help digestion. Bile contains chemicals that emulsify fats. In other words it acts to disperse fat globules into tiny droplets, which speeds up their digestion.

Bile consists of bile salts, bile pigments, cholesterol, and lecithin. The **bile salts** assist in the breakdown and absorption of fats, while **bile pigments** are the breakdown products of old red blood cells, which are passed into the gut to be eliminated with the faeces.

bile

To remember the properties of bile:

Bile from the liver emulsifies greases
Tinges the urine and colours the faeces
Aids peristalsis, prevents putrefaction
If you remember all this you'll give satisfaction

bilharzia

or schistosomiasis

disease that causes anaemia, inflammation, formation of scar tissue, dysentery, enlargement of the spleen and liver, cancer of the bladder, and cirrhosis of the liver. It is contracted by bathing in water contaminated with human sewage. Some 200 million people are thought to suffer from this disease in the tropics, and 750,000 people a year die.

Freshwater snails act as host to the first larval stage of blood flukes of the genus *Schistosoma*; when these larvae leave the snail in their second stage of development, they are able to pass through human skin, become sexually mature, and produce quantities of eggs, which pass to the intestine or bladder. Numerous eggs are excreted from the body in urine or faeces to continue the cycle. Treatment is by means of drugs, usually containing antimony, to kill the parasites.

bill

in birds, the projection of the skull bones covered with a horny sheath. It is not normally sensitive, except in some aquatic birds, rooks, and woodpeckers, where the bill is used to locate food that is not visible. The bills of birds are adapted by shape and size to specific diets, for example, shovellers use their bills to sieve mud in order to extract food; birds of prey have hooked bills adapted to tearing flesh; the bills of the avocet and the curlew are long and narrow for picking tiny invertebrates out of the mud; and those of woodpeckers are sharp for pecking holes in trees and plucking out insects. The bill is also used by birds for preening, fighting, display, and nest-building.

billion

cardinal number represented by a 1 followed by nine zeros (1,000,000,000 or 10^9), equivalent to a thousand million.

binary fission

in biology, a form of asexual reproduction, whereby a single-celled organism, such as a bacterium or amoeba, divides into two smaller 'daughter' cells.

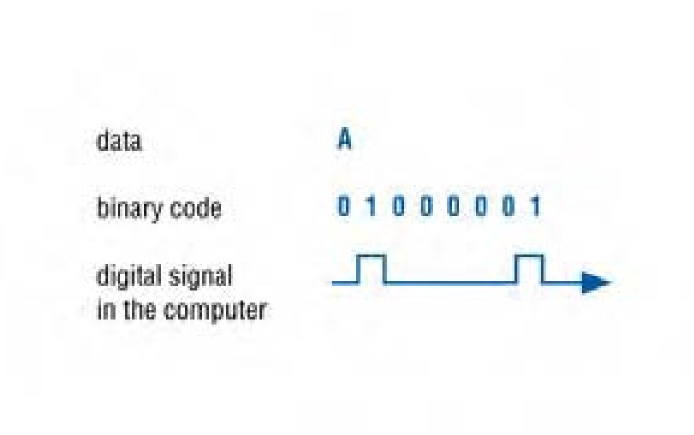
binary number system

system of numbers to base two, using combinations of the digits 1 and 0. Codes based on binary numbers are used to represent instructions and data in all modern digital computers, the values of the binary digits (contracted to 'bits') being stored or transmitted as, for example, open/closed switches, magnetized/unmagnetized disks and tapes, and high/low voltages in circuits.

The value of any position in a binary number increases by powers of 2 (doubles) with each move from right to left (1, 2, 4, 8, 16, and so on). For example, 1011 in the binary number system represents (1 × 8) + (0 × 4) + (1 × 2) + (1 × 1), which adds up to 11 in the decimal system.

The value of any position in a normal decimal, or base-10, number increases by powers of 10 with each move from right to left (1, 10, 100, 1,000, 10,000, and so on). For example, the decimal number 2,567 stands for (2 × 1,000) + (5 × 100) + (6 × 10) + (7 × 1).

binary number system



(Image © Research Machines plc)

The capital letter A represented in binary form.

binary search

in computing, rapid technique used to find any particular record in a list of records held in sequential order. The computer is programmed to compare the record sought with the record in the middle of the ordered list. This being done, the computer discards the half of the list in which the record does not appear, thereby reducing the number of records left to search by half. This process of selecting the middle record and discarding the unwanted half of the list is repeated until the required record is found.

binary star

pair of stars moving in orbit around their common centre of mass. Observations show that most stars are binary, or even multiple - for example, the nearest star system to the Sun, Rigil Kent (Alpha Centauri).

One of the stars in the binary system Epsilon Aurigae may be the largest star known. Its diameter is 2,800 times that of the Sun. If it were in the position of the Sun, it would engulf Mercury, Venus, Earth, Mars, Jupiter, and Saturn. A spectroscopic binary is a binary in which two stars are so close together that they cannot be seen separately, but their separate light spectra can be distinguished by a spectroscope.

Another type is the eclipsing binary, a double star in which the two stars periodically pass in front of each other as seen from Earth. When one star crosses in front of the other, the total light received on Earth from the two stars declines. The first eclipsing binary to be noticed was Algol, in 1670, by Italian astronomer Geminiano Montanari.

binding energy

in physics, the amount of energy needed to break the nucleus of an atom into the neutrons and protons of which it is made.

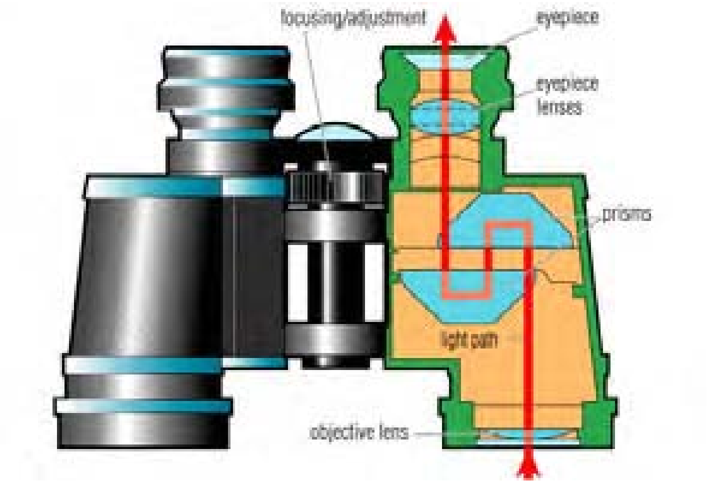
binoculars

optical instrument for viewing an object in magnification with both eyes; for example, field glasses and opera glasses. Binoculars consist of two telescopes containing lenses and prisms, which produce a stereoscopic effect as well as magnifying the image.

Use of prisms has the effect of 'folding' the light path, allowing for a compact design.

The first binocular telescope was constructed by the Dutch inventor Hans Lippershey in 1608. Later development was largely due to the German Ernst Abbe of Jena, who at the end of the 19th century designed prism binoculars that foreshadowed the instruments of today, in which not only magnification but also stereoscopic effect is obtained.

binoculars



(Image © Research Machines plc)

The essential components of binoculars are objective lenses, eyepieces, and a system of prisms to invert and reverse the image. A focusing system provides a sharp image by adjusting the relative positions of these components.

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binomial

in mathematics, an expression consisting of two terms, such as $a + b$ or $a - b$.

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binomial system of nomenclature

in biology, the system in which all organisms are identified by a two-part Latinized name. Devised by the biologist Linnaeus, it is also known as the Linnaean system. The first name is capitalized and identifies the genus; the second identifies the species within that genus, for example the bear genus *Ursus* includes *Ursus arctos*, the grizzly bear, and *Ursus maritimus*, the polar bear.

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binomial theorem

formula whereby any power of a binomial quantity may be found without performing the progressive multiplications.

It was discovered by Isaac Newton and first published in 1676.

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binturong

shaggy-coated mammal *Arctitis binturong*, the largest member of the mongoose family, nearly 1 m/3 ft long excluding a long muscular tail with a prehensile tip. Mainly nocturnal and tree-dwelling, the binturong is found in the forests of Southeast Asia, feeding on fruit, eggs, and small animals.

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biochemical oxygen demand

BOD

amount of dissolved oxygen taken up by micro-organisms in a sample of water. Since these micro-organisms live by decomposing organic matter, and the amount of oxygen used is proportional to their number and metabolic rate, BOD can be used as a measure of the extent to which the water is polluted with organic compounds.

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biochemistry

science concerned with the chemistry of living organisms: the structure and reactions of proteins (such as enzymes), nucleic acids, carbohydrates, and lipids.

Its study has led to an increased understanding of life processes, such as those by which organisms synthesize essential chemicals from food materials, store and generate energy, and pass on their characteristics through their genetic material. A great deal of medical research is concerned with the ways in which these processes are disrupted. Biochemistry also has applications in agriculture and in the food industry (for instance, in the use of enzymes).

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biodegradable

capable of being broken down by living organisms, principally bacteria and fungi. In biodegradable substances, such as food and sewage, the natural processes of decay lead to compaction and liquefaction, and to the release of nutrients that are then recycled by the ecosystem.

This process can have some disadvantageous side effects, such as the release of methane, an explosive greenhouse gas. However, the technology now exists for waste tips to collect methane in underground pipes, drawing it off and using it as a cheap source of energy. Nonbiodegradable substances, such as glass, heavy metals, and most types of plastic, present serious problems of disposal.

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biodiversity

contraction of biological diversity

measure of the variety of the Earth's animal, plant, and microbial species, of genetic differences within species, and of the ecosystems that support those species. High biodiversity means there are lots of different species in an area. The maintenance of biodiversity is important for ecological stability and as a resource for research into, for example, new drugs and crops.

Estimates of the number of species vary widely because many species-rich ecosystems, such as tropical forests, contain unexplored and unstudied habitats. Among small organisms in particular many are unknown. For example, it is thought that less than 1% of the world's bacterial species have been identified.

The most significant threat to biodiversity comes from the destruction of rainforests and other habitats. It is estimated that 7% of the Earth's surface hosts 50-75% of the world's biological diversity. Costa Rica, for example, has an area less than 10% of the size of France but possesses three times as many vertebrate species.

Animal Diversity Web

Go to site

Impressive database on animal diversity from the Museum of Zoology at the University of Michigan. The user may click on a group of animals then go to an individual animal to receive information on its taxonomy, habitat, and behaviour.

ARKive

Go to site

A growing database of zoomable photographs and video clips of the world's endangered plants, animals, and habitats form the core of this visually stunning Web site. In an effort to harness the power of cyberspace in the interests of global biodiversity, the ARKive project provides well-researched biological and taxonomic information on each species, an impassioned page on the importance of conserving rare species, and a wealth of educational and fun resources for children and teachers.

Biodiversity: Measuring the Variety of Nature

Go to site

Exhibition on biodiversity and conservation from the Natural History Museum in London, with sections on 'Biodiversity value', 'Rarity and endemism', and 'Conservation priority and gap analysis'.

'Biodiversity Loss Threatens New Treatments'

Go to site

Part of a collection of articles maintained by the *British Medical Journal*, this page features the full text of a news article originally published on 25 April 1998 that reports on how the loss of biodiversity will adversely affect the future of human health. You can also search the collections under which this article appears, search other articles written by the author of this article, and submit or read responses to this article.

Center for Biodiversity: Study of Plants and Animals

Go to site

If you have ever wondered about the mysteries of astacology, this site will provide the answers, as well as introducing other, less obscure, branches of taxonomic biology such as herpetology, mammology, and botany. Linked to the Illinois Natural History Survey's vast collection of photographs, this is an excellent resource for anyone wanting to explore the vast diversity of life on Earth.

Exploring the Environment

Go to site

Learning modules on environment-related earth science topics. Issues covered include biodiversity, land use, global warming, and water pollution. Information pages are accompanied by interactive learning activities.

Unexplored Spaces

Go to site

Visually stunning *National Geographic* page exploring some of the world's little-known biomes, and showing how much they have to teach scientists about the way in which life is organized. Taking a cobble-bed off the coast of New England, USA, as its starting point, this wide-ranging article branches off into the ocean floor, outer space and other unsuspected sources of knowledge about the processes of life.

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biodynamic farming

agricultural practice based on the principle of homeopathy: tiny quantities of a substance are applied to transmit vital qualities to the soil. It is a form of organic farming, and was developed by the Austrian holistic mystic Rudolf Steiner and Ehrenfried Pfiffer.

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bioenergetics

in alternative medicine, extension of Reichian therapy principles developed in the 1960s by US physician Alexander Lowen, and designed to promote, by breathing, physical exercise, and the elimination of muscular blockages, the free flow of energy in the body and thus restore optimum health and vitality. Bioenergetics is also known by the terms bioenergetic therapy and bioenergetic analysis.

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bioengineering

application of engineering to biology and medicine. Common applications include the design and use of artificial limbs, joints, and organs, including hip joints and heart valves.

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biofeedback

in biology, modification or control of a biological system by its results or effects. For example, a change in the position or trophic level of one species affects all levels above it.

Many biological systems are controlled by negative feedback. When enough of the hormone thyroxine has been released into the blood, the hormone adjusts its own level by 'switching off' the gland that produces it. In ecology, as the numbers in a species rise, the food supply available to each individual is reduced. This acts to reduce the population to a sustainable level.

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biofeedback

in medicine, the use of electrophysiological monitoring devices to 'feed back' information about internal processes and thus facilitate conscious control. Developed in the USA in the 1960s, independently by neurophysiologist Barbara Brown and neuropsychiatrist Joseph Kamiya, the technique is effective in alleviating hypertension and preventing associated organic and physiological dysfunctions.

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biofuel

any solid, liquid, or gaseous fuel produced from organic (once living) matter, either directly from plants or indirectly from industrial, commercial, domestic, or agricultural wastes. There are three main methods for the development of biofuels: the burning of dry organic wastes (such as household refuse, industrial and agricultural wastes, straw, wood, and peat); the fermentation of wet wastes (such as animal dung) in the absence of oxygen to produce biogas (containing up to 60% methane), or the fermentation of sugar cane or maize to produce alcohol and esters; and energy forestry (producing fast-growing wood for fuel).

Fermentation produces two main types of biofuels: alcohols and esters. These could theoretically be used in place of fossil fuels but, because major alterations to engines would be required, biofuels are usually mixed with fossil fuels. The EU allows 5% ethanol, derived from wheat, beet, potatoes, or maize, to be added to fossil fuels. In Brazil ethanol from sugar cane is used in cars run either on ethanol, on gasohol (a blend of petrol and ethanol), or on both ('dual-fuel' engines). Ethanol replaces 40% of the petrol that the country would use for motor transport.

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biogenesis

biological term coined in 1870 by English scientist Thomas Henry Huxley to express the hypothesis that living matter always arises out of other similar forms of living matter. It superseded the opposite idea of spontaneous generation or abiogenesis (that is, that living things may arise out of nonliving matter).

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biogeography

study of how and why plants and animals are distributed around the world, in the past as well as in the present; more specifically, a theory describing the geographical distribution of species developed by Robert MacArthur and US zoologist Edward O Wilson. The theory argues that, for many species, ecological specializations mean that suitable habitats are patchy in their occurrence. For example, for a dragonfly, ponds in which to breed are separated by large tracts of land, and for edelweiss adapted to alpine peaks the deep valleys between cannot be colonized.

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biological clock

regular internal rhythm of activity, produced by periodic changes in the concentrations of certain molecules, described as circadian rhythms. Such clocks are known to exist in almost all animals, and also in many plants, fungi, and unicellular organisms. In higher organisms, there appears to be a series of clocks of graded importance. For example, although body temperature and activity cycles in human beings are normally 'set' to 24 hours, the two cycles may vary independently, showing that two clock mechanisms are involved.

The first biological clock gene in plants was isolated in 1995 by a US team of researchers.

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biological control

control of pests such as insects and fungi through biological means, rather than the use of chemicals. This can include breeding resistant crop strains; inducing sterility in the pest; infecting the pest species with disease organisms; or introducing the pest's natural predator. Biological control tends to be naturally self-regulating, but as ecosystems are so complex, it is difficult to predict all the consequences of introducing a biological controlling agent.

Ladybirds are sometimes used to control aphids because both adults and larvae feed on them. In 1998 French researchers patented a method of selective breeding to produce hardy, flightless ladybirds for use in biological control, as captive populations are far more effective than mobile ones.

The introduction of the cane toad to Australia 50 years ago to eradicate a beetle that was destroying sugar beet provides an example of the unpredictability of biological control. Since the cane toad is poisonous it has few Australian predators and it is now a pest, spreading throughout eastern and northern Australia at a rate of 35 km/22 mi a year.

Biological Control

Go to site

University-based site on the various methods of biological control used by farmers in the USA. This includes sections on parasitoids, predators, pathogens, and weed feeders. Each section contains images and sections on 'Relative effectiveness' and 'Pesticide susceptibility'.

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biological shield

shield around a nuclear reactor that is intended to protect personnel from the effects of radiation. It usually consists of a thick wall of steel and concrete.

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biological weathering

or organic weathering

form of weathering caused by the activities of living organisms - for example, the growth of roots or the burrowing of animals. Tree roots are probably the most significant agents of biological weathering as they are capable of prising apart rocks by growing into cracks and joints. Plants also give off organic acids that help to break down rocks chemically (see chemical weathering).

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biology

(Greek bios 'life', logos 'discourse')

science of life. Biology includes all the life sciences - for example, anatomy and physiology (the study of the structure of living things), cytology (the study of cells), zoology (the study of animals), botany (the study of plants), ecology (the study of habitats and the interaction of living species), animal behaviour, embryology, and taxonomy (classification), and plant breeding. Increasingly biologists have concentrated on molecular structures: biochemistry, biophysics, and genetics (the study of inheritance and variation).

Biological research has come a long way towards understanding the nature of life. From the late 1990s our knowledge was greatly extended by the Human Genome Project, which mapped the entire genome sequences of many species, including human and chimpanzee. In the 'postgenomic' era, interpretation of this vast body of information in terms of protein function and metabolism (known as proteomics and metabolomics respectively) has become an important challenge, as is the understanding of organisms on the systems level (systems biology).

living organisms

To remember the major characteristics of living organisms:

Newmarket **r**uns **e**very **g**reat **r**ace **i**n **M**ay

nutrition, **r**espiration, **e**xcretion, **g**rowth, **r**eproduction, **i**rritability (response to conditions), **m**ovement

Biology: key dates

c. 500 BC	First studies of the structure and behaviour of animals, by the Alcmaeon of Croton.
c. 450	Hippocrates of Kos undertakes the first detailed studies of human anatomy.
c. 350	Aristotle lays down the basic philosophy of the biological sciences and outlines a theory of evolution.
c. 300	Theophrastus carries out the first detailed studies of plants.
c. AD 175	Galen establishes the basic principles of anatomy and physiology.
c. 1500	Leonardo da Vinci studies human anatomy to improve his drawing ability and produces detailed anatomical drawings.
1628	William Harvey describes the circulation of the blood and the function of the heart as a pump.
1665	Robert Hooke uses a microscope to describe the cellular structure of plants. This is the first description of cells.
1672	Marcello Malpighi undertakes the first studies in embryology by describing the development of a chicken egg.
1677	Anton van Leeuwenhoek greatly improves the microscope and uses it to describe spermatozoa as well as many micro-organisms.
1736	Carolus Linnaeus (Carl von Linné) publishes his systematic classification of plants, so establishing taxonomy.
1768-79	James Cook's voyages of discovery in the Pacific reveal a great diversity of living species, prompting the development of theories to explain their origin.
1796	Edward Jenner establishes the practice of vaccination against smallpox, laying the foundations for theories of antibodies and immune reactions.
1809	Jean-Baptiste Lamarck advocates a theory of evolution through inheritance of acquired characteristics.
1812	Mary Anning discovers the fossilized skeleton of an ichthyosaurus, one of the first finds proving that huge reptiles once dominated the Earth. The discovery paves the way for a new understanding of the Earth's remote past, challenging the Biblical account of creation.
1822	Gideon and Anne Mantell discover the fossil of an iguanadon.
1839	Theodor Schwann proposes that all living matter is made up of cells.
1842	Richard Owen coins the word 'dinosaur' (from the Greek for terrible lizard) to describe the animals belonging to what we now know as two groups of reptiles that dominated the Earth for 175 million years during the Triassic, Jurassic, and Cretaceous periods.
1857	Louis Pasteur establishes that micro-organisms are responsible for fermentation, creating the discipline of microbiology.
1859	Charles Darwin publishes *On the Origin of Species*, expounding his theory of the evolution of species by natural selection.
1865	Gregor Mendel pioneers the study of inheritance with his experiments on peas, but achieves little recognition.
1869	Alfred Russell Wallace, who arrived at a theory of the origin of species independently of Darwin, describes the differences between the flora and fauna in the western and eastern parts of the Malay archipelago. Those in the west are related to plants and animals in Asia, those of the east are related to species found in Australia. An imaginary line, called Wallace's Line, divides the two populations.
1883	August Weismann proposes his theory of the continuity of the germ plasm.
1900	Mendel's work is rediscovered and the science of genetics founded.
1910	T H Morgan discovers that genes are physically located on chromosomes within cell nuclei.
1935	Konrad Lorenz publishes the first of many major studies of animal behaviour, creating the discipline of ethology.
1944	Oswald Avery and co-workers discover that genes consist of DNA.
1953	James Watson and Francis Crick describe the molecular structure of DNA.
1964	William Hamilton recognizes the importance of inclusive fitness, so paving the way for the development of sociobiology.
1969	Jonathan Beckwith and co-workers isolate a single gene for the first time.
1973	Stanley H Cohen and Herbert W Boyer demonstrate the use of restrictive enzymes for slicing up DNA.
1975	Discovery of endogenous opiates (the brain's own painkillers) opens up a new phase in the study of brain chemistry.

1976	Har Gobind Khorana and his colleagues construct the first artificial gene to function naturally when inserted into a bacterial cell, a major step in genetic engineering.
1982	Gene databases are established at Heidelberg, Germany, for the European Molecular Biology Laboratory, and at Los Alamos, USA, for the US National Laboratories.
1985	The first human cancer gene, retinoblastoma, is isolated by researchers at the Massachusetts Eye and Ear Infirmary and the Whitehead Institute, Massachusetts, USA.
1988	The Human Genome Organization (HUGO) is established in Washington, DC, USA, with the aim of mapping the complete sequence of human DNA.
1991	Biosphere 2, an experiment that attempts to reproduce the world's biosphere in miniature within a sealed glass dome, is launched in Arizona, USA.
1992	Researchers at the University of California, USA, stimulate the multiplication of isolated brain cells of mice, overturning the axiom that mammalian brains cannot produce replacement cells once birth has taken place. The world's largest organism, a honey fungus with underground hyphae (filaments) spreading across 600 hectares/1,480 acres, is discovered in Washington State, USA.
1994	Scientists from Pakistan and the USA unearth a 50-million-year-old fossil whale with hind legs that would have enabled it to walk on land.
1996	The sequencing of the genome of brewer's yeast *Saccharomyces cerevisiae* is completed, the first time this has been achieved for an organism more complex than a bacterium. The 12 million base pairs of genes took 300 scientists six years to map. A new muscle is discovered by two US dentists. It is 3 cm/1 in long, and runs from the jaw to behind the eye socket.
1997	The first mammal to be cloned from a nonreproductive cell is born. The lamb (named Dolly) has been cloned from an udder cell from a six-year-old ewe.
1999	Canadian researchers engineer an artificial chromosome that can be inserted into mammal cells and then transmitted from one generation to the next. The development has important implications towards germ-line therapy where a defect is corrected in the gametes and the change passed on to future generations.
2000	Scientists complete a rough working draft of the map of the entire human genome.
2002	According to a United Nations report, a quarter of the world's species of mammals face extinction within 30 years.
2004	A new species of human, 1 metre tall, is discovered to have lived in Indonesia up until 12,000 years ago.
2005	A report commissioned by the UK government notes that climate change affects migration routes and could lead to the extinction of many animals.
2006	The Human Genome Project is completed, with the publication of the DNA sequence of the final chromosome.

Biology for Kids

Go to site

Lively introduction to Biology with vivid diagrams and explanations. The four Biology sections cover 'Cells','Biochemistry', 'Ecology', and the study of scientific method.

Biology Project

Go to site

A large, educational Web site set up by the University of Arizona that deals with many aspects of biology, including cell biology, developmental biology, human health, genetics, and molecular biology.

Biology Timeline

Go to site

Chronology of important developments in palaeontology and the biological sciences from 610 BC to the present. It mentions items from the realization by early philosophers that fossilized species found inland lived in the sea, to the publication of a theory on the origins of life by modern scientists.

GCSE Bitesize Revision - Biology

Go to site

Handy revision guide from the BBC's 'Bitesize' revision Web site. Work your way through 'Revision bites' on key areas of the syllabus, then move on to the 'Test bites' on each subject when you are feeling more confident of your level of knowledge.

Instructional Multimedia - Introductory Biology

Go to site

With a strong graphical emphasis, this Web site introduces the basic concepts of biology. It is useful as a topic refresher, or as an alternative explanation to a difficult topic. The Web site relies heavily upon Flash technology, which is available via a download link.

Life in Extreme Environments

Go to site

Fully searchable database of information on the scientific research into plants and animals living in extreme conditions. The site includes sections on organisms that can survive extremes of darkness, cold, radiation, and heat.

MIT Biology Hypertextbook

Go to site

Hypertext biology book, with topics on all the main aspects of biology. Pictures illustrate the text, and each page of the book features easy navigation controls.

Protein Data Bank WWW Home Page

Go to site

Expanding scientific site that contains a fully searchable database of molecules. This is useful for students as well as more in-depth researchers.

Quia: Biology

Go to site

Twenty biology activities are included on this site, which can be used to highlight the topics that require extra revision. Each activity, on average, contains three types of test: concentration, flashcards, and a word search, although some activities may feature other tests. A list of terms for each topic is also available.

Webwise SPINNERET Biology

Go to site

Packed full of information on practically all the topics that are required for the biology component of double award science and biology as a single science. Try out some of the worksheets! To use the full scope of this site a registration process is required, but this is simple to complete.

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bioluminescence

production of light by living organisms. It is a feature of many deep-sea fishes, crustaceans, and other marine animals. On land, bioluminescence is seen in some nocturnal insects such as glow-worms and fireflies, and in certain bacteria and fungi. Light is usually produced by the oxidation of luciferin, a reaction catalysed by the enzyme luciferase. This reaction is unique, being the only known biological oxidation that does not produce heat. Animal luminescence is involved in communication, camouflage, or the luring of prey, but its function in some organisms is unclear.

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biomass

total mass of living organisms present in a given area. It may be used to describe the mass of a particular species (such as earthworm biomass), for a general category (such as herbivore biomass – animals that eat plants), or for everything in a habitat. Estimates also exist for the entire global plant biomass. Biomass can be the mass of the organisms as they are – wet biomass – or the mass of the organisms after they have been dried to remove all the water – dry biomass. Measurements of biomass can be used to study interactions between organisms, the stability of those interactions, and variations in population numbers. Growth results in an increase in biomass, so biomass is a good measure of the extent to which organisms thrive in particular habitats. For a plant, biomass increase occurs as a result of the process of photosynthesis. For a herbivore, biomass increase depends on the availability of plant food. Studying biomass in a habitat is a useful way to see how food is passed from organism to organism along food chains and through food webs.

Some two-thirds of the world's population cooks and heats water by burning biomass, usually wood. Plant biomass can be a renewable source of energy as replacement supplies can be grown relatively quickly. Fossil fuels, however, originally formed from biomass, accumulate so slowly that they cannot be considered renewable. The burning of biomass (defined either as natural areas of the ecosystem or as forest, grasslands, and fuel woods) produces 3.5 million tonnes of carbon in the form of carbon dioxide each year, accounting for up to 40% of the world's annual carbon dioxide production.

Plant biomass can be changed into liquid or gaseous fuels to generate electricity or heat, or to fuel internal combustion engines. Fuel from biomass is burned in a reactor to generate heat energy, which is then converted into mechanical energy to turn turbine blades in a generator to produce electricity. Biomass power stations of 80 megawatts can produce electricity to power approximately 42,000 homes.

Biomass

Go to site

Information on biomass from the US Department of Energy. There is a clear explanation of the chemical composition of biomass and development of technologies to transform it into usable fuel sources.

Willow Biomass for Energy

Go to site

Description of the environment friendly use of willow biomass as an energy source. The site goes on to discuss the possibilities of wood energy plantations which could be producing 'green' energy in the near future.

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biome

broad natural assemblage of plants and animals shaped by common patterns of vegetation and climate. Examples include the tundra biome, the rainforest biome, and the desert biome.

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biomechanics

application of mechanical engineering principles and techniques in the field of medicine and surgery, studying natural structures to improve those produced by humans. For example, mother-of-pearl is structurally superior to glass fibre, and deer antlers have outstanding durability because they are composed of microscopic fibres. Such natural structures may form the basis of 'high-tech' composites. Biomechanics has been responsible for many advances in orthopaedics, anaesthesia, and intensive care. Biomechanical assessment of the requirements for replacement of joints, including evaluation of the stresses and strains between parts, and their reliability, has allowed development of implants with very low friction and long life.

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biometry

literally, the measurement of living things, but generally used to mean the application of mathematics to biology. The term is now largely obsolete, since mathematical or statistical work is an integral part of most biological disciplines.

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bionics

(from 'biological electronics')

design and development of electronic or mechanical artificial systems that imitate those of living things. The bionic arm, for example, is an artificial limb (prosthesis) that uses electronics to amplify minute electrical signals generated in body muscles to work electric motors, which operate the joints of the fingers and wrist.

The first artificial eye that connects directly into the optic nerve was successfully implanted in 2000 for an initial trial. The eye was composed of a video camera, radio antenna, and microchip, and stimulated different parts of the optic nerve enabling visual sensations in the brain. Bionic ears work by replacing with electrodes the hairs in the ear that naturally convert sounds into electrical impulses. The first person to receive two bionic ears was Peter Stewart, an Australian journalist, who received his right ear in 1984 and his left in 1989.

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biophysics

application of physical laws to the properties of living organisms. Examples include using the principles of mechanics to calculate the strength of bones and muscles, and thermodynamics to study plant and animal energetics.

In a broader sense, biological or biochemical investigations using physical methods such as X-ray crystallography are also described as biophysics.

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biopsy

removal of a living tissue sample from the body for diagnostic examination.

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biorhythm

rhythmic change, mediated by hormones, in the physical state and activity patterns of certain plants and animals that have seasonal activities. Examples include winter hibernation, spring flowering or breeding, and periodic migration. The hormonal changes themselves are often a response to changes in day length (photoperiodism); they signal the time of year to the animal or plant. Other biorhythms are innate and continue even if external stimuli such as day length are removed. These include a 24-hour or circadian rhythm, a 28-day or circalunar rhythm (corresponding to the phases of the Moon), and even a year-long rhythm in some organisms.

Such innate biorhythms are linked to an internal or biological clock, whose mechanism is still poorly understood.

Often both types of rhythm operate; thus many birds have a circalunar rhythm that prepares them for the breeding season, and a photoperiodic response. There is also a nonscientific and unproven theory that human activity is governed by three biorhythms: the **intellectual** (33 days), the **emotional** (28 days), and the **physical** (23 days). Certain days in each cycle are regarded as 'critical', even more so if one such day coincides with that of another cycle.

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biosensor

device based on microelectronic circuits that can directly measure medically significant variables for the purpose of diagnosis or monitoring treatment. One such device measures the blood sugar level of diabetics using a single drop of blood, and shows the result on a liquid crystal display within a few seconds.

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biosphere

narrow zone that supports life on our planet. It is limited to the waters of the Earth, a fraction of its crust, and the lower regions of the atmosphere. The biosphere is made up of all the Earth's ecosystems. It is affected by external forces such as the Sun's rays, which provide energy, the gravitational effects of the Sun and Moon, and cosmic radiations.

BioSphere 2

BS2

ecological test project, a 'planet in a bottle', in Arizona, USA. Under a sealed glass and metal dome, different habitats are recreated, with representatives of nearly 4,000 species, to test the effects that various environmental factors have on ecosystems. Simulated ecosystems, or 'mesocosms', include savannah, desert, rainforest, marsh, and Caribbean reef. The response of such systems to elevated atmospheric concentrations of carbon dioxide gas (CO_2) are among the priorities of Biosphere 2 researchers.

Biosphere 2 Centre

Go to site

All about the Biosphere 2 project in Oracle, Arizona, including a virtual tour of the site. There are full details of the research programmes being conducted on the 'seven wilderness ecosystems' contained within the dome. The site also contains tailored educational resources for schoolchildren.

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biosynthesis

synthesis of organic chemicals from simple inorganic ones by living cells – for example, the conversion of carbon dioxide and water to glucose by plants during photosynthesis.

Other biosynthetic reactions produce cell constituents including proteins and fats.

Biosynthesis requires energy; in the initial or light-dependent stages of photosynthesis this is obtained from sunlight, but in all other instances, it is supplied chemically by ATP and NADPH. The term is also used in connection with the products achieved through biotechnology processes.

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biotechnology

industrial use of living organisms. Examples of its uses include fermentation, genetic engineering (gene technology), and the manipulation of reproduction. The brewing and baking industries have long relied on the yeast micro-organism for fermentation purposes, while the dairy industry employs a range of bacteria and fungi to convert milk into cheeses and yoghurts. Enzymes, whether extracted from cells or produced artificially, are central to most biotechnological applications. Recent advances include genetic engineering, in which single-celled organisms with modified DNA are used to produce insulin and other drugs.

There are many medical and industrial applications of the use of micro-organisms, such as drug production. One important area is the production of antibiotics such as penicillin.

It is thought that biotechnology may be helpful in reducing world food shortages. Micro-organisms grow very quickly in suitable conditions and they often take substances that humans cannot eat and use them to produce foods that we can eat.

Access Excellence

Go to site

US-based site for biology teachers sponsored by a biotechnology company, this site has plenty to interest the casual browser as well – particularly its 'What's new?' section, with weekly science reports and interviews with scientists making the news, and 'About biotech', an in-depth look at the field of biotechnology.

Chemisty and Industry Magazine

Go to site

Latest developments in the fast-changing world of biotechnology. This online edition of *Chemistry and Industry* has well-written and readily understandable articles on biotechnology, chemistry, and the pharmaceutical industry. There is also a searchable archive of articles dating back to 1995.

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biotin

or vitamin H

vitamin of the B complex, found in many different kinds of food; egg yolk, liver, legumes, and yeast contain large amounts. Biotin is essential to the metabolism of fats. Its absence from the diet may lead to dermatitis.

In structural and molecular biology, biotin is widely used as a marker substance, as it is easily recognized with the help of molecules such as streptavidin.

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biotite

dark mica, $K(Mg, Fe)_3Al\ Si_3O_{10}(OH, F)_2$, a common silicate mineral. It is brown to black with shiny surfaces, and like all micas, it splits into very thin flakes along its one perfect cleavage. Biotite is a mineral found in igneous rocks, such as granites, and metamorphic rocks such as schists and gneisses.

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birch

any of a group of slender trees with small leaves and fine, peeling bark. About 40 species are found in cool temperate parts of the northern hemisphere. Birches grow rapidly, and their hard, beautiful wood is used for veneers and cabinet work. (Genus *Betula*, family Betulaceae.)

Birch, Common

Go to site

Detailed information about this tree, including an informative description of the common birch, its history, and its habitat. This site also features notes on the constituents and medicinal uses of the common birch, which range from acting as an astringent to treating skin conditions.

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bird

backboned animal of the class Aves, the biggest group of land vertebrates, characterized by warm blood, feathers, wings, breathing through lungs, and egg-laying by the female. Birds are bipedal; feet are usually adapted for perching and never have more than four toes. Hearing and eyesight are well developed, but the sense of smell is usually poor. No existing species of bird possesses teeth.

Most birds fly, but some groups (such as ostriches) are flightless, and others include flightless members. Many communicate by sounds (nearly half of all known species are songbirds) or by visual displays, in connection with which many species are brightly coloured, usually the males. Birds have highly developed patterns of instinctive behaviour. There are nearly 8,500 species of birds.

According to the Red List of endangered species published by the World Conservation Union for 1996, 11% of bird species are threatened with extinction.

wing structure

The wing consists of the typical bones of a forelimb, the humerus, radius and ulna, carpus, metacarpus, and digits. The first digit is the pollex, or thumb, to which some feathers, known as ala spuria, or bastard wing, are attached; the second digit is the index, which bears the large feathers known as the primaries or manuals, usually ten in number. The primary feathers, with the secondaries or cubitals, which are attached to the ulna, form the large wing-quills, called remiges, which are used in flight.

anatomy

The sternum, or breastbone, of birds is affected by their powers of flight: those birds which are able to fly have a keel projecting from the sternum and serving as the basis of attachment of the great pectoral muscles which move the wings. In birds that do not fly the keel is absent or greatly reduced. The vertebral column is completed in the tail region by a flat plate known as the pygostyle, which forms a support for the rectrices, or steering tailfeathers.

The legs are composed of the femur, tibia and fibula, and the bones of the foot; the feet usually have four toes, but in many cases there are only three. In swimming birds the legs are placed well back.

The uropygial gland on the pygostyle (bone in the tail) is an oil gland used by birds in preening their feathers, as their skin contains no sebaceous glands. The eyes have an upper and a lower eyelid and a semitransparent nictitating membrane with which the bird can cover its eyes at will.

The **vascular system** contains warm blood, which is kept usually at a higher temperature (about 41°C/106°F) than that of mammals; death from cold is rare unless the bird is starving or ill. The aortic arch (main blood vessel leaving the heart) is on the right side of a bird, whereas it is on the left in a mammal. The heart of a bird consists of a right and a left half with four chambers.

The **lungs** are small and prolonged into air-sacs connected to a number of air-spaces in the bones. These air-spaces are largest in powerful fliers, but they are not so highly developed in young, small, aquatic, and terrestrial birds. These air-spaces increase the efficiency of the respiratory system and reduce the weight of the bones. The lungs themselves are more efficient than those of mammals; the air is circulated through a system of fine capillary tubes, allowing continuous gas exchange to take place, whereas in mammals the air comes to rest in blind air sacs.

The organ of voice is not the larynx, but usually the syrinx, a peculiarity of this class formed at the bifurcation of the trachea (windpipe) and the modulations are effected by movements of the adjoining muscles.

digestion

Digestion takes place in the oesophagus, stomach, and intestines in a manner basically similar to mammals. The tongue aids in feeding, and there is frequently a **crop**, a dilation of the oesophagus, where food is stored and softened. The stomach is small with little storage capacity and usually consists of the proventriculus, which secretes digestive juices, and the gizzard, which is tough and muscular and grinds the food, sometimes with the aid of grit and stones retained within it. Digestion is completed, and absorption occurs, in the intestine and the digestive caeca. The intestine ends in a cloaca through which both urine and faeces are excreted.

nesting and eggs

Typically eggs are brooded in a nest and, on hatching, the young receive a period of parental care. The collection of nest material, nest building, and incubation may be carried out by the male, female, or both. The cuckoo neither builds a nest nor rears its own young, but places the eggs in the nest of another bird and leaves the foster parents to care for them.

hatching

Just before hatching the chick's head breaks through the egg membrane so that it is now breathing air in the air space between membrane and shell. Chicks in a clutch may make a clicking noise (sometimes clicking at a rate of over a hundred clicks per second) that enables them to communicate with the other chicks that are hatching, so that they can synchronize hatching. This is often that case with ground hatching birds that will usually abandon the nest site once chicks are hatched, to help avoid detection by predators by not staying too long in one place. For example, the female quail lays her eggs over two weeks, and yet the eggs will hatch together.

To escape from the egg, the chick must force its way through the shell. Its beak is still very soft but it has upon it a beak tooth or egg tooth, a small spike, usually on top of the beak, with which it pushes against the shell. There is a special muscle at the back of its neck that gives the chick extra strength to hammer against the shell. It may also kick with its legs.

The study of birds is called ornithology.

bird: names

Rifleman, short-tailed pygmy tyrant, frilled coquette, bobwhite, tawny frogmouth, trembler, wattle-eye, fuscous honeyeater, dickcissel, common grackle, and forktailed drongo are all common names for species of bird.

bird: reproduction

Only 3% of bird species possess a penis (intromittent organ). Most of these are large birds such as the ostrich and goose. Most bird species reproduce by placing their cloacas together. The male deposits his sperm and the female draws it in.

bird: weight

The weight of a bird's plumage may be greater than the weight of its bones.

Bird: Fossils of Early Birds

early birds

Archaeopteryx has always been regarded as the success story of evolutionary study. Since its first discovery in late Jurassic rocks in Germany in 1861, six specimens have come to light. A seventh was unearthed in the summer of 1992.

As the transitional form between dinosaurs and birds, *Archaeopteryx* combines the dinosaur features of clawed hands, toothed jaws, and long bony tail, with the bird features of feathers and functioning wings. In the absence of other fossils it can be imagined that the descendants of *Archaeopteryx* gradually lost the hands, the jaws, and the tail, and became more and more like modern birds. But a few bird fossils have ben unearthed in recent years, which show that the evolutionary progression is not as simple as envisaged.

other bird fossils

Sparrow-sized *Sinornis* from the early Cretaceous of China, discovered in 1990, looked very much like a modern bird, with its stump of a tail and perching feet. It still had claws on its wings, and teeth in its jaws, and was almost a transitional form between *Archaeopteryx* and modern birds.

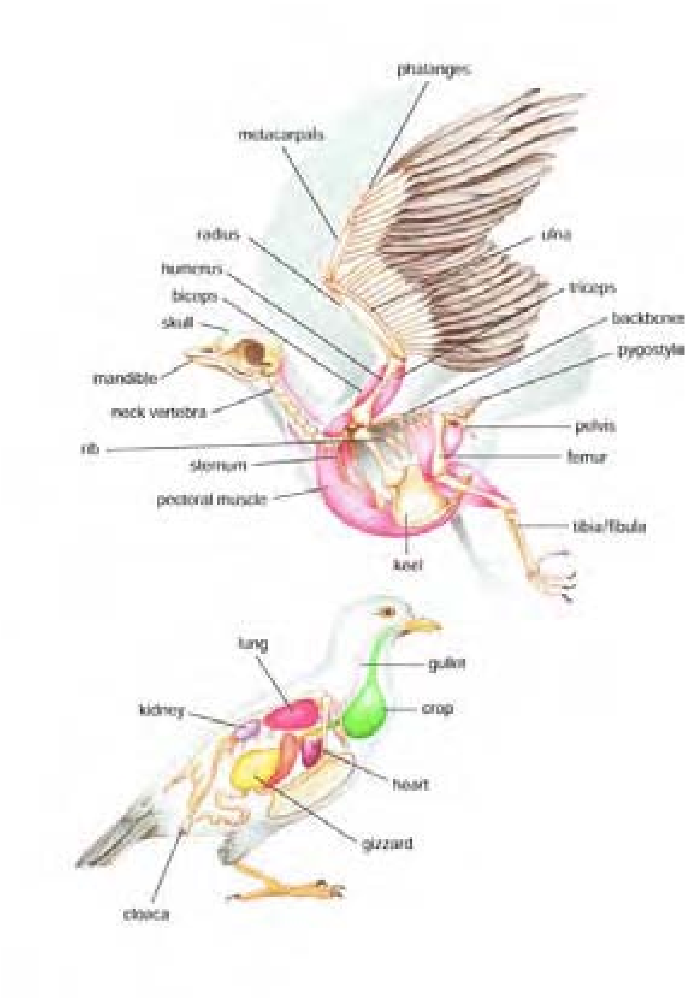
However, a hen-sized flightless bird from the late Cretaceous of Argentina (as yet unnamed) had a short but lizard-like tail, and wings that were too small to allow it to fly. It probably had flying ancestors but later reverted to a ground-dwelling existence.

A late Cretaceous oddity called *Mononychus*, discovered in Mongolia in 1992, was essentially a slimly-built pheasant-sized dinosaur. But it had the legs of a wading bird and stumpy forelimbs, like degenerate bird's wings, each with a large claw at the tip. It fits into no imagined scheme of bird evolution.

so how did birds evolve?

It seems that after *Archaeopteryx* the birds branched out into many different lineages, most of which became extinct, leaving only the line that evolved into the modern types. And to confuse the issue further, a contentious jumble of bones from the Triassic of Texas has been given the name *Protoavis* and is regarded by its discoverer as the earliest bird – 75 million years older than *Archaeopteryx* itself.

bird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sternum
pectoral muscle
tibia/fibula
keel
lung
gullet
kidney
crop
heart
gizzard
cloaca

(Image © Research Machines plc)

Cross sections of a bird (a pigeon) showing skeleton, muscles, feathers, and major organs. Many of a bird's bones are hollow and the weight of its skeleton may be as little as 5% of its total body weight.

Classification of major bird groups

Orders are listed from what is traditionally considered to be the most primitive to the most advanced.

Order	Examples
Struthioniformes	ostrich
Rheiformes	rhea
Casuariiformes	cassowary, emu
Apterygiformes	kiwi
Tinamiformes	tinamous
Sphenisciformes	penguin
Gaviiformes	loon
Podicipediformes	grebe
Procellariformes	albatross, petrel, shearwater, storm petrel
Pelecaniformes	pelican, booby, gannet, frigate bird
Ciconiiformes	heron, ibis, stork, spoonbill, flamingo
Anseriformes	duck, goose, swan
Falconiformes	falcon, hawk, eagle, buzzard, vulture
Galliformes	grouse, partridge, pheasant, turkey
Gruiformes	crane, rail, bustard, coot
Charadriiformes	wader, gull, auk, oyster-catcher, plover, puffin, tern
Columbiformes	dove, pigeon, sandgrouse

Psittaciformes	parrot, macaw, parakeet
Cuculiformes	cuckoo, roadrunner
Strigiformes	owl
Caprimulgiformes	nightjar, oilbird
Apodiformes	swift, hummingbird
Coliiformes	mousebird
Trogoniformes	trogon
Coraciiformes	kingfisher, hoopoe
Piciformes	woodpecker, toucan, puffbird
Passeriformes	finch, crow, warbler, sparrow, weaver, jay, lark, blackbird, swallow, mockingbird, wren, thrush

Raptor Centre

Go to site

Facts, stories, and other information about birds of prey, including multimedia files of raptor images and their sounds, a species census, plus information about endangered and threatened birds and the environmental issues affecting them, with a large amount of information on Internet resources and publications.

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bird flu

or avian flu

highly infectious form of the influenza virus that affects birds. The disease was thought to infect only birds until the first human cases were identified in Hong Kong in 1997. The symptoms of the disease in humans are similar to other types of flu, with characteristic sore throat, coughing, and high fever. However the death rate in those infected with the disease is significantly higher when compared with the fatality rates in the human forms of influenza. In the 1997 outbreak one-third of the 18 people infected with the disease died. In the outbreak in December 2003–early 2004, 20 people died.

Humans can become infected only if in close proximity to live infected birds by the inhalation of their excrement that has dried and been reduced to powder. There are 15 known strains of the bird flu virus, of which the H5N1 strain has been found to be transferable to humans. The scale of the bird flu outbreaks has been very small compared with recent health emergencies such as SARS; in the SARS outbreak 800 people died, compared to 26 deaths in both bird flu outbreaks combined. However, scientists consider the real danger with bird flu to be the possibility that the avian virus could exchange genes with the human form of the virus if a person happened to be infected with both forms of the disease simultaneously. This could result in a highly infectious new form of the human virus that would have the same high mortality rate as the bird form of the disease.

Researchers are working on the development of a vaccine. There have been no confirmed cases of a human passing this form of the disease on to another human.

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bird louse

parasitic biting louse, found mainly on birds, less frequently on mammals. Bird lice are wingless ectoparasites (living on the skin of their hosts), have biting mouthparts (as opposed to true lice which have sucking mouthparts), and reduced eyes.

classification

Bird lice are in the order Mallophaga, class Insecta, phylum Arthropoda.

The **chicken body louse** *Menacanthus stramineus* is small, yellowish, and about 2.8–3.3 mm/0.1–0.13 in long. The parasite feeds on the skin debris and feathers of the chicken. A heavily infested bird can carry over 8,000 lice on its body. The host appears to withstand the usual degree of infestation without apparent ill-effects, but heavy infestation can result in loss of plumage and a decline in the bird's health.

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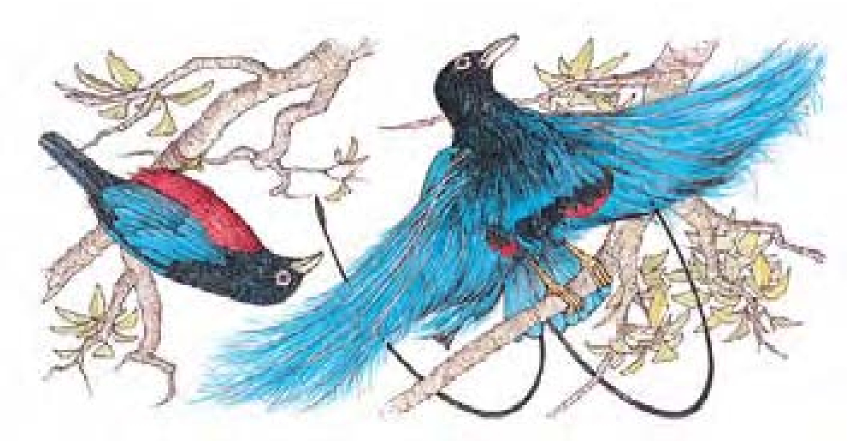
bird of paradise

one of 40 species of crowlike birds in the family Paradiseidae, native to New Guinea and neighbouring islands. Females are generally drably coloured, but the males have bright and elaborate plumage used in courtship display. Hunted almost to extinction for their plumage, they are now subject to conservation.

They are smallish birds, extremely active, and have compressed beaks, large toes, and strong feet. Their food consists chiefly of fruits, seeds, and nectar, but it may also include insects and small animals, such as worms. The Australian bowerbirds are closely related.

bird of paradise



(Image © Research Machines plc)

The male blue bird of paradise displays to the female high up in the tree canopy. It swings upside down, exposing its bright blue plumage and tail streamers, at the same time uttering low mechanical-sounding cries.

Birdseye, Clarence (1886-1956)

US inventor who pioneered food refrigeration processes. While working as a fur trader in Labrador 1912-16 he was struck by the ease with which food could be preserved in an Arctic climate. Back in the USA he found that the same effect could be obtained by rapidly freezing prepared food between two refrigerated metal plates. To market his products he founded the General Sea Foods Company in 1924, which he sold to General Foods in 1929.

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birth

act of producing live young from within the body of female animals. Both viviparous and ovoviviparous animals give birth to young. In viviparous animals, embryos obtain nourishment from the mother via a placenta or other means.

In ovoviviparous animals, fertilized eggs develop and hatch in the oviduct of the mother and gain little or no nourishment from maternal tissues. See also pregnancy.

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birth control

the use of contraceptives prevent pregnancy. It is part of the general practice of family planning.

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bismuth

chemical symbol Bi

hard, brittle, pinkish-white, metallic element, atomic number 83, relative atomic mass 208.98. It has the highest atomic number of all the stable elements (the elements from atomic number 84 up are radioactive). Bismuth occurs in ores and occasionally as a free metal (native metal). It is a poor conductor of heat and electricity, and is used in alloys of low melting point and in medical compounds to soothe gastric ulcers. The name comes from the Latin *besemutum*, from the earlier German *Wismut*.

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bison

large, hoofed mammal of the bovine family. There are two species, both brown. The **European bison** or **wisent** *Bison bonasus*, of which only a few protected herds survive, is about 2 m/7 ft high and weighs up to 1,100 kg/2,500 lb. The **North American bison** (also known historically as the North American buffalo) *Bison bison* is slightly smaller, with a heavier mane and more sloping hindquarters. Formerly roaming the prairies in vast numbers, it was almost exterminated in the 19th century, but survives in protected areas. There were about 14,000 bison in North American reserves in 1994.

Crossed with domestic cattle, the North American bison has produced a hardy hybrid, the 'beefalo', producing a lean carcass on an economical grass diet.

bison

(Image © Corel)

The North American bison *Bison bison* was hunted almost to extinction for food and sport by the European colonials. At one time the population of bison numbered up to 50 million, living in massive herds of thousands of individual animals. By 1889 there were only 540 left. Today they live in protected reserves.

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bit

contraction of binary digit

in computing, a single binary digit, either 0 or 1. A bit is the smallest unit of data stored in a computer; all other data must be coded into a pattern of individual bits. A byte represents sufficient computer memory to store a single character of data, and usually contains eight bits. For example, in the ASCII code system used by most microcomputers the capital letter A would be stored in a single byte of memory as the bit pattern 01000001.

The maximum number of bits that a computer can normally process at once is called a **word**. Microcomputers are often described according to how many bits of information they can handle at once. For instance, the first microprocessor, the Intel 4004 (launched in 1971), was a 4-bit device. In the 1970s several different 8-bit computers, many based on the Zilog Z80 or Rockwell 6502 processors, came into common use. In 1981, the IBM Personal Computer (PC) was introduced, using the Intel 8088 processor, which combined a 16-bit processor with an 8-bit data bus. Business micros of the later 1980s began to use 32-bit processors such as the Intel 80386 and Motorola 68030. Machines based on the first 64-bit microprocessor appeared in 1993.

The higher the number of bits a computer can process simultaneously, the more powerful the computer is said to be. However, other factors influence the overall speed of a computer system, such as the clock rate of the processor and the amount of RAM available. Tasks that require a high processing speed include sorting a database or doing long, complex calculations in spreadsheets. A system running slowly with a graphical user interface may benefit more from the addition of extra RAM than from a faster processor.

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bittern

any of several species of small herons, in particular the common bittern *Botaurus stellaris* of Europe and Asia. It is shy, stoutly built, buff-coloured, speckled with black and tawny brown, with a long bill and a loud, booming call. Its habit of holding its neck and bill in a vertical position conceals it among the reeds, where it rests by day, hunting for frogs, reptiles, and fish towards nightfall. An inhabitant of marshy country, it is now extremely rare in Britain. In 2000 there were only an estimated 20 pairs of bitterns breeding in the British Isles.

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bittersweet

alternative name for the woody nightshade plant.

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bitumen

involatile, tarry material, containing a mixture of hydrocarbons (mainly alkanes), that is the residue from the fractional distillation of crude oil (unrefined petroleum). Sometimes the term is restricted to a soft kind of pitch resembling asphalt.

Naturally occurring solid bitumen may have arisen as a residue from the evaporation of petroleum. If evaporation took place from a pool or lake of petroleum, the residue might form a pitch or asphalt lake, such as Pitch Lake in Trinidad. Bitumen was used in ancient times as a mortar, and by the Egyptians for embalming.

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bivalent

in biology, a name given to the pair of homologous chromosomes during reduction division (meiosis). In chemistry, the term is sometimes used to describe an element or group with a valency of two, although the term 'divalent' is more common.

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bivalve

marine or freshwater mollusc whose body is enclosed between two shells hinged together by a ligament on the dorsal side of the body.

The shell is closed by strong 'adductor' muscles. Ventrally, a retractile 'foot' can be put out to assist movement in mud or sand. Two large platelike gills are used for breathing and also, with the cilia present on them, make a mechanism for collecting the small particles of food on which bivalves depend. The bivalves form one of the five classes of molluscs, the Lamellibranchiata, otherwise known as Bivalvia or Pelycypoda, containing about 8,000 species.

Black, James Whyte (1924-)

Scottish physiologist, director of therapeutic research at Wellcome Laboratories (near London) from 1978, who was awarded a Nobel Prize for Physiology or Medicine in 1988, together with US scientists George Hitchings and Gertrude Elion, for their work on the principles governing the design of new drug treatment. He was active in the development of beta-blockers (which reduce the rate of heartbeat) and anti-ulcer drugs. He was knighted in 1981.

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black beetle

another name for cockroach, although cockroaches belong to an entirely different order of insects (Dictyoptera) from the beetles (Coleoptera).

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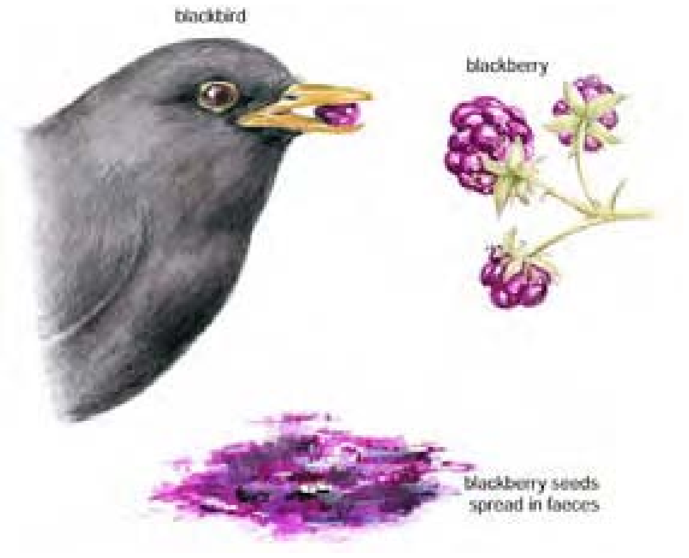
blackberry

prickly shrub, closely related to raspberries and dewberries. Native to northern parts of Europe, it produces pink or white blossom and edible black compound fruits. (*Rubus fruticosus*, family Rosaceae.)

blackberry


blackbird
blackberry
blackberry seeds spread in faeces

(Image © Research Machines plc)

Blackberry seeds are dispersed by the birds and animals that feed on the berries. Here a blackbird eats a berry. By the time the seeds have worked through the bird's digestive system it is likely that it will have moved some distance away from the original plant.

Blackberry

Go to site

Contains detailed information about the bilberry, including an informative description of the plant, its history, and its habitat. This site also features notes on the uses of the plant, which include treating dysentery and diarrhoea. There is also information about making blackberry wine and vinegar.

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blackbird

bird *Turdus merula* of the thrush family, Muscicapidae, order Passeriformes, about 25 cm/10 in long. The male is black with a yellow bill and eyelids, the female dark brown with a dark beak. It lays three to five blue-green eggs with brown spots in a nest of grass and moss, plastered with mud, built in thickets or creeper-clad trees. The blackbird feeds on fruit, seeds, worms, grubs, and snails. Its song is rich and flutelike.

Found across Europe, Asia, and North Africa, the blackbird adapts well to human presence and gardens, and is one of the most common British birds. North American 'blackbirds' belong to a different family of birds, the Icteridae.

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black box

popular name for the unit containing an aeroplane's flight and voice recorders. These monitor the plane's behaviour and the crew's conversation, thus providing valuable clues to the cause of a disaster. The box is nearly indestructible and usually painted orange for easy recovery. The name also refers to any compact electronic device that can be quickly connected or disconnected as a unit.

The voice recorder records in a 30-minute loop, so that the last minutes of a flight can be listened to if there has been an accident. The flight data recorder functions on a 25-hour loop. Neither recorder is battery operated so, as happened in the 1998 Swissair crash that killed 229 people, the final data may be missing as power gets cut off. The only part of a blackbox that is battery operated is its underwater locator, that will transmit a signal for 35 days after the crash to aid its location.

The maritime equivalent is the **voyage recorder**, installed in ships from 1989. It has 350 sensors to record the performance of engines, pumps, navigation lights, alarms, radar, and hull stress.

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blackbuck

antelope *Antilope cervicapra* found in central and northwestern India. It is related to the gazelle, from which it differs in having spirally-twisted horns. The male is black above and white beneath, whereas the female and young are fawn-coloured above.

It is about 76 cm/2.5 ft in height.

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blackcap

warbler*Sylvia atricapilla*, family Muscicapidae, order Passeriformes. The male has a black cap, the female a reddish-brown one. The general colour of the bird is an ashen-grey, turning to an olive-brown above and pale or whitish-grey below. About 14 cm/5.5 in long, the blackcap likes wooded areas, and is a summer visitor to northern Europe, wintering in Africa.

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blackcock

or heathcock

large grouse *Lyrurus tetrix* found on moors and in open woods in northern Europe and Asia. The male is mainly black with a lyre-shaped tail, and grows up to 54 cm/1.7 ft in height. The female is speckled brown and only 40 cm/1.3 ft tall. Their food consists of buds, young shoots, berries, and insects.

Blackcocks are polygamous, and in the spring males attract females by curious crowings. In males a piece of bright red skin above the eyes also becomes more intense during the pairing season.

They are related to the quail, partridge, and capercaillie, in the order Galliformes.

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blackcurrant

variety of currant.

Currant, Black

Go to site

Complete source of information about the blackcurrant. Contained here are informative descriptions of the plant and its habitat. This site also features notes on the uses of the plant, which include the preparation of lozenges and the treatment of dropsy. There is also information about making blackcurrant jelly, wine, and even cheese!

Black Death

great epidemic of plague, mainly the bubonic variant, that ravaged Europe in the mid-14th century. Contemporary estimates that it killed between one-third and half of the population (about 75 million people) are probably accurate. The cause of the plague was the bacterium *Yersinia pestis*, transmitted by fleas that infested migrating Asian black rats. Originating in China, the disease followed the trade routes through India into Europe. The name Black Death was first used in England in the early 19th century.

The plague arrived in Sicily, Italy, in October 1347, reached southern France in January 1348, and was first recorded in England in August 1348, after two fishing boats from France docked at Weymouth, Dorset. Symptoms were violent headache; dark blotches caused by bleeding under the skin; and buboes, massively swollen lymph glands that could grow to the size of an orange in the groin or armpit. Buboes were variously described as black pustules, boils, and abscesses. Few victims lived longer than four to seven days, though there were rare cases of survival if the buboes burst. Medieval medicine was helpless, and many doctors and priests simply ran away. Doctors blamed bad air or a conjunction of the planets for the disease, others suggested that beggars or the Jews had poisoned the wells. Most agreed that the plague was a punishment from God. Ignorance of the cause made the disease even more terrifying. It was, wrote one Flemish priest, 'the most terrible of all terrors'.

Black Death

Go to site

Part of a larger site on the history of western civilization maintained by Boise State University, this page provides an introduction to the Black Death. Information is organized into 22 brief articles, each concerning a specific aspect of the plague, such as its origins and arrival in the West, a description of the disease and the various forms of plague, medical measures to combat it, and its wide-reaching effects on the population, economy, culture, and so on. You can start at the beginning and work your way through the articles in chronological order or go directly to a page that interests you. There is also a list of references for further study.

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black earth

exceedingly fertile soil that covers a belt of land in northeastern North America, Europe, and Asia.

In Europe and Asia it extends from Bohemia through Hungary, Romania, southern Russia, and Siberia, as far as Manchuria, having been deposited when the great inland ice sheets melted at the close of the last ice age. In North America, it extends from the Great Lakes east through New York State, having been deposited when the last glaciers melted and retreated from the terminal moraine.

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blackfly

small but stoutly built blood-sucking flies with short antennae. Blackflies have broad wings with all the obvious veins in the anterior part of the wing. The family is widely distributed, the adults often occurring in such large numbers as to make them a nuisance. They are most abundant in north temperate and subarctic regions.

classification

Blackflies are in family Simuliidae, order Diptera, class Insecta, phylum Arthropoda.

There are six larval stages that are found in running water, including cascades and waterfalls; they have a well capsulated head, a solitary thoracic proleg and a posterior sucker composed of small hooks by which they anchor themselves against the current. They are found on stones, reeds, mayfly larvae, and other aquatic forms. The pupae usually rest in a tent of silk in similar situations to the larvae.

Simulium species are the vectors of onchocerciasis in Central and South America, Africa, and the Yemen. They also transmit other filarial worms to cattle and to ducks. Blackflies are vectors of a large number of avian malarias to many birds including domestic stock, turkeys, ducks, and geese in North America and Canada. In addition, number of blackflies attacking livestock can be so great, and the attacks so fierce, as to kill the livestock, and human deaths have also occurred.

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blackfly

plant-sucking insect, a type of aphid.

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black hole

object in space whose gravity is so great that nothing can escape from it, not even light. It is thought to form when a massive star shrinks at the end of its life. A black hole sucks in more matter, including other stars, from the space around it. Matter that falls into a black hole is squeezed to infinite density at the centre of the hole. Black holes can be detected because gas falling towards them becomes so hot that it emits X-rays.

Black holes containing the mass of millions of stars are thought to lie at the centres of quasars. Satellites have detected X-rays from a number of objects that may be black holes, but only a small number of likely black holes have been identified in our galaxy.

Black Holes and Beyond

Go to site

Well-written guide to black holes. There is a good balance of text and images, with clear explanatory diagrams. Video and audio clips of scientists explain some of the current theories of the evolution and behaviour of black holes.

blacksnake

any of several species of snake. The blacksnake *Pseudechis porphyriacus* is a venomous snake of the cobra family found in damp forests and swamps in eastern Australia. The blacksnake, *Coluber constrictor* from the eastern USA, is a relative of the European grass snake, growing up to 1.2 m/4 ft long, and without venom.

blackthorn

densely branched spiny European bush. It produces white blossom on bare black branches in early spring. Its sour plumlike blue-black fruit, the sloe, is used to make sloe gin. (*Prunus spinosa*, family Rosaceae.)

Blackwell, Elizabeth (1821-1910)

English-born US physician, the first woman to qualify in medicine in the USA in 1849, and the first woman to be recognized as a qualified physician in the UK in 1869.

black widow

North American spider *Latrodectus mactans*. The male is small and harmless, but the female is 1.3 cm/0.5 in long with a red patch below the abdomen and a powerful venomous bite. The bite causes pain and fever in human victims, but they usually recover.

black widow

The black widow has the strongest silk of any spider yet tested. *Latrodectus mactans*, found in the southern USA, produces two kinds of silk. One type can extend up to 27% before breaking and the other, which has a slightly smaller rate of extension, can absorb more energy than Kevlar, the material used to make bullet-proof vests.

bladder

hollow elastic-walled organ which stores the urine produced in the kidneys. It is present in the urinary systems of some fishes, most amphibians, some reptiles, and all mammals. Urine enters the bladder through two ureters, one leading from each kidney, and leaves it through the urethra.

bladder

US urologists succeeded in growing a whole bladder in 1998. The bladder was grown over 6 weeks from 1 cm of bladder tissue which had been separated into muscle and epithelial tissue. The cells were then 'painted' onto a bladder-shaped biodegradable polymer (muscle outside, epithelial cells inside). The research was carried out on dogs and the engineered bladders were found to function normally with almost the same capacity as a natural bladder.

bladderwort

any of a large group of carnivorous aquatic plants. They have leaves with bladders (hollow sacs) that trap small animals living in the water. (Genus *Utricularia*, family Lentibulariaceae.)

blast freezing

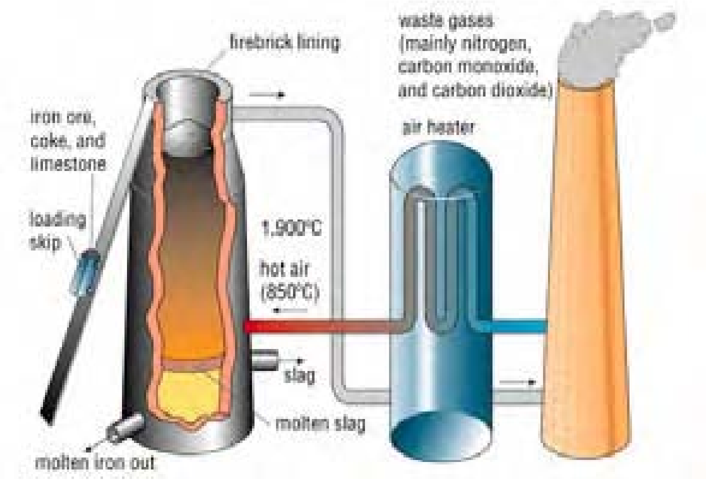
industrial method of freezing substances such as foods by blowing very cold air over them. See deep freezing.

blast furnace

smelting furnace used to extract metals from their ores, chiefly pig iron from iron ore. The temperature is raised by the injection of an air blast.

In the extraction of iron the ingredients of the furnace are iron ore (iron(III) oxide), coke (carbon), and limestone (calcium carbonate). The coke is the fuel and provides the agent (carbon monoxide) for the reduction of the iron ore.

blast furnace


firebrick lining
waste gases (mainly nitrogen, carbon monoxide, and carbon dioxide)
iron ore, coke, and limestone
air heater
loading skip
1,900°C
hot air (850°C)
slag
molten slag
molten iron out

(Image © Research Machines plc)

The blast furnace is used to extract iron from a mixture of iron ore, coke, and limestone. The less dense impurities float above the molten iron and are tapped off as slag. The molten iron sinks to the bottom of the furnace and is tapped off into moulds referred to as pigs. The iron extracted this way is also known as pig iron.

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blastocyst

in mammals, the hollow ball of cells which is an early stage in the development of the embryo, roughly equivalent to the blastula of other animal groups.

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blastomere

in biology, a cell formed in the first stages of embryonic development, after the splitting of the fertilized ovum, but before the formation of the blastula or blastocyst.

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blastula

early stage in the development of a fertilized egg, when the egg changes from a solid mass of cells (the morula) to a hollow ball of cells (the blastula), containing a fluid-filled cavity (the blastocoel). See also embryology.

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bleaching

decolorization of coloured materials. The two main types of bleaching agent are **oxidizing bleaches**, which bring about the oxidation of pigments and include the ultraviolet rays in sunshine, hydrogen peroxide, and chlorine in household bleaches; and **reducing bleaches**, which bring about reduction and include sulphur dioxide.

Bleach is used in industry to lighten or whiten fabrics, yarns, or fibres. Bleaching processes have been known from antiquity, mainly those acting through sunlight. Both natural and synthetic pigments usually possess highly complex molecules, the colour property often being due to only a part of the molecule. Bleaches usually attack only that small part, yielding another substance similar in chemical structure but colourless.

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bleak

freshwater fish *Alburnus alburnus* of the carp family. It is up to to 20 cm/8 in long, and lives in still or slow-running clear water in Britain and Europe.

In Eastern Europe its scales are used in the preparation of artificial pearls.

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bleeding

loss of blood from the circulation; see haemorrhage.

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blenny

any fish of the family Blenniidae, mostly small fishes found near rocky shores, with elongated slimy bodies tapering from head to tail, no scales, and long pelvic fins set far forward.

Blériot, Louis (1872-1936)

French aviator. In a 24-horsepower monoplane of his own construction, he made the first flight across the English Channel on 25 July 1909.

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blesbok

African antelope *Damaliscus albifrons*, about 1 m/3 ft high, with curved horns, brownish body, and a white blaze on the face. It was seriously depleted in the wild at the end of the 19th century. A few protected herds survive in South Africa. It is farmed for meat.

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blight

any of a number of plant diseases caused mainly by parasitic species of fungus, which produce a whitish appearance on leaf and stem surfaces; for example, **potato blight** *Phytophthora infestans*. General damage caused by aphids or pollution is sometimes known as blight.

In 1998 a new virulent strain of *P. infestans*, US-8, was decimating potato and tomato crops throughout the USA and eastern Canada, proving to be resistant to previously effective fungicides.

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blindness

complete absence or impairment of sight. It may be caused by heredity, accident, disease, or deterioration with age. Blind people can be trained to use echolocation and in certain cases blindsight to navigate around obstacles. Other aids include electronic devices that convert print to recognizable mechanical speech, and sonar devices.

Globally, the leading cause of blindness is trachoma. Other important causes include:

Age-related macular degeneration (AMD), the commonest form of blindness, occurs as the retina gradually deteriorates with age. It affects 1% of people over the age of 70, with many more experiencing marked reduction in sight.

Retinitis pigmentosa, a common cause of blindness, is a hereditary disease affecting 1.2 million people worldwide.

Audio Description Home Page

Go to site

Ingenious site that produces audio description files for blind people. These files, of which there are several samples here, describe exhibitions, museums, etc, so that they can be enjoyed by blind people just as much as by the sighted.

Royal National Institute for the Blind United Kingdom

Go to site

Well-organized site of Britain's leading organization for the visually impaired. RNIB's work is clearly explained. Advice and general information on loss of eyesight is provided.

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blind spot

area where the optic nerve and blood vessels pass through the retina of the eye. No visual image can be formed as there are no light-sensitive cells in this part of the retina. Thus the organism is blind to objects that fall in this part of the visual field.

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blister beetle

or oil beetle

any of a small group of medium sized (3-20 mm/0.1-0.8 in) often brightly coloured beetles. Most give off an evil-smelling liquid, containing the irritant cantharidin, from the joints of their legs as a defence mechanism. When in contact with human skin, the liquid causes inflammation and blisters.

classification

Blister beetles are members of the family Meloidae, order Coleoptera, class Insecta, phylum Arthropoda.

The general characteristics of the group include: head strongly bent downwards, narrow neck, and cylindrical and fairly soft body.

The **Spanish fly** *Lytta vesicatoria* was used to produce cantharidin for medicinal purposes, when blistering was a common medical treatment.

Bloch, Konrad (Emil) (1912-2000)

German-born US chemist who was awarded a Nobel Prize for Physiology or Medicine in 1964, together with his collaborator in Germany, Feodor Lynen, for work on cholesterol and fatty-acid metabolism. Making use of the radioisotope carbon-14 (the radioactive form of carbon), Bloch was able to follow the complex steps by which the body chemically transforms acetic acid into cholesterol.

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blog

abbreviation for Web log

online journal on the World Wide Web. Blogs started in the USA in 1997 and became ubiquitous in the early 2000s, driven by the ease with which new blogs can be created on hosting services with dedicated software. Blogs are often autobiographical or special interest-based, comprising text, images, and links to other sites. The immediate, interactive, and inexpensive nature of blogs made them an important news, marketing, and media source from the early 2000s.

A compiler of a blog is called a 'blogger' and the act of creating or contributing to a blog is called 'blogging'. Politics is a major theme, and many large companies also use blogs for customer relations management, public relations, and brand development. A blog is usually organized in reverse chronological order, and a typical blog entry consists of a title, the opening text of an article, a link to the full text of the article, and the date the entry was posted.

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blood

fluid pumped by the heart, that circulates in the arteries, veins, and capillaries of vertebrate animals forming the bloodstream. The term also refers to the corresponding fluid in those invertebrates that possess a closed circulatory system. Blood carries nutrients and oxygen to each body cell and removes waste products such as carbon dioxide. It is also important in the immune response and, in many animals, in the distribution of heat throughout the body.

The adult human body contains about 5.5 l/10 pt of blood (about 5% of the body weight). It is composed of a fluid called plasma, in which are suspended microscopic cells of three main varieties:

Red blood cells (erythrocytes) form nearly half the volume of the blood, with about 6 million red blood cells in every millilitre of an adult's blood. They transport oxygen around the body. Oxygen is absorbed into the millions of blood capillaries surrounding the tiny air sacs of the lungs and is carried in the blood by haemoglobin, a red protein within the red blood cells.

White blood cells (leucocytes) are of various kinds. Some (phagocytes) ingest invading bacteria and so protect the body from disease; these also help to repair injured tissues. Others (lymphocytes) produce antibodies, which help provide immunity by binding to disease-causing bacteria and destroying them. Yet others can kill cells infected by viruses.

Blood platelets (thrombocytes) assist in the clotting of blood.

Blood cells constantly wear out and die and are replaced from the bone marrow. Red blood cells die at the rate of 200 billion per day but the body produces new cells at an average rate of 9,000 million per hour.

Many different substances are transported by the blood around the body. Following digestion small food molecules are absorbed into the blood from the gut. The blood transports these nutrients (for example glucose) to the cells of the body. Waste products produced by the cells, such as carbon dioxide, are carried by the blood to the lungs to be exhaled. Hormones (such as oestrogen) are transported by the blood from glands to body cells in order to regulate various processes.

blood: artificial

In February 1998, the US Food and Drug Administration approved artificial blood for vets to use in dogs.

blood cells

A cubic centimetre of human blood contains 4.5-5.5 million red blood cells, 7,000-12,000 white blood cells, and 150,000-400,000 platelets.

Blood, Artificial

risky blood

Blood transfusions are the oldest and most important of all tissue transplants. If an artificial blood substitute could be developed that would replace some or all of the donated blood that is currently required, it would be one of the medical breakthroughs of the century. The pursuit of this goal has been given added impetus by the rise of blood-borne diseases, particularly HIV. Although all donated blood is now tested for antibodies to the virus, there is still a small risk that HIV-infected blood could be donated by someone who has contracted the virus but not had time to develop antibodies.

other benefits

Artificial blood would have several other benefits: it could be manufactured to meet demand, have a long shelf life and would not require labour-intensive cross-matching. It would not wholly eliminate the need for natural blood, which is a complex tissue containing cells, antibodies, clotting factors, and transport proteins. In emergencies, however, the function which it is essential to restore by transfusion is the oxygen-carrying capacity of the blood. Artificial blood would be most useful in replacing short-term blood loss, of the type that occurs following surgery or in emergencies. Over half the 2.5 million pints of blood that are donated each year in the UK are used for this purpose.

the pursuit of a blood substitute

Red blood cells carry oxygen from the lungs to the rest of the body, using a transport protein, haemoglobin, which is made up of four protein subunits bound to an iron atom. Two approaches have been tried in the pursuit of a blood substitute, using either artificial fluids in which oxygen dissolves easily, or solutions of haemoglobin itself. There are problems, however, with both methods.

perfluorocarbons

In 1966 in Birmingham, Alabama, Leland C Clark discovered that mice could survive for prolonged periods submerged in oxygenated solutions of a perfluorocarbon, a biologically inert substance which can dissolve large amounts of oxygen. Although perfluorocarbons are insoluble in water, they can be given into the bloodstream by forming an emulsion.

One perfluorocarbon, Fluosol DA20, has been used to treat patients suffering from severe blood loss who, for religious reasons, have been unable to accept transfusions. Unfortunately, in spite of promising experiments which showed that it could keep alive animals which had effectively no natural blood left, Fluosol DA20 did not improve survival in humans. Oxygenated Fluosol DA20 has proved successful, however, in improving the supply of oxygen to the heart muscle in patients undergoing angioplasty of their coronary arteries.

In spite of the disappointing track record of these chemicals, there remains hope that they may one day prove successful. A new perfluorocarbon, perfluoroctobromide, can carry five times as much oxygen as Fluosol DA20, and the results of clinical trials are eagerly awaited.

haemoglobin solutions

Haemoglobin solutions might be considered a more natural approach to artificial blood. Oxygen carriage would be similar to that in normal red cells, but the separation of the haemoglobin from the rest of the red cell would mean that the substitute would not require cross-matching.

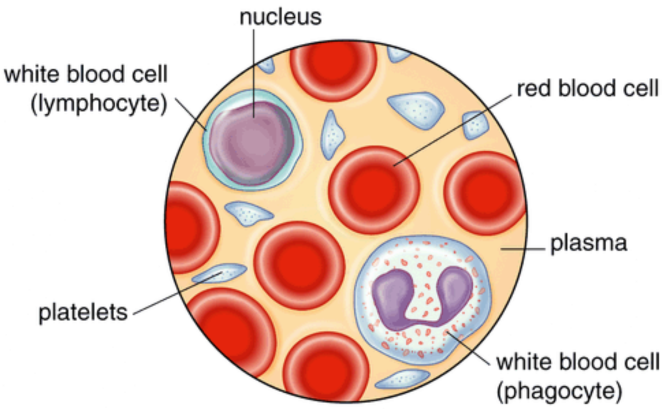
Early attempts to produce artificial blood by this method used haemoglobin that had been extracted from fragmented red cells, but unfortunately there were major problems. The haemoglobin, once outside its normal red-cell environment, quickly split into two separate pieces, each of which was then small enough to pass through the blood filter of the kidneys and into the urine, so that the solution only remained in the circulation for a few hours. Both the red cell fragments and the haemoglobin subunits were found to be very toxic to the kidneys. Human haemoglobin made by these methods has in any case always been scarce because only out of date blood transfusions could be spared to prepare it.

promising developments

Recently, however, the haemoglobin approach has taken a leap forward. In 1991 Dr Kiyoshi Nagai, of the Medical Research Council laboratories in Cambridge, used bacteria to produce a modified haemoglobin that remains fully assembled in the circulation, and has improved oxygen-carrying characteristics.

Clinical trials were underway in 1994 to assess its safety. If these are successful it has been suggested that a working blood substitute might be available within five years, to meet a market worth tens of billions of dollars worldwide.

blood



(Image © Research Machines plc)

Composition of blood. Human blood contains red blood cells, white blood cells (phagocytes and lymphocytes), and platelets, suspended in plasma.

blood

To remember the functions of the blood:

Old **C**harlie **F**oster **h**ates **w**omen **h**aving **d**ull **c**lothes

Oxygen (transport), **c**arbon dioxide (transport), **f**ood, **h**eat, **w**aste, **h**ormones, **d**isease, **c**lotting

Lifeblood

Go to site

Introduction to blood, with graphics and links to other pages where you will find out everything you might ever think to ask about blood. Keywords and concepts are highlighted and provide links to more detailed pages of information.

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blood bank

in medicine, institution in which blood products are prepared, tested, and stored prior to transfusion into patients. Blood is screened for infections such as hepatitis and HIV and sorted by blood group. Whole blood may be stored for three weeks when refrigerated. It can also be used to obtain blood products, such as platelets and blood cells.

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blood-brain barrier

theoretical term for the defence mechanism that prevents many substances circulating in the bloodstream (including some germs) from invading the brain.

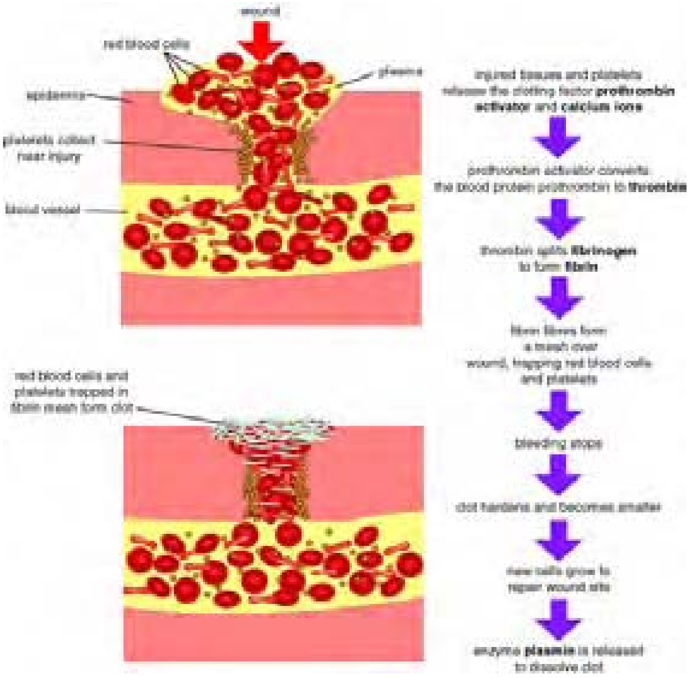
The blood-brain barrier is not a single entity, but a defensive complex comprising various physical features and chemical reactions to do with the permeability of cells. It ensures that 'foreign' proteins, carried in the blood vessels supplying the brain, do not breach the vessel walls and enter the brain tissue. Many drugs are unable to cross the blood-brain barrier.

---

blood clotting

complex series of events (known as the blood clotting cascade) resulting from a series of enzymatic reactions in the blood that prevents excessive bleeding after injury. The result is the formation of a meshwork of protein fibres (fibrin) and trapped blood cells over the cut blood vessels.

blood clotting


wound
red blood cells
plasma
epidermis
platelets collect near injury
blood vessel
injured tissues and platelets release the clotting factor **prothrombin activator** and **calcium ions**
prothrombin activator converts the blood protein prothrombin to **thrombin**
thrombin splits **fibrinogen** to form **fibrin**
fibrin fibres form a mesh over wound, trapping red blood cells and platelets
bleeding stops
clot hardens and becomes smaller
new cells grow to repair wound site
enzyme **plasmin** is released to dissolve clot
red blood cells and platelets trapped in fibrin mesh form clot

(Image © Research Machines plc)

The blood clotting cascade. When there is a wound in the skin, the clotting factor prothrombin activator is released by the injured tissues and platelets. This converts the blood protein prothrombin to thrombin. Thrombin splits fibrinogen to form fibrin, which forms a mesh over the wound trapping red blood cells and forming a clot.

---

blood group

any of the types into which blood is classified according to the presence or otherwise of certain antigens on the surface of its red cells. Red blood cells of one individual may carry molecules on their surface that act as antigens in another individual whose red blood cells lack these molecules. The two main antigens are designated A and B. These give rise to four blood groups: having A only (A), having B only (B), having both (AB), and having neither (O). Each of these groups may or may not contain the rhesus factor. Correct typing of blood groups is vital in transfusion, since incompatible types of donor and recipient blood will result in coagulation, with possible death of the recipient.

The ABO system was first described by Austrian scientist Karl Landsteiner in 1902. Subsequent research revealed at least 14 main types of blood group systems, 11 of which are involved with induced antibody production. Blood typing is also of importance in forensic medicine, cases of disputed paternity, and in anthropological studies.

Compatibility of blood groups

Blood group	Antigen on red blood cell	Antibody in plasma	Blood groups that can be received by this individual	Blood groups that can receive donations from this individual
A	A	anti-B	A, O	A, AB
B	B	anti-A	B, O	B, AB
AB	A and B	none	any	AB
O	neither A nor B	anti-A and anti-B	O	any

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bloodhound

breed of dog that originated as a hunting dog in Belgium in the Middle Ages. Black and tan in colour, it has long, pendulous ears and distinctive wrinkled head and face. It grows to a height of about 65 cm/26 in. Its excellent powers of scent have been employed in tracking and criminal detection from very early times.

American Bloodhound Club

Go to site

Source of information containing details of the origins of the breed, breed standards, and shows. There are also a large number of photos and links to other bloodhound sites.

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blood poisoning

presence in the bloodstream of quantities of bacteria or bacterial toxins sufficient to cause serious illness.

blood pressure

pressure, or tension, of the blood against the inner walls of blood vessels, especially the arteries, due to the muscular pumping activity of the heart. Abnormally high blood pressure (hypertension) may be associated with various conditions or arise with no obvious cause; abnormally low blood pressure (hypotension) occurs in shock and after excessive fluid or blood loss from any cause.

In mammals, the left ventricle of the heart pumps blood into the arterial system. This pumping is assisted by waves of muscular contraction by the arteries themselves, but resisted by the elasticity of the inner and outer walls of the same arteries. Pressure is greatest when the heart ventricle contracts (**systole**) and lowest when the ventricle relaxes (**diastole**), and pressure is solely maintained by the elasticity of the arteries. Blood pressure is measured in millimetres of mercury (the height of a column on the measuring instrument, a sphygmomanometer). Normal human blood pressure varies with age, but in a young healthy adult it is around 120/80mm Hg; the first number represents the systolic pressure and the second the diastolic. Large deviations from this reading usually indicate ill health.

bloodstream

in animals, the means of carrying substances around the body. Oxygen needed by the cells of the body for respiration is absorbed into the blood at the lungs by diffusion and is transported to every part of the body by the blood stream. The oxygen is carried by specialized cells – the red blood cells. Inside each cell there are lots of haemoglobin molecules, which can combine with oxygen and release it when it is needed. Cells that respire produce carbon dioxide. The blood stream carries carbon dioxide from cells to the lungs where it is lost from the body by diffusion. The bloodstream also has an important role in carrying food around the body to cells that need it. This food is absorbed into the blood following digestion in the gut.

blood test

laboratory evaluation of a blood sample. There are numerous blood tests, from simple typing to establish the blood group to sophisticated biochemical assays of substances, such as hormones, present in the blood only in minute quantities.

The majority of tests fall into one of three categories: **haematology** (testing the state of the blood itself), **microbiology** (identifying infection), and **blood chemistry** (reflecting chemical events elsewhere in the body). Before operations, a common test is haemoglobin estimation to determine how well a patient might tolerate blood loss during surgery.

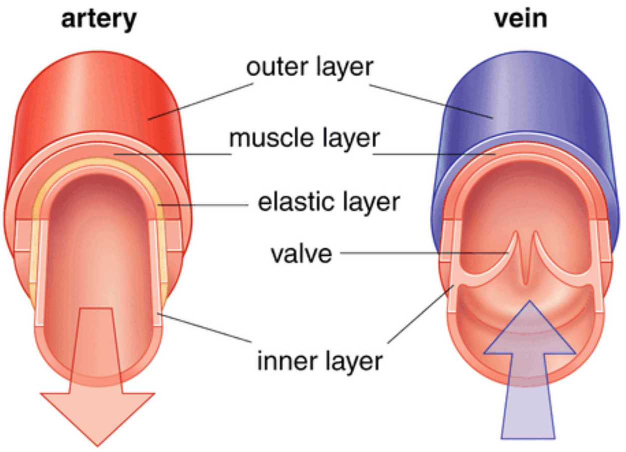
blood transfusion

see transfusion.

blood vessel

tube that conducts blood either away from or towards the heart in multicellular animals. The principal types are arteries, which conduct blood away from the heart, veins, which conduct blood towards the heart, and capillaries, which conduct blood from arteries to veins. Arteries always carry oxygenated blood and veins deoxygenated blood, with the exception of the **pulmonary artery** which carries deoxygenated blood from the heart to the lungs, and the **pulmonary vein**, which carries oxygenated blood from the lungs to the heart.

blood vessel



(Image © Research Machines plc)

Cross sections of an artery and a vein. Arteries have thicker walls than veins as they have to withstand a higher blood pressure than do veins. Veins have valves to prevent blood from flowing backwards.

bloodworm

larvae of the midge. They are red because their blood plasma contains haemoglobin like human blood, which increases its ability to take up oxygen. This is of value to the larvae, which commonly burrow in the oxygen-poor mud bottom of pools and rivers. They feed on algae and detritus.

Bloodworms are long, with a distinct head, and segmentation of the abdomen. Prolegs (leglike projections) are found on the first thoracic and last abdominal segments. Gills are present on the last abdominal segment, and often on the segment preceding it. On average they measure 6 mm/0.2 in in length.

Bloodworms frequently build tubes of mud around themselves, which may be attached to stones. They constitute a major part of the diet of fish, hence they are often used as bait by anglers.

Not all midge larvae are red. Those that do not live in mud tubes, but frequent the surface waters, are green, and some species have blue bands.

bloom

whitish powdery or waxlike coating over the surface of certain fruits that easily rubs off when handled. It often contains yeasts that live on the sugars in the fruit.

The term bloom is also used to describe a rapid increase in number of certain species of algae found in lakes, ponds, and oceans.

Algal blooms may be natural but are often the result of nitrate pollution, in which artificial fertilizers, applied to surrounding fields, leach out into the waterways. This type of bloom can lead to the death of almost every other organism in the water; because light cannot penetrate the algal growth, the plants beneath can no longer photosynthesize and therefore do not release oxygen into the water. Only those organisms that are adapted to very low levels of oxygen survive.

blowfly

any fly of the genus *Calliphora*, also known as bluebottle, or of the related genus *Lucilia*, when it is greenbottle. It lays its eggs in dead flesh, on which the maggots feed.

blowfly

Blowfly larvae develop in less than two weeks. During this time they can gain 5% of their final larval weight each hour.

blubber

thick layer of fat under the skin of marine mammals, which provides an energy store and an effective insulating layer, preventing the loss of body heat to the surrounding water. Blubber has been used (when boiled down) in engineering, food processing, cosmetics, and printing, but all of these products can now be produced synthetically.

blueberry

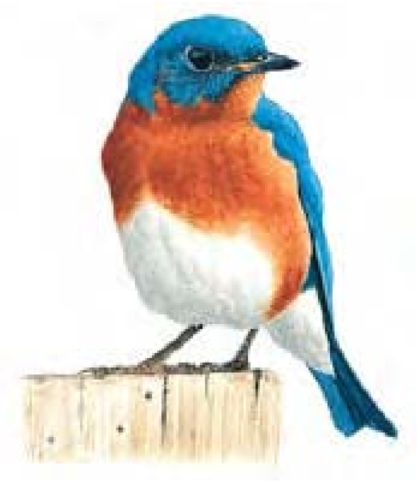
any of various North American shrubs belonging to the heath family, growing in acid soil. The genus also includes huckleberries, bilberries, deerberries, and cranberries, many of which resemble each other and are difficult to tell apart from blueberries. All have small oval short-stalked leaves, slender green or reddish twigs, and whitish bell-like blossoms. Only true blueberries, however, have tiny granular speckles on their twigs. Blueberries have black or blue edible fruits, often covered with a white bloom.
(Genus *Vaccinium*, family Ericaceae.)

bluebird

or blue robin or blue warbler

three species of a North American bird, genus *Sialia*, belonging to the thrush subfamily, Turdinae, order Passeriformes. The eastern bluebird *Sialia sialis* is regarded as the herald of spring as it returns from migration. About 18 cm/7 in long, it has a reddish breast, the upper plumage being sky-blue, and a distinctive song. It lays about six pale-blue eggs.

bluebird



(Image © Research Machines plc)

The eastern bluebird is found throughout the eastern part of North America, where it may be seen perching on fences. Bluebirds nest in holes in tree trunks; both male and female build the nest. The female lays four or five eggs and incubates them for about two weeks. The young leave the nest after two to three weeks. Usually two broods are produced each year.

bluebottle

another name for blowfly.

bluebuck

any of several species of antelope, including the blue duiker*Cephalophus monticola* of South Africa, about 33 cm/13 in high. The male of the Indian nilgai antelope is also known as the bluebuck.

The bluebuck or blaubok, *Hippotragus leucophaeus*, was a large blue-grey South African antelope. Once abundant, it was hunted to extinction, the last being shot in 1800.

bluegrass

dense spreading grass, which is blue-tinted and grows in clumps. Various species are known from the northern hemisphere. Kentucky bluegrass (*Poa pratensis*), introduced to the USA from Europe, provides pasture for horses. (Genus *Poa*, family Gramineae.)

blue-green algae

obsolete name for a group of photosynthetic micro-organisms now known as cyanobacteria.

blue gum

either of two Australian trees: Tasmanian blue gum (*Eucalyptus globulus*) of the myrtle family, with bluish bark, a chief source of eucalyptus oil; or the tall, straight Sydney blue gum (*E. saligna*). The former is widely cultivated in California and has also been planted in South America, India, parts of Africa, and southern Europe.

blueprint

photographic process used for copying engineering drawings and architectural plans, so called because it produces a white copy of the original against a blue background.

The plan to be copied is made on transparent tracing paper, which is placed in contact with paper sensitized with a mixture of iron ammonium citrate and potassium hexacyanoferrate. The paper is exposed to ultraviolet radiation and then washed in water. Where the light reaches the paper, it turns blue (Prussian blue). The paper underneath the lines of the drawing is unaffected, so remains white.

blue shift

in astronomy, manifestation of the Doppler effect in which light from an object appears to be of shorter wavelength (and therefore of higher frequency) when the object and observer are approaching each other (blue light is of a higher frequency than other colours in the visible spectrum). The blue shift is the opposite of the red shift.

BMR

abbreviation for **basal metabolic rate**.

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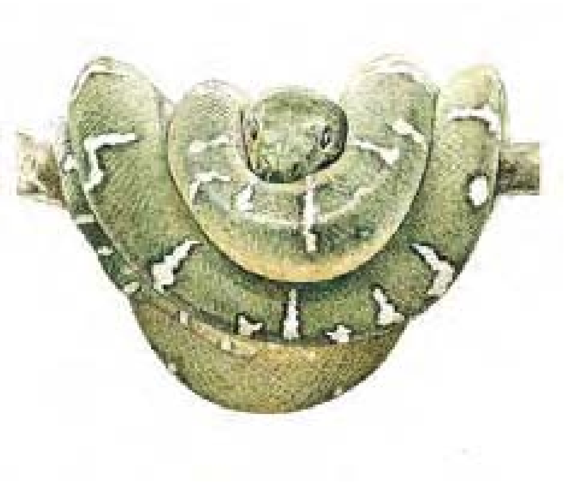
boa

any of various nonvenomous snakes of the family Boidae, found mainly in tropical and subtropical parts of the New World. Boas feed mainly on small mammals and birds. They catch these in their teeth or kill them by constriction (crushing the creature within their coils until it suffocates). The boa constrictor *Constrictor constrictor* can grow up to 5.5 m/18.5 ft long, but rarely reaches more than 4 m/12 ft. Other boas include the anaconda and the emerald tree boa *Boa canina*, about 2 m/6 ft long and bright green.

Some small burrowing boas live in North Africa and western Asia, while other species live on Madagascar and some Pacific islands, but the majority of boas live in South and Central America. The name boa is sometimes used loosely to include the pythons of the Old World, which also belong to the Boidae family, and which share with boas vestiges of hind limbs and constricting habits.

boa



(Image © Research Machines plc)

The emerald tree boa is the fastest-moving member of the boa family. It lives in trees, where it lies in wait for its prey – chiefly parrots, monkeys, and bats. It kills these with its teeth, not by constriction.

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boar

wild member of the pig family, such as the Eurasian wild boar *Sus scrofa*, from which domestic pig breeds derive. The wild boar is sturdily built, being 1.5 m/4.5 ft long and 1 m/3 ft high, and possesses formidable tusks. Of gregarious nature and mainly woodland-dwelling, it feeds on roots, nuts, insects, and some carrion.

The dark coat of the adult boar is made up of coarse bristles with varying amounts of underfur, but the young are striped. The male domestic pig is also known as a boar, the female as a sow.

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boarfish

marine bony fish found chiefly in the Mediterranean and northeast Atlantic. It has a flat oval body that is reddish coloured with seven transverse orange bands on the back. Boarfish are related to the dory.

classification

Boarfish *Capros aper* belongs to the order Zeiformes, class Osteichthyes.

The name boarfish is derived from its projecting hoglike snout.

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bobcat

wild cat *Lynx rufus* living in a variety of habitats from southern Canada through to southern Mexico. It is similar to the lynx, but only 75 cm/2.5 ft long, with reddish fur and less well-developed ear tufts.

Lynx Rufus - Bobcat

Go to site

Good profile of the bobcat. Contents include physical characteristics, behaviour, geographic range, and reproduction. There is also a photo of a bobcat.

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bobolink

North American songbird *Dolichonyx oryzivorus*, family Icteridae, order Passeriformes, that takes its common name from the distinctive call of the male. It has a long middle toe and pointed tailfeathers. Breeding males are mostly black, with a white rump; females are buff-coloured with dark streaks. Bobolinks are about 18 cm/7 in long and build their nests on the ground in hayfields and weedy meadows.

Bode, Johann Elert (1747-1826)

German astronomer and mathematician. He contributed greatly to the popularization of astronomy. He published the first atlas of all stars visible to the naked eye, *Uranographia* (1801), and popularized Bode's law.

Bode's law

or Titius-Bode law

numerical sequence that gives the approximate distances, in astronomical units (distance between Earth and Sun = one astronomical unit), of the planets from the Sun by adding 4 to each term of the series 0, 3, 6, 12, 24, ... and then dividing by 10. Bode's law predicted the existence of a planet between Mars and Jupiter, which led to the discovery of the asteroid belt.

The 'law' breaks down for Neptune and Pluto. The relationship was first noted in 1766 by the German mathematician Johann Titius, and developed by German astronomer Johann Bode.

Boeing Company, the

US military and commercial aircraft manufacturer. Among the models Boeing has produced are the B-17 Flying Fortress, 1935; the B-52 Stratofortress (1952); the Chinook helicopter (1961); the first jetliner, the Boeing 707 (1957); the jumbo jet or Boeing 747 (1969); the jetfoil (1975); and the 777-300 jetliner (1997).

The company was founded in 1916 near Seattle, Washington, by William E Boeing, as the Pacific Aero Products Company. Renamed the following year, the company built its first seaplane and in 1919 set up an airmail service between Seattle and Victoria, Canada.

Boeing bought US aircraft manufacturers McDonnell Douglas in 1997 for US$16.3 billion, to create the world's largest aerospace company, manufacturing about three-quarters of the world's commercial airliners. The same year it unveiled its 777-300 jetliner, the world's longest and largest twin-engine aircraft of its kind, which would replace the four-engine Boeing 747. The company employed 198,900 people wordwide in 2001.

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bog

type of wetland where decomposition is slowed down and dead plant matter accumulates as peat. Bogs develop under conditions of low temperature, high acidity, low nutrient supply, stagnant water, and oxygen deficiency. Typical bog plants are sphagnum moss, rushes, and cotton grass; insectivorous plants such as sundews and bladderworts are common in bogs (insect prey make up for the lack of nutrients).

Bogazköy

village in Turkey 145 km/90 mi east of Ankara. It is on the site of **Hattusas**, the ancient Hittite capital established about 1640 BC. Thousands of tablets excavated here over a number of years by the German Oriental Society revealed, when their cuneiform writing was deciphered by Bedrich Hrozny (1879-1952), a great deal about the customs, religion, and history of the Hittite people.

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bogbean

or buckbean

aquatic or bog plant belonging to the gentian family, with a creeping rhizome (underground stem) and leaves and pink flower spikes held above water. It is found over much of the northern hemisphere. (*Menyanthes trifoliata*, family Gentianaceae.)

Bogbean

Go to site

Detailed information about this aquatic or bog plant. This site contains an informative description of the plant, its history, and its habitat. It also features notes on the bogbean's constituents and many medicinal uses, which include treating gout and skin diseases.

Bohr, Niels Henrik David (1885-1962)

Danish physicist who was awarded the Nobel Prize for Physics in 1922 for his discovery of the structure of atoms and the radiation emanating from them. He pioneered quantum theory by showing that the nuclei of atoms are surrounded by shells of electrons, each assigned particular sets of quantum numbers according to their orbits. He explained the structure and behaviour of the nucleus, as well as the process of nuclear fission. Bohr also proposed the doctrine of **complementarity**, the theory that a fundamental particle is neither a wave nor a particle, because these are complementary modes of description.

quantum theory and atomic structure

Bohr's first model of the atom was developed working in Manchester, England, with Ernest Rutherford, who had proposed a nuclear theory of atomic structure from his work on the scattering of alpha rays in 1911. It was not, however, understood how electrons could continually orbit the nucleus without radiating energy, as classical physics demanded. In 1913, Bohr developed his theory of atomic structure by applying quantum theory to the observations of radiation emitted by atoms. Ten years earlier, Max Planck had proposed that radiation is emitted or absorbed by atoms in discrete units, or **quanta**, of energy. Bohr postulated that an atom may exist in only a certain number of stable states, each with a certain amount of energy, in which electrons orbit the nucleus without emitting or absorbing energy. He proposed that emission or absorption of energy occurs only with a transition from one stable state to another. When a transition occurs, an electron moving to a higher orbit absorbs energy and an electron moving to a lower orbit emits energy. In so doing, a set number of quanta of energy are emitted or absorbed at a particular frequency.

the liquid-droplet model

In 1939, Bohr proposed his liquid-droplet model for the nucleus, in which nuclear particles are pulled together by short-range forces, similar to the way in which molecules in a drop of liquid are attracted to one another. In the case of uranium, the extra energy produced by the absorption of a neutron causes the nuclear particles to separate into two groups of approximately the same size, thus breaking the nucleus into two smaller nuclei – a process called nuclear fission. The model was vindicated when Bohr correctly predicted the differing behaviour of nuclei of uranium-235 and uranium-238 from the fact that the numbers of neutrons in the two nuclei is odd and even respectively.

Niels Bohr Institute History

Go to site

Short survey of the development of the Niels Bohr Institute, so intimately connected with Bohr's life work as a physicist. There are sections on the Institute today, a history from 1929 to 1965, and a picture gallery.

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bohrium

chemical symbol Bh

synthesized, radioactive element of the transactinide series, atomic number 107, relative atomic mass 262. It was first synthesized by the Joint Institute for Nuclear Research in Dubna, Russia, in 1976; in 1981 the Laboratory for Heavy-Ion Research in Darmstadt, Germany, confirmed its existence. Until 1997 it was known by the temporary name, unnilseptium. It was named in 1997 after Danish physicist Niels Bohr.

The first chemical study of bohrium was published in 2000, after experiments by Swiss researchers produced six atoms of bohrium-267 (half-life 17 seconds). It behaved like a typical group VII element, with chemical similarities to technetium and rhenium.

Bohr model

model of the atom conceived by Danish physicist Niels Bohr in 1913. It assumes that the following rules govern the behaviour of electrons: (1) electrons revolve in orbits of specific radius around the nucleus without emitting radiation; (2) within each orbit, each electron has a fixed amount of energy; electrons in orbits farther away from the nucleus have greater energies; (3) an electron may 'jump' from one orbit of high energy to another of lower energy causing the energy difference to be emitted as a photon of electromagnetic radiation such as light; (4) an electron may absorb a photon of radiation and jump from a lower-energy orbit to a higher-energy one. The Bohr model has been superseded by wave mechanics (see quantum theory).

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boiler

any vessel that converts water into steam. Boilers are used in conventional power stations to generate steam to feed steam turbines, which drive the electricity generators. They are also used in steamships, which are propelled by steam turbines, and in steam locomotives. Every boiler has a furnace in which fuel (mainly coal, oil, or gas) is burned to produce hot gases, and a system of tubes in which heat is transferred from the gases to the water.

The common kind of boiler used in ships and power stations is the **water-tube** type, in which the water circulates in tubes surrounded by the hot furnace gases. The water-tube boilers at power stations produce steam at a pressure of up to 300 atmospheres and at a temperature of up to 600°C/1,100°F to feed to the steam turbines. It is more efficient than the **fire-tube** type that is used in steam locomotives. In this boiler the hot furnace gases are drawn through tubes surrounded by water.

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boiling point

for any given liquid, the temperature at which the application of heat raises the temperature of the liquid no further, but converts it into vapour.

The boiling point of water under normal pressure is 100°C/212°F. The lower the pressure, the lower the boiling point and vice versa.

Boiling points of selected liquids

Liquid	Boiling point	
	°C	°F
Methanol	64.7	148.5
Ethanol	78.2	172.8
Benzene	80.1	176.2
Water	100.0	212.0
Octane	125.6	258.1
Turpentine	156.0	312.8
Glycerol	290.0	554.0
Mercury	356.9	674.4

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boletus

any of several fleshy fungi (see fungus) with thick stems and caps of various colours. The European *Boletus edulis* is edible, but some species are poisonous. (Genus *Boletus*, class Basidiomycetes.)

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boll weevil

small American beetle *Anthonomus grandis* of the weevil group. The female lays her eggs in the unripe pods or 'bolls' of the cotton plant, and on these the larvae feed, causing great destruction.

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bolometer

sensitive thermometer that measures the energy of radiation by registering the change in electrical resistance of a fine wire when it is exposed to heat or light.

The US astronomer Samuel Langley devised it in 1880 for measuring radiation from stars.

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bolometric magnitude

in astronomy, measure of the brightness of a star over all wavelengths. Bolometric magnitude is related to the total radiation output of the star. See magnitude.

Boltzmann, Ludwig Eduard (1844-1906)

Austrian physicist who studied the kinetic theory of gases, which explains the properties of gases by reference to the motion of their constituent atoms and molecules. He established the branch of physics now known as statistical mechanics.

He derived a formula, the **Boltzmann distribution**, which gives the number of atoms or molecules with a given energy at a specific temperature. The constant in the formula is called the **Boltzmann constant**.

Boltzmann, Ludwig

Go to site

Biography of the physicist and mathematician. The site contains a description of the work of Boltzmann, and also describes his working relationships with his contemporaries, which due to the radical nature of his work were often strained. Also included are several literature references for further reading, and a photograph of Boltzmann.

Boltzmann constant

symbol k

in physics, the constant that relates the kinetic energy (energy of motion) of a gas atom or molecule to temperature. Its value is 1.38065 × 10^{-23} joules per kelvin. It is equal to the gas constant *R*, divided by Avogadro's number.

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bombardier beetle

beetle that emits an evil-smelling fluid from its abdomen, as a defence mechanism. This fluid rapidly evaporates into a gas, which appears like a minute jet of smoke when in contact with air, and blinds the predator about to attack.

classification

Bombardier beetles in genus *Brachinus*, family Carabidae, order Coleoptera, class Insecta, phylum Arthropoda.

Bombay duck

or bummalow

small fish *Harpodon nehereus* found in the Indian Ocean. It has a thin body, up to 40 cm/16 in long, and sharp, pointed teeth. It feeds on shellfish and other small fish. It is valuable as a food fish, and is eaten, salted and dried, with dishes such as curry.

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bond

in chemistry, the result of the forces of attraction that hold together atoms in an element or compound. The principal types of bonding are ionic, covalent, metallic, and intermolecular (such as hydrogen bonding).

The type of bond formed depends on the elements concerned and their electronic structure. In an ionic or electrovalent bond, common in inorganic compounds, the combining atoms gain or lose electrons to become ions; for example, sodium (Na) loses an electron to form a sodium ion (Na^+) while chlorine (Cl) gains an electron to form a chloride ion (Cl^-) in the ionic bond of sodium chloride (NaCl).

In a covalent bond, the atomic orbitals of two atoms overlap to form a molecular orbital containing two electrons, which are thus effectively shared between the two atoms. Covalent bonds are common in organic compounds, such as the four carbon-hydrogen bonds in methane (CH_4). In a dative covalent or coordinate bond, one of the combining atoms supplies both of the valence electrons in the bond.

A metallic bond joins metals in a crystal lattice, the atoms occupy lattice positions as positive ions, and valence electrons are shared between all the ions in an 'electron gas'.

In a hydrogen bond, a hydrogen atom joined to an electronegative atom, such as nitrogen or oxygen, becomes partially positively charged, and is weakly attracted to another electronegative atom on a neighbouring molecule.

Bondi, Hermann (1919-2005)

Austrian-born British cosmologist. In 1948 he joined with English astronomer and cosmologist Fred Hoyle and Austrian-born US astronomer Thomas Gold in developing the steady-state theory of cosmology, which suggested that matter is continuously created in the universe. He was knighted in 1973.

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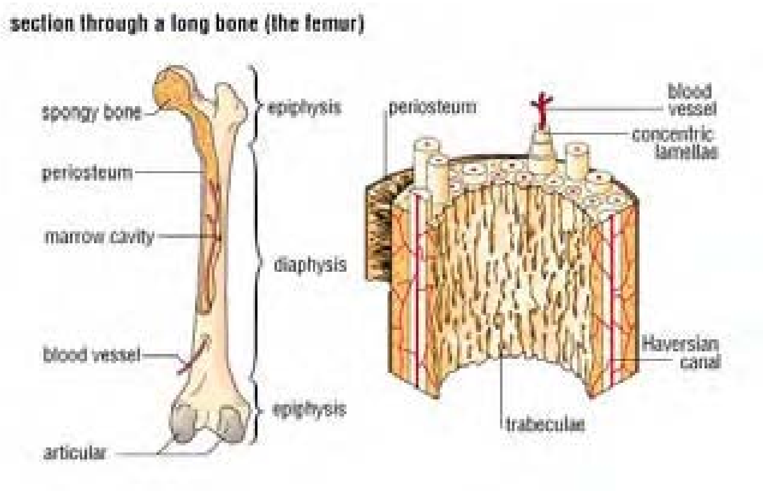
bone

hard connective tissue comprising the skeleton of most vertebrate animals. Bone is composed of a network of collagen fibres impregnated with mineral salts (largely calcium phosphate and calcium carbonate), a combination that gives it great density and strength, comparable in some cases with that of reinforced concrete. Enclosed within this solid matrix are bone cells, blood vessels, and nerves. The interior of the long bones of the limbs consists of a spongy matrix filled with a soft marrow that produces blood cells.

There are two types of bone: those that develop by replacing cartilage and those that form directly from connective tissue. The latter, which includes the bones of the cranium, are usually platelike in shape and form in the skin of the developing embryo. Humans have 206 distinct bones in the skeleton (see human body), of which the smallest are the three ossicles in the middle ear. However, a different total is sometimes given, because of a number of fused pairs of bones in the skull that may be counted as one or two bones.

bone


section through a long bone (the femur)
spongy bone
periosteum
marrow cavity
blood vessel
articular
epiphysis
diaphysis
epiphysis
periosteum
blood vessel
concentric lamellae
Haversian canal
trabeculae

(Image © Research Machines plc)

The upper end of the thighbone or femur is made up of spongy bone, which has a fine lacework structure designed to transmit the weight of the body. The shaft of the femur consists of hard compact bone designed to resist bending. Fine channels carrying blood vessels, nerves, and lymphatics interweave even the densest bone.

bones

To remember the bones of the upper limb:

Some **c**riminals **h**ave **u**nderestimated **R**oyal **C**anadian **M**ounted **P**olice

Scapula, **c**lavicle, **h**umerus, **u**lna, **r**adius, **c**arpals, **m**etacarpals, **p**halanges

Bones of the Body

Go to site

Large resource on most of the bones in the human body. The page is divided into two frames: the left-hand frame lists all of the bones covered, ordered under the headings of 'Skull', 'Vertebrae', 'Thorax', 'Upper extremity', 'Pelvis', and 'Lower extremity'. Clicking on a specific bone under one of the headings brings up information in the right-hand frame.

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bone marrow

substance found inside the cavity of bones. In early life it produces red blood cells but later on lipids (fat) accumulate and its colour changes from red to yellow.

Bone marrow may be transplanted in the treatment of some diseases, such as leukaemia, using immunosuppressive drugs in the recipient to prevent rejection.

bone marrow

(Image © Research Machines plc)

Syringes are used to harvest bone marrow from the pelvis of a donor prior to transplantation into a patient with leukaemia. Bone marrow is rich in blood-forming and immune system cells. Donated bone marrow can be used to save the lives of patients whose own marrow cells have been destroyed by the chemotherapy and radiotherapy needed to eradicate their cancers.

bongo

Central African antelope *Boocercus eurycerus*, living in dense humid forests. Up to 1.4 m/4.5 ft at the shoulder, it has spiral horns which may be 80 cm/2.6 ft or more in length. The body is rich chestnut, with narrow white stripes running vertically down the sides, and a black belly.

bonito

any of various species of medium-sized tuna, predatory fish of the genus *Sarda*, in the mackerel family. The ocean bonito *Katsuwonus pelamis* grows to 1 m/3 ft and is common in tropical seas. The Atlantic bonito *Sarda sarda* is found in the Mediterranean and tropical Atlantic and grows to the same length but has a narrower body.

bony fish

fish of the class Osteichthyes, the largest and most important class of fish. The head covering and the scales are based on bone. Bony fish have a swimbladder, which may be modified into lungs and the gills are covered by a flap, the operculum.

The bony fish are divided into two subclasses.

Subclass **Sarcopterygii**, the fleshy-finned fish, has two orders: Crossopterygii, represented today by the coelacanth, and Dipnoi, represented by the lungfish.

Subclass **Actinopterygii**, which contains all those fish whose fins are supported by bony rays, is sometimes divided into three superorders: Chondrostei, which includes the sturgeons, birchirs, and reedfishes; Holostei, which includes the garpikes and bowfins; and Teleostei, which includes about 20,000 species of 'modern' bony fishes, such as salmon, pike, and cod.

boobook

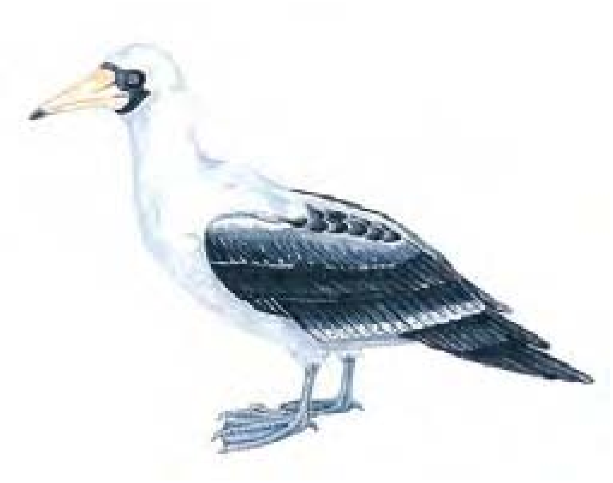
owl *Ninox novaeseelandiae* found in Australia, so named because of its call.

booby

tropical seabird of the genus *Sula*, in the same family, Sulidae, as the northern gannet, order Pelicaniformes. There are six species, including the circumtropical brown booby *S. leucogaster*. Plumage is white and black or brown, with no feathers on the throat and lower jaw. They inhabit coastal waters, and dive to catch fish. The name was given by sailors who saw the bird's tameness as stupidity.

One species, **Abbott's booby**, breeds only on Christmas Island, in the western Indian Ocean. Unlike most boobies and gannets, it nests high up in trees. Large parts of its breeding ground have been destroyed by phosphate mining, but conservation measures now protect the site. A new species of booby, *Sula granti*, was discovered by US ornithologists in 2001, off the coast of Central and South America. There were estimated to be 75,000-100,000 of the species in the region.

booby



(Image © Research Machines plc)

Abbott's booby. Like the closely related gannet, boobies plunge into the sea to catch fish and squid.

booklouse

any of numerous species of tiny wingless insects of the order Psocoptera, especially *Atropus pulsatoria*, which lives in books and papers, feeding on starches and moulds.

Most of the other species live in bark, leaves, and lichens. They thrive in dark, damp conditions.

Boole, George (1815-1864)

English mathematician. His work *The Mathematical Analysis of Logic* (1847) established the basis of modern mathematical logic, and his **Boolean algebra** can be used in designing computers.

Boole's system is essentially two-valued. By subdividing objects into separate classes, each with a given property, his algebra makes it possible to treat different classes according to the presence or absence of the same property. Hence it involves just two numbers, 0 and 1 – the binary system used in the computer.

Boole, George

Go to site

Extensive biography of the mathematician. The site contains a clear description of his working relationship with his contemporaries, and also includes the title page of his famous book *Investigation of the Laws of Thought*. Several literature references for further reading on the mathematician are also listed, and the Web site also features a portrait of Boole.

boomslang

rear-fanged venomous African snake *Dispholidus typus*, often green but sometimes brown or blackish, and growing to a length of 2 m/6 ft. It lives in trees, and feeds on tree-dwelling lizards such as chameleons. Its venom can be fatal to humans; however, boomslangs rarely attack people.

booster

first-stage rocket of a launching vehicle, or an additional rocket strapped to the main rocket to assist lift-off.

The US Delta rocket, for example, has a cluster of nine strap-on boosters that fire on lift-off. Europe's Ariane 3 rocket uses twin strap-on boosters, as does the US space shuttle.

booster

(Image © NASA)

Test-firing the DM-2 (Demonstration Motor 2) for the solid rocket booster (SRB) used on the space shuttle. The shuttle's SRBs give the spacecraft most of its lift, providing a combined thrust of 2.6 million kg/5.8 million lb. After two minutes of flight, having accelerated the shuttle to 4,979 kph/3,094 mph, they separate and fall back to Earth for retrieval and re-use.

boot

or bootstrap

in computing, the process of starting up a computer. Most computers have a small, built-in boot program that starts automatically when the computer is switched on – its only task is to load a slightly larger program, usually from a hard disk, which in turn loads the main operating system.

Boötes

constellation of the northern hemisphere represented by a herdsman driving a bear (Ursa Major) around the pole. Its brightest star is Arcturus (or Alpha Boötis), which is 36 light years from Earth. The herdsman is assisted by the neighbouring Canes Venatici, 'the Hunting Dogs'.

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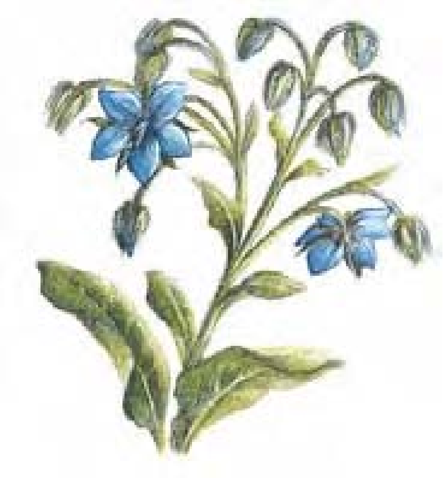
borage

plant native to southern Europe, used in salads and in medicine. It has small blue flowers and hairy leaves. (*Borago officinalis*, family Boraginaceae.)

borage



(Image © Research Machines plc)

Borage is an annual plant, growing between 90 cm/3 ft and 120 cm/4 ft high.

Borage

Go to site

Large source of information about this European plant. This site contains an interesting description of the plant, its history, and its habitat. It also features notes on borage's constituents and many medicinal uses, which include treating fevers and acting as a diuretic. There are also notes on the cultivation of borage.

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borax

hydrous sodium borate, $Na_2B_4O_7.10H_2O$, found as soft, whitish crystals or encrustations on the shores of hot springs and in the dry beds of salt lakes in arid regions, where it occurs with other borates, halite, and gypsum. It is used in bleaches and washing powders.

A large industrial source is Borax Lake, California. Borax is also used in glazing pottery, in soldering, as a mild antiseptic, and as a metallurgical flux.

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border terrier

small, hardy, short-tailed dog with an otterlike head, moderately broad skull and short, strong muzzle. Its small, V-shaped ears drop forward. The coat is hard and dense with a close undercoat and is red, beige, and tan, or blue and tan. Dogs weigh 6-7 kg/13-15.5 lb; bitches 5-6.5 kg/ 11-14.5 lb.

Bordet, Jules Jean Baptiste Vincent (1870-1961)

Belgian bacteriologist and immunologist who was awarded a Nobel Prize for Physiology or Medicine in 1919 for his work on immunity. He researched the role of blood serum in the human immune response, and was the first to isolate the whooping-cough bacillus, in 1906.

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bore

surge of tidal water up an estuary or a river, caused by the funnelling of the rising tide by a narrowing river mouth. A very high tide, possibly fanned by wind, may build up when it is held back by a river current in the river mouth. The result is a broken wave, a metre or a few feet high, that rushes upstream.

Famous bores are found in the rivers Severn (England), Seine (France), Hooghly (India), and Chang Jiang (China), where bores of over 4 m/13 ft have been reported.

Borelli, Giovanni Alfonso (1608-1679)

Italian scientist who explored the links between physics and medicine and showed how mechanical principles could be applied to animal physiology. This approach, known as iatrophysics, has proved basic to understanding how the mammalian body works.

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boric acid

or boracic acid; $B(OH)_3$

acid formed by the combination of hydrogen and oxygen with non-metallic boron. It is a weak antiseptic and is used in the manufacture of glass and enamels. It is also an efficient insecticide against ants and cockroaches.

Borlaug, Norman Ernest (1914-)

US microbiologist and agronomist. He developed high-yielding varieties of wheat and other grain crops to be grown in developing countries, and was the first to use the term 'Green Revolution'. He was awarded the Nobel Prize for Peace in 1970 for his development of agricultural technology.

Born, Max (1882-1970)

German-born British physicist. He was awarded the Nobel Prize for Physics in 1954 for fundamental work on the quantum theory, especially his 1926 discovery that the wave function of an electron is linked to the probability that the electron is to be found at any point.

In 1924 Born coined the term 'quantum mechanics'. He made Göttingen a leading centre for theoretical physics and together with his students and collaborators - notably Werner Heisenberg - he devised in 1925 a system called matrix mechanics that accounted mathematically for the position and momentum of the electron in the atom. He also devised a technique, called the Born approximation method, for computing the behaviour of subatomic particles, which is of great use in high-energy physics.

Born, Max

Go to site

Biography of the German-born British physicist. The Web site details the work of Born, and his relationships with his contemporaries and colleagues. Also included are several literature references for further reading on the physicist, and a portrait photograph of Born.

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boron

chemical symbol B

non-metallic element, atomic number 5, relative atomic mass 10.811. In nature it is found only in compounds, as with sodium and oxygen in borax. It exists in two allotropic forms (see allotropy): brown amorphous powder and very hard, brilliant crystals. Its compounds are used in the preparation of boric acid, water softeners, soaps, enamels, glass, and pottery glazes. In alloys it is used to harden steel. Because it absorbs slow neutrons, it is used to make boron carbide control rods for nuclear reactors. It is a necessary trace element in the human diet. The element was named by Humphry Davy, who isolated it in 1808, from *bor*ax + -on, as in carb*on*.

boron

Boron becomes liquid at 2,100°C/ 3812°F and is so corrosive that it cannot be contained at all.

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borzoi

(Russian 'swift')

breed of large dog originating in Russia. It is of the greyhound type, white with darker markings, with a thick, silky coat, and stands 75 cm/30 in or more at the shoulder.

The borzoi's original quarry was hares and foxes, but it was selectively bred in the 19th century to produce a larger, stronger dog suitable for hunting wolves.

Borzoi Club of America

Go to site

Huge source of information containing details of the origins of the breed, breed standards, and shows. There are a large number of photos and links to other borzoi sites. A video allows you to watch this magnificent athlete in action.

Bose-Einstein condensate

BEC

hypothesis put forward in 1924 by German-born US physicist Albert Einstein and Indian physicist Satyendra Bose, suggesting that when a dense gas is cooled to a little over absolute zero it will condense and its atoms will lose their individuality and act as an organized whole. The first Bose-Einstein condensate was produced in June 1995 by US physicists cooling rubidium atoms to 10 billionths of a degree above absolute zero. The condensate existed for about a minute before becoming rubidium ice.

In 2003 scientists formed a new state of matter: a Bose-Einstein condensate made out of molecules – previously all BECs were composed of atoms. A gaseous cloud of lithium atoms was cooled, with the use of laser beams, until weak chemical bonds between atoms produced paired sets of lithium atoms. These paired atoms were then stable enough to form a BEC consisting of 150,000 molecules that lasted for 20 seconds.

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boson

in physics, an elementary particle whose spin can only take values that are whole numbers or zero. Bosons may be classified as gauge bosons (carriers of the four fundamental forces) or mesons. All elementary particles are either bosons or fermions.

Unlike fermions, more than one boson in a system (such as an atom) can possess the same energy state. That is, they do not obey the Pauli exclusion principle. When developed mathematically, this statement is known as the Bose-Einstein law, after its discoverers Indian physicist Satyendra Bose and Albert Einstein.

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botanical garden

place where a wide range of plants is grown, providing the opportunity to see a botanical diversity not likely to be encountered naturally. Among the earliest forms of botanical garden was the **physic garden**, devoted to the study and growth of medicinal plants; an example is the Chelsea Physic Garden in London, established in 1673 and still in existence. Following increased botanical exploration, botanical gardens were used to test the commercial potential of new plants being sent back from all parts of the world.

Today a botanical garden serves many purposes: education, science, and conservation. Many are associated with universities and also maintain large collections of preserved specimens (see herbarium), libraries, research laboratories, and gene banks. There are 1,600 botanical gardens worldwide.

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botany

(Greek botane 'herb')

study of living and fossil plants, including form, function, interaction with the environment, and classification.

Botany is subdivided into a number of specialized studies, such as the identification and classification of plants (taxonomy), their external formation (plant morphology), their internal arrangement (plant anatomy), their microscopic examination (plant histology), their functioning and life history (plant physiology), and their distribution over the Earth's surface in relation to their surroundings (plant ecology). Palaeobotany concerns the study of fossil plants, while economic botany deals with the utility of plants. Horticulture, agriculture, and forestry are branches of botany.

Carnivorous Plants FAQ

Go to site

Well-written source of general information about carnivorous plants. Each genus is presented with good text and pictures. There is advice on planting, growing, and feeding carnivorous plants. There is additional information on effort to conserve endangered species.

GardenWeb Glossary of Botanical Terms

Go to site

Searchable, text-only glossary of well over 2,000 botanical terms. There is a brief explanation of how the search engine works and a selection of criteria with which to refine your search, including 'terms' or 'definitions', as well as a basic and/or Boolean search.

botfly

any fly of the family Oestridae. The larvae are parasites that feed on the skin (warblefly of cattle) or in the nasal cavity (nostrilflies of sheep and deer). The horse botfly belongs to another family, the Gasterophilidae. It has a parasitic larva that feeds in the horse's stomach.

botfly

Human botfly larvae feed on healthy flesh. Female botflies lay their eggs on the abdomens of mosquitoes. When the mosquito bites a person, the warmth of that person's body causes the eggs to hatch and the botfly larvae crawl into the puncture. For up to three months they feed on the flesh until they metamorphose into flies and fly away.

bo tree

or peepul

Indian fig tree, said to be the tree under which the Buddha became enlightened. (*Ficus religiosa*, family Moraceae.)

bottlebrush

any of several trees or shrubs common in Australia, belonging to the myrtle family. They have cylindrical, composite flower heads in green, yellow, white, various shades of red, and violet. (Genus *Callistemon*, family Myrtaceae.)

botulism

rare, often fatal type of food poisoning. Symptoms include vomiting, diarrhoea, muscular paralysis, breathing difficulties and disturbed vision.

It is caused by a toxin produced by the bacterium *Clostridium botulinum*, found in soil and sometimes in improperly canned foods.

Thorough cooking destroys the toxin, which otherwise suppresses the cardiac and respiratory centres of the brain. In neurology, botulinum toxin is sometimes used to treat rare movement disorders.

Botulinal Toxins

Go to site

Part of a larger, educational site on biological and chemical warfare, this account of botulinal toxins covers toxicology, symptoms, cautions and precautions, and the potential devastation these toxins can cause when used as weapons of war.

Childhood Infections - Infant Botulism

Go to site

Useful information about infant botulism. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the possible ways to prevent of the infection and details of what to do should the symptoms occur.

bougainvillea

any plant of a group of South American tropical vines of the four o'clock family, now cultivated in warm countries around the world for the colourful red and purple bracts (leaflike structures) that cover the flowers. They are named after the French navigator Louis de Bougainville. (Genus *Bougainvillea*, family Nyctaginaceae.)

bougainvillea

(Image © Corel)

Bougainvillea in Mexico. The flowers are small, and surrounded by large brightly coloured bracts.

bougainvillea

(Image © Research Machines plc)

The climbing plant bougainvillea, of the family Nyctaginaceae, is a species native to the American tropical zone, and is renowned for its abundance of bright flowers. Plants such as this one in the Dominican Republic will grow all year round in the warmth and rich, loamy, well-drained soil of these regions. Further north, they need protecting in winter from temperatures under 10°C/50°F.

Bouguer anomaly

anomaly in the local gravitational force that is due to the density of rocks rather than local topography, elevation, or latitude. A positive anomaly, for instance, is generally indicative of denser and therefore more massive rocks at or below the surface. A negative anomaly indicates less massive materials. Calculations of Bouguer anomalies are used for mineral prospecting and for understanding the structure beneath the Earth's surface. The Bouguer anomaly is named after its discoverer, the French mathematician Pierre Bouguer, who first observed it in 1735.

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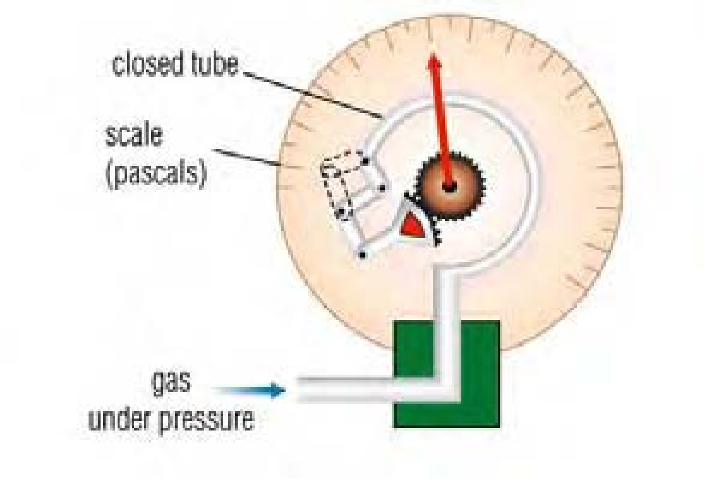
boulder clay

another name for till, a type of glacial deposit.

Bourdon gauge

instrument for measuring pressure, patented by French watchmaker Eugène Bourdon in 1849. The gauge contains a C-shaped tube, closed at one end. When the pressure inside the tube increases, the tube uncurls slightly, causing a small movement at its closed end. A system of levers and gears magnifies this movement and turns a pointer, which indicates the pressure on a circular scale. Bourdon gauges are often fitted to cylinders of compressed gas used in industry and hospitals.

Bourdon gauge



(Image © Research Machines plc)

The most common form of Bourdon gauge is the C-shaped tube. However, in high-pressure gauges spiral tubes are used; the spiral rotates as pressure increases and the tip screws forwards.

bovine somatotropin

BST

hormone that increases an injected cow's milk yield by 10-40%. It is a protein naturally occurring in milk and breaks down within the human digestive tract into harmless amino acids. However, doubts have arisen as to whether such a degree of protein addition could in the long term be guaranteed harmless either to cattle or to humans.

Although no evidence of adverse side effects to consumers has been found, BST was banned in Europe in 1993 until the year 2000. In the USA genetically engineered BST has been in use since February 1994; in Vermont a law requiring milk containing BST to be labelled as such was passed in September 1995. In January 1999, Canada announced a ban on BST. The reasons given for the ban included a 25% increase in the likelihood of mastitis in cows given BST; an 18% increase in infertility; and double the risk of becoming lame.

bovine spongiform encephalopathy

BSE; or mad cow disease

disease of cattle, related to scrapie in sheep, that attacks the nervous system, causing aggression, lack of coordination, and collapse. It was formally identified in the UK in November 1986, and between 1986 and 2002 there were 181,376 cases of BSE identified in British cattle, which were all slaughtered to contain the spread of the disease. After safety measures were put in place for the selection and processing of cattle, British beef was declared safe (by the UK government) in 1999. Following outbreaks of BSE in French, German, and Spanish cattle in late 2000, European Union (EU) agriculture ministers agreed to ban, as of 1 January 2001, the use of meat-and-bone meal from animal feed and to ban all cattle over 30 months old from the food chain unless tested for BSE.

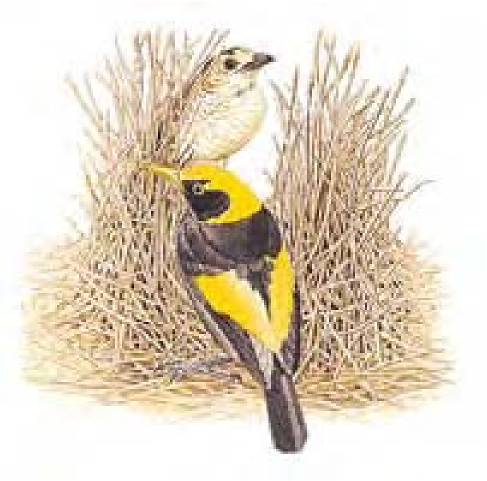
BSE is one of a group of diseases known as the transmissible spongiform encephalopathies, since they are characterized by the appearance of spongy changes in brain tissue. Some scientists believe that all these conditions, including Creutzfeldt-Jakob disease (CJD) in humans, are in effect the same disease, and in 1996 a link was established between the deaths of 10 young people from CJD and the consumption of beef products.

The cause of these universally fatal diseases is not fully understood, but they may be the result of a rogue protein called a prion. A prion may be inborn or it may be transmitted in contaminated tissue.

bower bird

New Guinean and northern Australian bird of the family Ptilonorhynchidae, order Passeriformes, related to the bird of paradise. The males are dull-coloured, and build elaborate bowers of sticks and grass, decorated with shells, feathers, or flowers, and even painted with the juice of berries, to attract the females. There are 17 species.

bower bird



(Image © Research Machines plc)

The regent bower bird *Sericulus chrysocephalus* is found in the rainforests of northeast Australia and New Guinea. The male seeks to impress his mate by building a colourfully decorated bower. It is the female who builds the nest; her dull plumage camouflages her while she is sitting on her eggs and feeding her young.

bowfin

North American fish *Amia calva* with a swim bladder highly developed as an air sac, enabling it to breathe air. It is the only surviving member of a primitive group of bony fishes.

bowhead

Arctic whale *Balaena mysticetus* with strongly curving upper jawbones supporting the plates of baleen with which it sifts planktonic crustaceans from the water. Averaging 15 m/50 ft long and 90 tonnes/100 tons in weight, these slow-moving, placid whales were once extremely common, but by the 17th century were already becoming scarce through hunting. In 2000 it was believed that only 700–1,000 bowhead whales remained in existence.

The bowhead whale eats up to 50,000 crustaceans a minute by forcing water through its 700 baleen sheets, using its 300 kg/660 lb tongue. Bowheads can be extremely long-lived. In 2000 one specimen, killed by hunters, was found to be 211 years old.

Bowlby, (Edward) John (Mostyn) (1907-1990)

English psychologist and author of *Child Care and the Growth of Love* (1953), in which he argued that a home environment for children is preferable to an institution, and stressed the bond between mother and child. He was consultant in mental health for the World Health Organization from 1972 to 1990.

box

any of several small evergreen trees and shrubs, with small, leathery leaves. Some species are used as hedging plants and for shaping into garden ornaments. (Genus *Buxus*, family Buxaceae.)

Box

Go to site

Detailed information about this type of tree or shrub. This site contains an informative description of the plant, its constituents, and its habitat. It also features notes on the many medicinal uses, which include acting as a sedative and treating rheumatism. There is also information about other species of this plant.

boxer

breed of dog, about 60 cm/24 in tall, with a smooth coat and a set-back nose. The tail is usually docked. A boxer is usually brown, often with white markings, but may be fawn or brindled.

American Boxer Club

Go to site

Best of many boxer sites. Contents include the history of the breed, the breed standard, veterinary advice, tips for owners, and news of boxer shows. There are extensive links to other boxer sites and a comprehensive bibliography.

boxfish

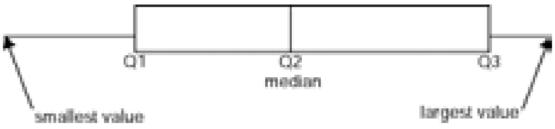
or trunkfish

any fish of the family Ostraciodontidae, with scales that are hexagonal bony plates fused to form a box covering the body, only the mouth and fins being free of the armour. Boxfishes swim slowly. The cowfish, genus *Lactophrys*, with two 'horns' above the eyes, is a member of this group.

box plot

or box and whisker diagram

in statistics, figure used to represent quartile information. The box represents the central 50% of the data and the whiskers extend from the box to the largest and smallest values. This method gives an overall spread of the data.

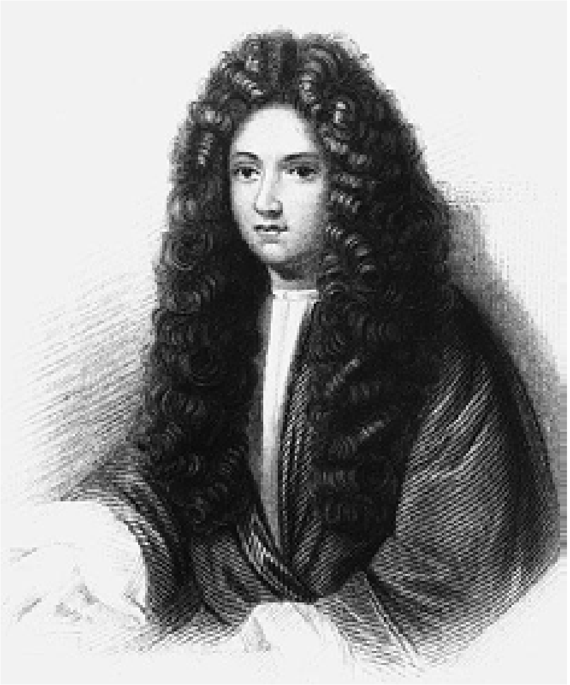


Boyle, Robert (1627-1691)

Irish chemist and physicist who published *The Sceptical Chymist* (1661), a groundbreaking book that became the definitive text among scientists for decades to follow. He formulated Boyle's law in 1662. He was a pioneer in the use of experiment and scientific method.

Boyle questioned the alchemical basis of the chemical theory of his day, and the attempts made to produce impossible or mythical substances. Instead he moved towards research, teaching that the proper object of chemistry was to determine the compositions of substances in order to discover the make-up of the world. The term 'analysis' was coined by Boyle and many of the reactions still used in qualitative work were known to him. He introduced certain plant extracts, notably litmus, for the indication of acids and bases. He was also the first chemist to collect a sample of gas.

Boyle



(Image © Billie Love)

Irish-born pioneer of modern day chemistry Robert Boyle, who formulated Boyle's Law. A founder member of the Royal Society, he was largely responsible for establishing chemistry as a serious discipline, through his insistence on experiment and accurate observation. His famous law stated that at a given temperature, pressure and volume are inversely proportional.

Boyle, Robert

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of chemist and physicist Robert Boyle. In addition to biographical information, you will find a list of references about Boyle and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Boyle. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

Boyle's law

law stating that the volume of a given mass of gas at a constant temperature is inversely proportional to its pressure. For example, if the pressure on a gas doubles, its volume will be reduced by a half, and vice versa. The law was discovered in 1662 by Irish physicist and chemist Robert Boyle. See also gas laws.

If a gas is compressed in a cylinder the volume of the gas decreases. The number of particles of gas in the cylinder remains the same. The particles get closer together, collide with each other more frequently, and the pressure of the gas increases due to the force of the particles colliding. If the pressure is P and the volume is V, then $P = 1/V$. Therefore, as the volume decreases the pressure increases.

Boyle's law can be investigated by using an apparatus consisting of a foot pump attached to a pressure gauge. This is attached to a glass tube (with a scale) containing an oil and trapped air. As more air is pumped into the apparatus from the foot pump and into the oil reservoir, the oil in the glass tube is forced in and the pressure on the trapped air gets higher. A series of pressure and volume readings are taken. It is found that multiplying pressure by volume for each of the readings produces the same result. Therefore, $P \times V = \text{constant}$. The results of P and $1/V$ plotted as a graph give a straight line. Readings from the experiment show that:

$P_1 V_1 = P_2 V_2$

where P_1 and V_1 are the initial pressure and volume of a gas, and P_2 and V_2 are its final pressure and volume.

Boyle's Law: Discovery

measuring the spring of the air

In the 1600s, orthodox science held that 'Nature abhorred a vacuum'. In 1643 Italian physicist Evangelista Torricelli (1608-1647) invented the mercury barometer, and suggested that it contained a vacuum. But in general, a vacuum was very rare. Scientists who believed that a vacuum could exist had to explain their scarcity. Irish-born Robert Boyle (1627-1691), who settled in Oxford in 1656, felt that air had an in-built expansive power, or 'spring', which made it expand to fill any vacuum.

the active spring

In 1660, Boyle set out to demonstrate and measure this expansive power. Later, describing his experiments, he wrote:

'Diverse ways have been proposed to show both the Pressure of the Air, as the Atmosphere is a heavy Body, and the Air, especially when compressed by outward force, has a Spring that enables it to sustain or resist equal to that as much of the atmosphere, as can come to bear against it, and also to show, that such Air as we live in, and is not condensed by any human or Adventitious force, has not only a resisting Spring, but an active Spring (if I may so speak) in some measure, as when it distends a flaccid or breaks a full-blown bladder.'

Boyle began by demonstrating the 'active' spring of the air, helped by his assistant Robert Hooke (1635-1703), who had made an improved air pump for use in Boyle's experiments. Together they devised an apparatus comprising of a container from which air could be extracted, holding a small inner tube containing air trapped and compressed by mercury. When the air was pumped from the outer container, this compressed air expanded, pushing the mercury from the small tube, amply demonstrating the active spring of the trapped air.

the passive spring

Next, they studied the 'passive' or resisting spring of air when compressed by external pressure. They made a long glass tube 'crooked at the bottom ... The orifice of the shorter leg ... being hermetically sealed'. They pasted strips of paper, carefully marked with a scale in inches, along each arm of the apparatus, poured mercury in the long, open end, and tilted the tube to one side, so that 'the air in the enclosed tube should be of the same laxity (pressure) as the rest of the air about it'.

Then they added more mercury to increase the pressure on the trapped gas, until its volume decreased by half. The additional 'head' of mercury measured 29 in/73.7 cm. Earlier, they had used a Torricellian barometer to measure the atmospheric pressure: it was equivalent to 29 in of mercury. Hence, Boyle concluded, 'this observation does both very well agree with and confirm our hypothesis... that the greater the weight is, that leans upon the air, the more forcible is its endeavour of dilation and consequently its power of resistance (as other springs are stronger when bent by greater weights)'.

further experiments

At this point, the glass tube broke, scattering mercury around the laboratory. They constructed a new stronger tube, with a 'pretty bigness', placed it in a wooden box as a precaution against another breakage, and made a series of measurements of the relationship between the volume of the air and the weight of mercury needed to compress it.

They considered the effect of temperature on the results, putting a wet cloth around the tube to cool it; 'it sometimes seemed a little to shrink, but not so manifestly that we dare build anything upon it'. When they heated the closed end with a candle, 'the head had a more sensible operation' but, once again, no conclusion could be drawn. Boyle noted that 'a want of exactness ... in such experiments is scarce avoidable'.

Boyle's law

The next step was to investigate the effect of reduced pressure on trapped air, noting the expansion of the trapped gas. Boyle describes the apparatus: 'We provided a slender glass-pipe of about the bigness of a swan's quill'. The tube, with a paper scale marked in inches along its length and its top end sealed with wax, was inserted into a wide, mercury-filled tube so that about one inch extended above the mercury.

The procedure was to raise the slender tube gradually, reducing the pressure of the air inside. First, the mercury level inside rose until the weight of mercury and the reduced air pressure in the tube balanced the external air pressure. Then the volume of the trapped air gradually increased to double its original volume, when the mercury in the tube was about 14.8 in/37.6 cm above its original level. Atmospheric pressure on that day was 29.5 in/74.9 cm: the trapped air had doubled its volume when the pressure was halved. According to Boyle, this accorded well with 'the hypothesis that supposes the pressures and expansions to be in reciprocal proportions' – a proposition now known as Boyle's Law.

Boyle's Law

Go to site

Excellent tutorial on Boyle's law. The Web site outlines Boyle's law, describes a practical investigation, uses a Java applet simulation, then tests the user's understanding.

Bq

in physics, symbol for becquerel, the SI unit of radioactivity (equal to the average number of disintegrations per second in a given time).

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brachiopod

or lamp shell

any member of the phylum Brachiopoda, marine invertebrates with two shells, resembling but totally unrelated to bivalves.

There are about 300 living species; they were much more numerous in past geological ages. They are suspension feeders, ingesting minute food particles from water. A single internal organ, the lophophore, handles feeding, aspiration, and excretion.

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bracken

any of several large ferns (especially *Pteridium aquilinum*) which grow abundantly in the northern hemisphere. The rootstock produces coarse fronds each year, which die down in autumn.

bracken

Bracken is one of the world's six most common plants and also one of the six oldest, being at least 90 million years old.

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brackets

pairs of signs that show which part of a calculation should be worked out first.

For example, 4(7+3) indicates that 4 is to be multiplied by the result obtained from adding 7 and 3. The mnemonic BODMAS can help one to remember the order in which an arithmetical expression should be calculated. Brackets may be nested, for example, 4(20-(7+3)), in which case the expression 7+3 within the innermost pair of brackets is evaluated first, the result subtracted from 20 and that result multiplied by 4.

Brackets are also used to contain the argument of a function. For example, *f(x)*.

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bracket fungus

any of a group of fungi (see fungus) with fruiting bodies that grow like shelves from the trunks and branches of trees. (Class Basidiomycetes.)

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bract

leaflike structure in whose axil a flower or inflorescence develops. Bracts are generally green and smaller than the true leaves. However, in some plants they may be brightly coloured and conspicuous, taking over the role of attracting pollinating insects to the flowers, whose own petals are small; examples include poinsettia *Euphorbia pulcherrima* and bougainvillea.

A whorl of bracts surrounding an inflorescence is termed an **involucre**. A **bracteole** is a leaflike organ that arises on an individual flower stalk, between the true bract and the calyx.

Bradley, James (1693-1762)

English astronomer. In 1728 he discovered the aberration of starlight. From the amount of aberration in star positions, he was able to calculate the speed of light. In 1748 he announced the discovery of nutation (variation in the Earth's axial tilt).

Brahe, Tycho (1546-1601)

Danish astronomer. His accurate observations of the planets enabled German astronomer and mathematician Johannes Kepler to prove that planets orbit the Sun in ellipses. Brahe's discovery and report of the 1572 supernova brought him recognition, and his observations of the comet of 1577 proved that it moved in an orbit among the planets, thus disproving Aristotle's view that comets were in the Earth's atmosphere.

Brahe was a colourful figure who wore a silver nose after his own was cut off in a duel, and who took an interest in alchemy. In 1576 Frederick II of Denmark gave him the island of Hven, where he set up an observatory. Brahe was the greatest observer in the days before telescopes, making the most accurate measurements of the positions of stars and planets. He moved to Prague as imperial mathematician in 1599, where he was joined by Kepler, who inherited his observations when he died.

Brahe, Tycho

Tycho Brahe, the 16th-century Danish astronomer, wore a false nose made of silver. His own had been cut off in a duel while he was a student in Rostock.

Brahe, Tycho

Go to site

Full account of the life and work of the Danish astronomer. There are pictures of Brahe, instruments he used, and the observatory he founded. There is an explanation of the Tychonic world view whereby the Earth was held to be the centre of the universe while planets revolved around the Sun.

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brain

in higher animals, a mass of interconnected nerve cells forming the anterior part of the central nervous system, whose activities it coordinates and controls. In vertebrates, the brain is contained by the skull. It is composed of three main regions. At the base of the brainstem, the **medulla oblongata** contains centres for the control of respiration, heartbeat rate and strength, blood pressure, and thermoregulatory control (the control of body temperature). Overlying this is the **cerebellum**, which is concerned with coordinating complex muscular processes such as maintaining posture and moving limbs, and the control of balance. The **cerebrum** (cerebral hemispheres) are paired outgrowths of the front end of the forebrain, in early vertebrates mainly concerned with the senses, but in higher vertebrates greatly developed and involved in the integration of all sensory input and motor output, and in thought, emotions, memory, and behaviour. Sensory information arrives in the cerebrum in the form of nerve impulses that come from receptors - these may be found in sense organs, such as cones (light sensitive cells) in the retina of the eye, which send impulses to the brain along the optic nerve. The cerebrum processes the information received and can cause impulses to be sent out to the body to produce a response, such as moving towards an object that has been seen. Because a decision is made whether to make this kind of movement it is said to be voluntary.

In vertebrates, many of the nerve fibres from the two sides of the body cross over as they enter the brain, so that the left cerebral hemisphere is associated with the right side of the body and vice versa. In humans, a certain asymmetry develops in the two halves of the cerebrum. In right-handed people, the left hemisphere seems to play a greater role in controlling verbal and some mathematical skills, whereas the right hemisphere is more involved in spatial perception. In general, however, skills and abilities are not closely localized. In the brain, nerve impulses are passed across synapses by neurotransmitters, in the same way as in other parts of the nervous system.

In mammals the cerebrum is the largest part of the brain, carrying the **cerebral cortex**. This consists of a thick surface layer of cell bodies (grey matter), below which fibre tracts (white matter) connect various parts of the cortex to each other and to other points in the central nervous system. As cerebral complexity grows, the surface of the brain becomes convoluted into deep folds. In higher mammals, there are large unassigned areas of the brain that seem to be connected with intelligence, personality, and higher mental faculties. Language is controlled in two special regions usually in the left side of the brain: **Broca's area** governs the ability to talk, and **Wernicke's area** is responsible for the comprehension of spoken and written words. In 1990 scientists at Johns Hopkins University, Baltimore, succeeded in culturing human brain cells.

The Human Brain

introduction

The brain is the most complex organ in the human body. It is the controller of all that we do and achieve.

Yet despite the wealth of research that has been carried out on the brain, our knowledge of how it works is very limited.

the composition of the brain

It would be reasonable to assume that the intelligence of an animal related directly to the size of the brain, but this is not the case. Intelligence more directly relates to the relative size of the brain compared to body weight. Thus, blue whales, as the largest mammal, have the largest brain (weighing about 8 kg/17.6 lb), but relative to body size humans have the largest brain (weighing about 1.4 kg/3.1 lb).

The human brain contains approximately 100 billion nerve cells. These cells can only be seen under a microscope. Each nerve cell is connected to, on average, over 1,000 other nerve cells, making over 100 trillion connections in all. The nerve cells consist of a body with finger-like extensions and a long arm called an **axon**. Electrical impulses travel down the axon from the cell body. When the impulses reach the end of the axon, they cause the release of a chemical (called a **neurotransmitter**) that travels across a small gap (the synaptic cleft) to act on 'receivers' termed **receptors** on the connected nerve cell. This is how nerve cells communicate with one another. Some of these chemicals 'excite' connected nerve cells, and if these nerve cells are sufficiently excited they fire (that is, they send an electrical impulse down their axons). If only excitation were present, then eventually all the nerve cells in the brain would be firing together; this is what happens in epileptic fits. To avoid this happening, some nerve cells release a chemical that prevents connected nerves from firing (it 'inhibits' connected nerve cells). The proper operation of the brain is dependent on this balance of excitation and inhibition.

A collection of nerve cells appears grey in colour, and thus areas of the brain in which there are mainly nerve cells are termed **grey matter**. The axons, on the other hand, often have an insulating coat that makes a collection of them appear white, and thus areas in which there are mainly axons are called **white matter**. The bulk of the human brain consists of white matter, surrounded by a rim of grey matter. The axons can travel great distances in the brain and can connect a nerve cell on one side of the brain to a nerve cell on the other side. The brain is surprisingly soft, having the consistency of crème caramel, and thus the skull is critical in protecting it. In addition, tough coverings, the **meninges** (it is these which are infected in patients suffering from meningitis), also protect the brain. Within the meninges, the brain is surrounded by fluid that both protects and provides nutrients; this fluid is termed **cerebrospinal fluid** as it covers the brain and spinal cord. Cerebrospinal fluid not only surrounds the brain, but is also contained within the brain in spaces called **ventricles**.

the structure of the brain

The brain can be divided into three parts: the brainstem, cerebellum, and forebrain.

The **brainstem** is the continuation of the spinal cord. It receives sensory inputs from the face, and from hearing and balance organs in the inner ear, and also sends nerve signals to facial muscles, including those that move the eyes and determine the size of the pupil. The base of the brainstem, called the medulla oblongata, has a vital function in controlling breathing and heart rate; people cannot live with significant damage to this area.

The **cerebellum** is involved in balance and coordination. It looks like a cauliflower and lies at the back of the brain. The cerebellum also provides a motor memory so that rapid repetitive movements such as typing or piano playing can be controlled without conscious attention.

The **forebrain** can be further divided into the diencephalon, which includes the thalamus, hypothalamus, and pituitary gland, and the telencephalon, consisting of the corpus striatum and the cerebral cortex.

The **thalamus** is like a telephone exchange, transmitting information from the sensory organs to specific areas of the cortex, where it is analysed. The thalamus also plays a role in memory formation and emotional response.

The **hypothalamus** controls functions necessary for survival, such as hunger and thirst. Close by is the pituitary gland which, in response to signals from the hypothalamus, releases hormones that control many sexual functions (such as menstruation and sperm production). Importantly, in addition, the hypothalamus and pituitary, through the release of hormones, control the internal environment of the body, for example by regulating body temperature and fluid balance.

The **corpus striatum**, along with the **substantia nigra**, form the basal ganglia. These help start and control movements. Degeneration of the substantia nigra is associated with Parkinson's disease, in which people have problems initiating movements, and degeneration of the corpus striatum is seen in Huntingdon's disease, which is characterized by an inability to stop moving.

The **cerebral cortex** provides the link between the appreciation of sensory inputs, the control of movement, and conscious thought. It also selects and stores memories and forms emotions. The cortex makes up 90% of the volume of the brain. It is divided into two halves (hemispheres) joined in the middle by the corpus callosum so that each half 'knows' what the other half is doing. The right half controls the left-hand side of the body, and the left half controls the right-hand side of the body. For most of us, the left half is dominant. To a certain extent, the dominant side determines handedness. Right-handed people are left-hemisphere dominant. However, only about half the people who are left-handed are right-hemisphere dominant. The dominant hemisphere is largely responsible for linguistic and logical ability. Recognizing where things are in space and recognising faces depends on the non-dominant hemisphere. Although much has been made of the right hemisphere being the 'artistic' hemisphere, this is largely untrue (for example, music appreciation and musicianship rely on both hemispheres). Indeed, studies of people who have the corpus callosum cut have revealed that many functions are shared between the hemispheres.

localization of function

Each hemisphere is further divided into four lobes: frontal (at the front), parietal (in the middle), temporal (at the sides), and occipital (at the back).

Certain functions of the brain are localized to specific regions of the cortex. The frontal lobe is involved in planning, reasoning, problem solving, speech, and controlling movement. The parietal lobe enables the perception of touch. The temporal lobe is involved in the perception of sound and smell, and plays a role in memory, emotion, and language. The occipital lobe processes visual information.

The inner part of the temporal lobe consists of a curved structure called the hippocampus (literally 'sea horse' because of its shape). The hippocampus is critical for memory formation, and damage to the hippocampus can result in problems forming new memories. The hippocampus connects to a variety of structures, including the amygdala (literally 'almond' because of its shape; which generates our response to fear), the hypothalamus, the thalamus, and other parts of the cortex that together make up the 'limbic' system. This system is essential for emotional response, memory formation, and the association of emotions with memories.

An area in the dominant temporal lobe first described in the late 19th century by German neurologist and psychiatrist Carl Wernicke (Wernicke's area) is necessary for understanding and recognizing language. People who have strokes affecting this area cannot understand what is said and tend to speak fluently using nonsense words. This area, which generates language, sends a signal to an area in the frontal lobe called Broca's area, which generates speech. People who have strokes affecting Broca's area cannot talk fluently and have problems naming objects but can understand what is said to them.

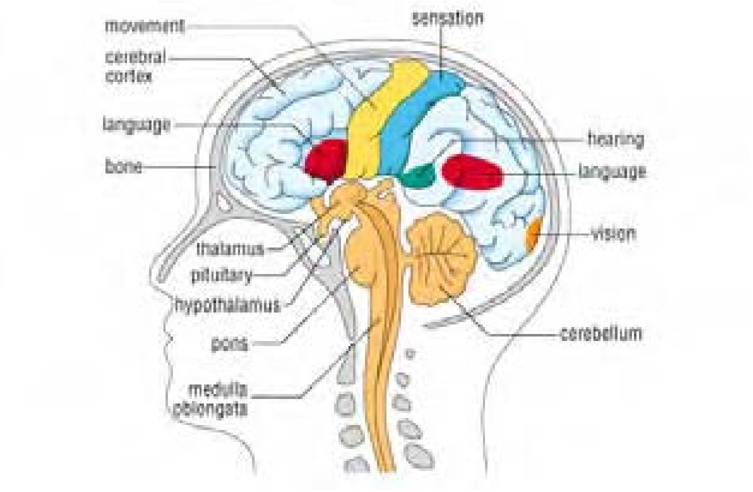
developments in research

Although there have been great advances in understanding the brain and the localization of various functions, much is still not understood. In the 19th century, localization of function was largely determined by studying people who had suffered injuries to the brain (often following strokes) and identifying where the defect was (usually after the person had died) and what the person could not do. More recently, advanced techniques have involved imaging people's brains using special scans such as magnetic resonance imaging (MRI) and positron emission tomography (PET). These techniques can look in detail at the brain, and can determine which parts are active when someone carries out a particular task.

Brain repair has also become the subject of much recent medical research, both by stimulating nerve cell production in the brain with drugs and by transplanting primitive nerve cells into the brain. Although this research is still in its early stages, it may be possible to repair parts of the brain that become damaged by strokes and head injuries, or that degenerate in Parkinson's or other similar diseases.

On a smaller scale, it is not clear how the working of nerve cells relates to the function of the brain. Techniques are now available to keep small pieces of tissue removed from the brain alive and to record the electrical activity of single nerve cells. This has given us a considerable insight into how nerve cells communicate with one another, and how drugs that act on the brain produce their effect. We are still, however, a long way from understanding how the brain works.

brain



(Image © Research Machines plc)

The structure of the human brain. At the back of the skull lies the cerebellum, which coordinates reflex actions that control muscular activity. The medulla controls respiration, heartbeat, and blood pressure. The hypothalamus is concerned with instinctive drives and emotions. The thalamus relays signals to and from various parts of the brain. The pituitary gland controls the body's hormones. Distinct areas of the large convoluted cerebral hemispheres that fill most of the skull are linked to sensations, such as hearing and sight, and voluntary activities, such as movement.

BodyQuest: The Nervous System

Go to site

Overview of the way in which the brain sends, receives, and processes the nerve impulses that control everything we do. The page, part of a much larger site on the human body, discusses the roles played by the central, peripheral, and autonomic nervous systems, and provides experiments to answer such questions as 'How do we balance?' and 'Why do we have two eyes?'.

Neuroscience for Kids

Go to site

Explore the nervous system (brain, spinal cord, nerve cells, and senses) by means of this impressive site, which is designed for primary and secondary school students and teachers.

Virtual Body

Go to site

Authoritative and interactive anatomical animations, complete with voice-overs, guide you around the whole body, with sections on the brain, digestive system, heart, and skeleton. The Flash plug-in is required to view this site but this can be downloaded simply if it is required.

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brain damage

impairment which can be caused by trauma (for example, accidents) or disease (such as encephalitis), or which may be present at birth. Depending on the area of the brain that is affected, language, movement, sensation, judgement, or other abilities may be impaired.

Everything You Ever Wanted To Know About Brain Surgery...Almost

Go to site

Comprehensive Web site on brain surgery. The Web site features sections suitable for both surgeons and prospective patients, including an online gallery of operations, a history of brain surgery, and an offer of a free consultation. Several diseases which are treated with brain surgery are also described here, and a guide to the various stages of the operation may also be useful for patients.

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brainstem

region where the top of the spinal cord merges with the undersurface of the brain, consisting largely of the medulla oblongata and midbrain.

The oldest part of the brain in evolutionary terms, the brainstem is the body's life-support centre, containing regulatory mechanisms for vital functions such as breathing, heart rate, and blood pressure. It is also involved in controlling the level of consciousness by acting as a relay station for nerve connections to and from the higher centres of the brain.

In many countries, death of the brainstem is now formally recognized as death of the person as a whole. Such cases are the principal donors of organs for transplantation. So-called 'beating-heart donors' can be maintained for a limited period by life-support equipment.

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brainstem death

in medicine, criterion for determining that 'death' has occurred when brain damage results in the irreversible loss of brain function, including that of the brainstem (which is important in the control of many processes which are essential to life, such as respiration and heart rate), so that the individual is unable to live without the aid of a ventilator. Many countries allow artificial ventilation to be stopped once brainstem death has been determined.

Artificial ventilation and heart beat are maintained after brainstem death has been established if organs are to be removed for use in transplantation procedures. This ensures that the organs are in the best condition for transplantation.

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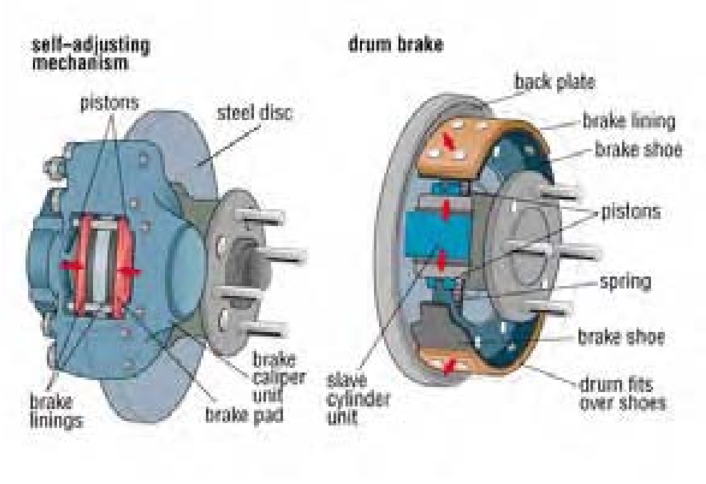
brake

device used to slow down or stop the movement of a moving body or vehicle. The mechanically applied calliper brake used on bicycles uses a scissor action to press hard rubber blocks against the wheel rim. The main braking system of a car works hydraulically: when the driver depresses the brake pedal, liquid pressure forces pistons to apply brakes on each wheel.

Two types of car brakes are used.
Disc brakes are used on the front wheels of some cars and on all wheels of sports and performance cars, since they are the more efficient and less prone to fading (losing their braking power) when they get hot. Braking pressure forces brake pads against both sides of a steel disc that rotates with the wheel.
Drum brakes are fitted on the rear wheels of some cars and on all wheels of some passenger cars. Braking pressure forces brake shoes to expand outwards into contact with a drum rotating with the wheels. The brake pads and shoes have a tough friction lining that grips well and withstands wear.

Many trucks and trains have **air brakes**, which work by compressed air. On landing, jet planes reverse the thrust of their engines to reduce their speed quickly. Space vehicles use retrorockets for braking in space and use the air resistance, or drag of the atmosphere, to slow down when they return to Earth.

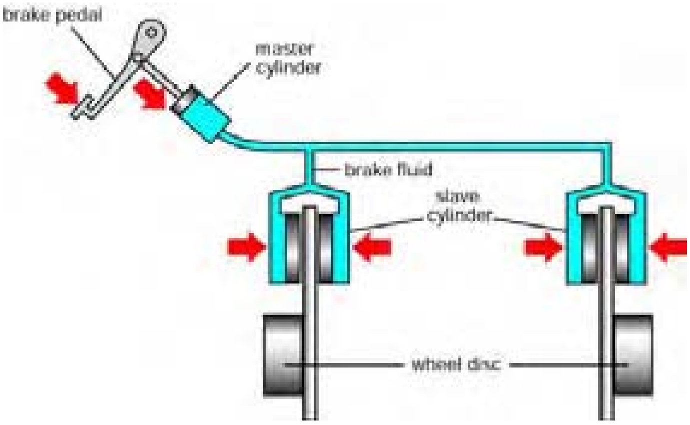
brake


self-adjusting mechanism
drum brake
pistons
steel disc
back plate
brake lining
brake shoe
pistons
spring
brake shoe
brake caliper unit
brake linings
brake pad
slave cylinder unit
drum fits over shoes

(Image © Research Machines plc)

Two common braking systems: the disc brake (left) and the drum brake (right). In the disc brake, increased hydraulic pressure of the brake fluid in the pistons forces the brake pads against the steel disc attached to the wheel. A self-adjusting mechanism balances the force on each pad. In the drum brake, increased pressure of the brake fluid within the slave cylinder forces the brake pad against the brake drum attached to the wheel.

brake


brake pedal
master cylinder
brake fluid
slave cylinder
wheel disc

(Image © Research Machines plc)

How disc brakes on a car work. A small braking force is applied to the brake pedal. This creates pressure on the brake fluid in the master cylinder, which is transmitted through the fluid to the slave cylinders. The slave cylinder pistons press the brake pads against the brake discs to slow the wheels. The mechanical advantage derives from the piston in the master cylinder having a narrow bore and moving a greater distance, while the slave cylinder has a larger bore and moves just a few millimetres.

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bramble

any of a group of prickly bushes belonging to the rose family. Examples are blackberry, raspberry, and dewberry. (Genus *Rubus*, family Rosaceae.)

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brambling

or bramble finch

bird *Fringilla montifringilla* belonging to the finch family Fringillidae, order Passeriformes. It is about 15 cm/6 in long, and breeds in northern Europe and Asia.

Brandt, Bill (1904-1983)

born Hermann Wilhelm Brandt

English photographer. During the 1930s he made a series of social records contrasting the lives of the rich and the poor, some of which were presented in his book *The English at Home* (1936). During World War II he documented conditions in London in the Blitz. The strong contrasts in his black-and-white prints often produced a gloomy and threatening atmosphere. His outstanding creative work was his treatment of the nude, published in *Perspective of Nudes* and *Shadows of Light* (both 1966).

brass

metal alloy of copper and zinc, with not more than 5% or 6% of other metals. The zinc content ranges from 20% to 45%, and the colour of brass varies accordingly from coppery to whitish yellow. Brasses are characterized by the ease with which they may be shaped and machined; they are strong and ductile, resist many forms of corrosion, and are used for electrical fittings, ammunition cases, screws, household fittings, and ornaments.

Brasses are usually classed into those that can be worked cold (up to 25% zinc) and those that are better worked hot (about 40% zinc).

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brassica

any of a group of plants, many of which are cultivated as vegetables. The most familiar is the common cabbage (*Brassica oleracea*), with its varieties broccoli, cauliflower, kale, and Brussels sprouts. (Genus *Brassica*, family Cruciferae.)

In 1990 US experiments in cross-pollinating the wild cabbage (*B. campestris*) with related varieties of cultivated cabbage, turnip, and swede produced a new plant with a life cycle of only five weeks. This is now being used in US schools to enable pupils to carry out plant-breeding experiments that can produce ten generations in one year.

Braun, Wernher von

German rocket engineer; see von Braun.

Brazil nut

gigantic South American tree; also its seed, which is rich in oil and highly nutritious. The seeds (nuts) are enclosed in a hard outer casing, each fruit containing 10-20 seeds arranged like the segments of an orange. The timber of the tree is also valuable. (*Bertholletia excelsa*, family Lecythidaceae.)

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brazing

method of joining two metals by melting an alloy or metal into the joint. It is similar to soldering (see solder) but takes place at a much higher temperature. Copper and silver alloys are widely used for brazing, at temperatures up to about 900°C/1,650°F.

Where high precision is needed, as in space technology, nickel-based filters are used in the temperature range 1,000-1,200°C/1,832-2,192°F.

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breadfruit

fruit of two tropical trees belonging to the mulberry family. It is highly nutritious and when baked is said to taste like bread. It is native to many South Pacific islands. (*Artocarpus communis* and *A. altilis*, family Moraceae.)

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bream

deep-bodied, flattened fish *Abramis brama* of the carp family, growing to about 50 cm/1.6 ft, typically found in lowland rivers across Europe.

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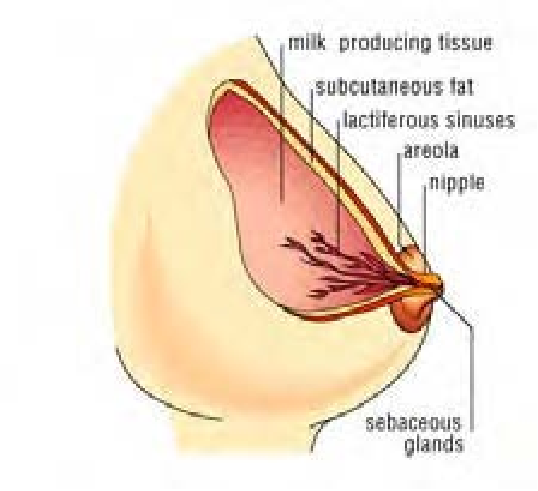
breast

one of a pair of organs on the chest of the adult human female, also known as a mammary gland. Each of the two breasts contains milk-producing cells and a network of tubes or ducts that lead to openings in the nipple.

Milk-producing cells in the breast do not become active until a woman has given birth to a baby. Breast milk is made from substances extracted from the mother's blood as it passes through the breasts, and contains all the nourishment a baby needs. Breast-fed newborns develop fewer infections than bottle-fed babies because of the antibodies and white blood cells contained in breast milk. These are particularly abundant in the colostrum produced in the first few days of breast-feeding.

breast



(Image © Research Machines plc)

The human breast or mammary gland. Milk produced in the tissue of the breast to feed a baby after a woman has given birth passes along ducts which lead to openings in the nipple.

breast cancer

in medicine, cancer of the breast. It is usually diagnosed following the detection of a painless lump in the breast (either through self-examination or mammography). Other, less common symptoms, include changes in the shape or texture of the breast and discharge from the nipple. It is the commonest cancer amongst women: there are 28,000 new cases of breast cancer in Britain each year and 185,700 in the USA.

treatment

If the tumour is caught early, only it and the immediate surrounding tissue needs removing, in a process called lumpectomy, usually accompanied by radiotherapy. In more advanced cases a mastectomy is performed. Chemotherapy or hormone-blocking drugs (such as tamoxifen) may also accompany either procedure. The average survival rate after 5 years was 83.2% in 1996. According to UK epidemiologists in May 2000, deaths from breast cancer had fallen by 25% since the late 1980s. The decline was attributed to early detection and surgery and the use of the drug tamoxifen.

risk factors

Possible risk factors include a family history of breast cancer (mutations in the genes *BRCA1* and *BRCA2* were found to cause more than 50% of inherited breast cancer cases, in the 1990s); childlessness or late childbearing; early onset of menstruation and late menopause.

breast-feeding

in medicine, the process by which a baby gains its nourishment from milk secreted from the breast, by sucking on the nipple. Breast milk provides complete nutrition and additional protection from infection for the infant, and helps to establish 'bonding' between the mother and the baby. It also helps the mother to return to her previous body weight and encourages the uterus to shrink to normal size following childbirth. The early establishment of breast feeding maintains and improves the milk supply.

Nursing mothers need to increase their intake of food and drinks to ensure that the milk supply is maintained. The extra food intake should be in the form of bread, cereals, pulses, and rice, which also provide generous amounts of the vitamins and minerals that are essential for infant health. Infants are usually weaned between four and six months but milk remains a crucial component of their diet even after the introduction of solid foods. Breast-feeding can be continued as long as the mother wants to do so.

breast screening

in medicine, examination of the breast to detect the presence of breast cancer at an early stage. Screening methods include self-screening by monthly examination of the breasts and formal programmes of screening by palpation (physical examination) and mammography in special clinics. Screening may be offered to older women on a routine basis and it is important in women with a family history of breast cancer.

Mammograms before the age of 50 can significantly reduce deaths from breast cancer according to a 1997 Swedish study. The study compared women in their forties who had mammograms every 18 months with women who didn't have a mammogram till age 50 (the current standard procedure in Western Europe and the USA). The researchers concluded that those women who received regularly screening were 45% less likely to die of breast cancer.

Breathalyzer

trademark for an instrument for on-the-spot checking by police of the amount of alcohol consumed by a suspect driver. The driver breathes into a plastic bag connected to a tube containing a chemical (such as a diluted solution of potassium dichromate in 50% sulphuric acid) that changes colour in the presence of alcohol. Another method is to use a gas chromatograph, again from a breath sample.

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breathing

or ventilation

movement of air into and out of the air passages of an animal, brought about by muscle contraction. It is a form of gas exchange. Breathing is sometimes referred to as external respiration, for true respiration is a cellular (internal) process. In a mammal, breathing involves the action of the muscles of the diaphragm and the intercostal muscles (between the ribs). When a mammal breathes in, the diaphragm muscles contract, which lowers the diaphragm. The external intercostal muscles contract, which raises the ribs. Lowering the diaphragm and raising the ribs increases the volume of the thorax. This lowers the pressure of the air inside the lungs in the thorax. The pressure is now lower than atmospheric pressure so air flows into the air passages and the lungs inflate.

Lungs are specialized for gas exchange but are not themselves muscular, consisting of spongy material. In order for oxygen to be passed to the blood and carbon dioxide removed, air is drawn into the lungs (inhaled) by the contraction of the diaphragm and intercostal muscles; relaxation of these muscles enables air to be breathed out (exhaled). The rate of breathing is controlled by the brain. High levels of activity lead to a greater demand for oxygen and an increased rate of breathing.

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breathing rate

number of times a minute the lungs inhale and exhale. The rate increases during exercise because the muscles require an increased supply of oxygen and nutrients. At the same time very active muscles produce a greater volume of carbon dioxide, a waste gas that must be removed by the lungs via the blood.

The regulation of the breathing rate is under both voluntary and involuntary control, although a person can only forcibly stop breathing for a limited time. The regulatory system includes the use of chemoreceptors, which can detect levels of carbon dioxide in the blood. High concentrations of carbon dioxide, occurring for example during exercise, stimulate a fast breathing rate.

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breccia

coarse-grained sedimentary rock, made up of broken fragments (clasts) of pre-existing rocks held together in a fine-grained matrix. It is similar to conglomerate but the fragments in breccia are jagged in shape.

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breed

recognizable group of domestic animals, within a species, with distinctive characteristics that have been produced by artificial selection. For example, the St Bernard is a breed of dog, the Merino a breed of sheep.

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breeder reactor

or fast breeder

alternative name for fast reactor, a type of nuclear reactor.

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breeding

in biology, the crossing and selection of animals and plants to change the characteristics of an existing breed or cultivar (variety), or to produce a new one. Selective breeding is breeding in which humans choose the parent plants or parent animals.

Ever since humans first carried out agriculture, they have been selecting which farm animals they allow to breed and which seeds to save from their crops to sow the following year. Plant and animal species show inherited variation. This is a result of the processes involved in sexual reproduction. Mutation also produces variation that is inherited. Selecting the parents used for breeding makes some variants more common, even though they may have been very rare originally. It can also bring together in one organism characteristics originally found in different organisms of the species.

If selective breeding is carried out over many generations this results in the production of varieties of plants and breeds of animals (see variety). For example 'Cox's', 'Golden Delicious', and 'Bramley' are different apple varieties. Cattle may be bred for increased meat or milk yield, sheep for thicker or finer wool, and horses for speed or stamina. Plants, such as wheat or maize, may be bred for disease resistance, heavier and more rapid cropping, and hardiness. Selective breeding of animals to produce new varieties helped Charles Darwin understand the effects of selection and understand its natural equivalent - natural selection, which can result in evolutionary change.

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breeding

in nuclear physics, a process in a reactor in which more fissionable material is produced than is consumed in running the reactor.

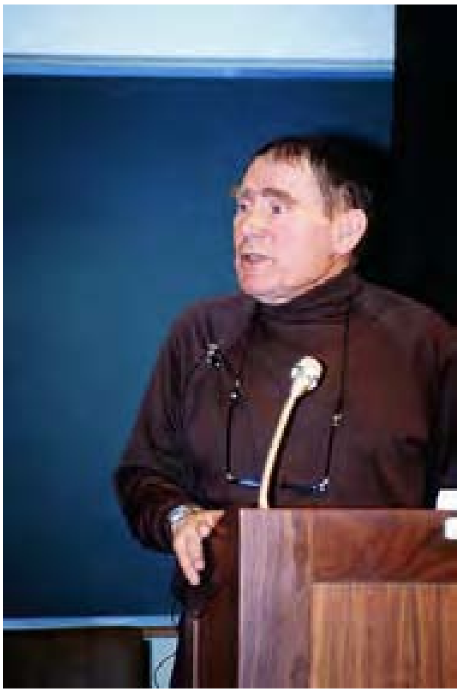
For example, plutonium-239 can be made from the relatively plentiful (but nonfissile) uranium-238, or uranium-233 can be produced from thorium. The Pu-239 or U-233 can then be used to fuel other reactors.

Brenner, Sydney (1927-)

South African scientist and one of the pioneers of genetic engineering. Brenner discovered messenger RNA (a link between DNA and the ribosomes in which proteins are synthesized) in 1960. He received the Lasker Award for Special Achievement in Medical Science in 2000, and was awarded the Nobel Prize for Physiology or Medicine in 2002 for his work on the genetic regulation of organ development and programmed cell death.

Brenner became engaged in one of the most elaborate efforts in anatomy ever attempted: investigating the nervous system of nematode worms and comparing the nervous systems of different mutant forms of the animal. About 100 genes are involved in constructing the nervous system of a nematode and most of the mutations that occur affect the overall design of a section of the nervous system. He has also conducted research in the use of genetic engineering for purifying proteins, cloning genes, and synthesizing amino acids.

Brenner



(Image © Research Machines plc)

South African scientist Sydney Brenner, lecturing at the Laboratory of Molecular Biology in Cambridge, *c.* 1985. A pioneer in genetic engineering, Brenner discovered messenger RNA in 1960.

Breuer, Josef (1842-1925)

Viennese physician, one of the pioneers of psychoanalysis. He applied it successfully to cases of hysteria, and collaborated with Freud on *Studien über Hysterie/Studies in Hysteria* (1895).

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brewing

making of beer, ale, or other alcoholic beverage, from malt and barley by steeping (mashing), boiling, and fermenting.

Mashing the barley releases its sugars. Yeast is then added, which contains the enzymes needed to convert the sugars into ethanol (alcohol) and carbon dioxide. Hops are added to give a bitter taste.

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brewster

symbol B

unit for measuring the reaction of optical materials to stress, defined in terms of the slowing down of light passing through the material when it is stretched or compressed.

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brick

common block-shaped building material, with all opposite sides parallel. It is made of clay that has been fired in a kiln. Bricks are made by kneading a mixture of crushed clay and other materials into a stiff mud and extruding it into a ribbon. The ribbon is cut into individual bricks, which are fired at a temperature of up to about 1,000°C/1,800°F. Bricks may alternatively be pressed into shape in moulds.

Refractory bricks used to line furnaces are made from heat-resistant materials such as silica and dolomite. They must withstand operating temperatures of 1,500°C/2,700°F or more.

Facing bricks are designed to be visually more attractive than than common bricks, and include specially moulded bricks.

Sun-dried bricks of mud reinforced with straw were first used in Mesopotamia some 8,000 years ago. Similar mud bricks, called adobe, are still used today in Mexico and other areas where the climate is warm and dry.

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brickwork

method of construction using bricks made of fired clay or sun-dried earth. In wall building, bricks are either laid out as stretchers (long side facing out) or as headers (short side facing out). The two principal patterns of brickwork are **English bond** in which alternate courses, or layers, are made up of stretchers or headers only, and **Flemish bond** in which stretchers and headers alternate within courses.

Some evidence exists of the use of fired bricks in ancient Mesopotamia and Egypt, although the Romans were the first to make extensive use of this technology. Today's mass production of fired bricks tends to be concentrated in temperate regions where there are plentiful supplies of fuel available.

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bridge

structure that provides a continuous path or road over water, valleys, ravines, or above other roads. The basic designs and composites of these are based on the way they bear the weight of the structure and its load.
Beam, or **girder**, bridges are supported at each end by the ground with the weight thrusting downwards.
Cantilever bridges are a complex form of girder in which only one end is supported.
Arch bridges thrust outwards and downwards at their ends.
Suspension bridges use cables under tension to pull inwards against anchorages on either side of the span, so that the span hangs from the main cables by a network of vertical cables. The **cable-stayed** bridge relies on diagonal cables connected directly between the bridge deck and supporting towers at each end. Some bridges are too low to allow traffic to pass beneath easily, so they are designed with movable parts, like swing and draw bridges.

The construction of a bridge is also affected by aesthetics (the preferred or fashionable style at the time of its building) and practicalities such as the materials at hand. The appearance and construction of a bridge reflects the technology and tastes of the era in which it was built; for example, the simple, stocky Pont Neuf constructed over the River Seine in Paris in the 16th century contrasts sharply with the ornate neo-Gothic style of Tower Bridge, built in London in 1894.

history

In prehistory, people used logs or wove vines into ropes that were thrown across the obstacle. Clapper bridges, made from flat stones simply laid across or supported by piles of stones, were some of the earliest bridges. By 4000 BC arched structures of stone and/or brick were used in the Middle East, and the Romans built long, arched spans, many of which are still standing. Cast iron bridges were introduced in 1779. The Bessemer process produced steel that made it possible to build long-lived framed structures that support great weight over long spans.

Bridges: Recent Developments

a bridge too far?

London has a new bridge across the Thames. The Dartford bridge, 30 km/19 mi downstream from central London, is the longest cable-stayed bridge in Europe, with a main span of 450 m/1,476 ft. It was also one of the swiftest construction jobs ever for a large bridge - barely six years from conception to opening. The Dartford bridge represents a design that has been eagerly adopted by bridge designers and builders worldwide as a cost-effective way of building long-span bridges. The race is on to build bigger and better cable-stayed bridges.

giants in the pipeline

Leading the field, at the moment, is the 465 m/1,526 ft Annacis bridge near Vancouver. The second Hooghly river bridge at Kolkata (formerly Calcutta), begun in 1974 and nearing completion, has a main span of 457 m/1,499 ft. The Rama IX bridge across Bangkok's Chao Phraya River, opened in late 1987, has a main span of 450 m/1,476 ft. Another giant, when completed, will be the 490 m/1,607 ft span of the Ikuchi bridge between the Japanese islands of Honshu and Shikoku.

Norway is planning to finish a 530 m/1,739 ft Skarnsundet bridge across a fjord northeast of Trondheim at around the same time. In 1995, the French completed a cable-stayed bridge of 2,200 m/7,220 ft spanning the mouth of the Seine at Honfleur, and by the end of the century, the Japanese expect to have completed a cable-stayed bridge of 890 m/2,919 ft between Honshu and Shikoku. But are designers pressing the new cable-stayed technology too far, beyond its safe limits without adequate testing or accumulated experience?

suspension versus cable-stayed bridges

Large bridges have traditionally been suspension bridges. Both forms of bridge rely on cables to support their weight. The suspension bridge uses cables draped between towers at each end, from which the bridge is suspended by vertical steel ropes. The longest suspension bridge is the 10-year-old bridge over the Humber River in NE England. Its main span is 1,410 m/4,626 ft. Cable-stayed bridges rely on diagonal cables connected directly between the bridge deck and the supporting towers at each end. In the past, the spans of cable-stayed bridges have been less than 350 m/1,150 ft, so the new bridges represent a quantum leap in size.

a leap that ended in disaster

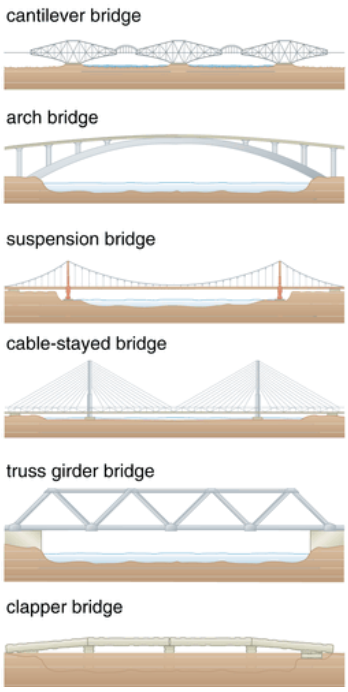
Bridge designers remember the last time their discipline took a quantum leap forward. In the 1930s, maximum bridge lengths doubled. Then, in Nov 1940, the collapse of the 860 m/2,821 ft bridge over the Tacoma Narrows, Washington State, revealed the fragility of that advance. Even now engineers do not know for certain what caused the Tacoma bridge collapse, but a likely culprit was the bridge deck's flexibility. The wind could twist the deck, which presented a large flat side surface to the wind.

design considerations

The Annacis bridge is just 250 km/155 mi north of the Tacoma Narrows and its builders studied the Tacoma collapse before finalizing their design. The bridge deck was made thinner, and the edges were streamlined to reduce interaction with side winds. Also, the deck was a concrete and steel composite, with concrete slabs on top of a structural steel framework. Composite decks are common on bridges supported by columns, but had not previously been widely used on suspension bridges. Attention was paid to the composition and arrangement of the cables, too, since these affect the bridge's stiffness.

The simplest cable arrangement is to attach the cables along the centre-line of the bridge and to uprights in the same vertical plane at each end of the bridge. However, a more rigid structure results if the cables are attached to the sides of the bridge and to two uprights at each end of the bridge. The cables themselves are made by winding together many thin steel wires, each a few millimetres across, to produce a final cable with a diameter of around 160 mm/6.3 in. Experience on the Annacis bridge encouraged designers to press ahead with more ambitious projects with apparent confidence. But the giant bridges being planned are large steps into the unknown.

bridge



(Image © Research Machines plc)

Different types of bridge. Clapper bridges were some of the earliest bridges. Bridges need to be designed to support their own weight and the weight of traffic over them, so upward forces must considerably outweigh downward forces. They also have to resist torsion (twisting force) and withstand strong winds and the movement of traffic crossing.

bridge

(Image © Research Machines plc)

The building of New Bridge across the River Torridge, north of Bideford in Devon. The finished structure has eight spans with a total length of 641 m/2,104 ft and is 24 m/79 ft above the spring tide water level. The opening of the bridge has greatly eased the pressure of traffic on the town of Bideford.

bridge

(Image © Research Machines plc)

The Tamar Suspension Bridge. When it first opened to traffic in 1961, the Tamar Bridge, at 335 m/1,100 ft in length, was the longest suspension bridge in the UK. Linking the counties of Devon and Cornwall, it replaced the old ferry, which for centuries had crossed the River Tamar just downstream of where the bridge now stands.

Remarkable bridges in the world

These bridges involve extraordinary feats of engineering in the construction of a passage for vehicles.

Bridge	Location	Description
Angostura	Cuidad Bolivar, Venezuela	suspension-type bridge; span 712 m/2,336 ft; total length 1,678 m/5,507 ft
Bendorf Bridge	Coblenz, Germany	three-span cement girder bridge; main span 208 m/682 ft; total length 1,030 m/3,378 ft
Bosporus Bridge	Istanbul, Turkey (linking Europe to Asia)	suspension bridge; total length 1,074 m/ 3,524 ft
Gladsville Bridge	Sydney, Australia	concrete arch bridge; 305 m/1,000 ft - the world's longest concrete arch
Humber Bridge	Kingston-upon-Hull, UK	suspension bridge; total span 1,410 m/4,626 ft - the world's longest suspension bridge
Ikuchi Bridge	Honshu/Shikoku, Japan	cable-stayed bridge; 490 m/1,608 ft span
Lake Pontchartrain Bridge	New Orleans, USA	multiple-span; 38,421 m/126,055 ft - the world's longest multiple span
Millau Bridge	Millau, France	total length 2460 m/8071 ft; maximum height 343 m/1126 ft - the world's tallest bridge
Oosterscelderbrug	Vlissingen/Rotterdam, the Netherlands	traffic causeway over Zeeland sea arm; total length 19 km/31.25 mi
Rio-Niteroi	Guanabara Bay, Brazil	continuous box and plate girder bridge; 14 km/8.7 mi - the world's longest box girder bridge
Tagus River Bridge	Lisbon, Portugal	main span 1,013 m/3,323 ft
Zoo Bridge	Cologne, Germany	steel box girder bridge; main span 259 m/850 ft

Bridges: Panoramic Photographs, 1851-1991

Go to site

Part of the Panoramic Photo Collection of the US Library of Congress, this page features approximately 100 panoramic photographs of bridges, mostly in the USA. To find a specific bridge, click on New Search and try a word search. Many of the photos include brief notes. Click on the images to increase their size.

Nova Online: Super Bridge

Go to site

What bridge should you use to span a canyon, or go over a motorway? This fascinating Web site explains the forces involved in bridge-building by allowing you to act as a civil engineer, matching bridge to location then seeing what happens.

Bright, Richard (1789-1858)

British physician who described many conditions and linked oedema to kidney disease.
Bright's disease, an acute inflammation of the kidneys (see nephritis), is named after him.

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brill

flatfish *Scophthalmus laevis*, living in shallow water over sandy bottoms in the northeastern Atlantic and Mediterranean. It is a freckled sandy brown, and grows to 60 cm/2 ft.

Brindley, James (1716-1772)

English canal builder. He was the first to employ tunnels and aqueducts extensively, in order to reduce the number of locks on a direct-route canal. His 580 km/360 mi of canals included the Bridgewater Canal (Manchester-Liverpool) and Grand Union Canal (Manchester-Potteries).

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brine

common name for a solution of sodium chloride (NaCl) in water. Brines are used extensively in the food-manufacturing industry for canning vegetables, pickling vegetables (sauerkraut manufacture), and curing meat. Industrially, brine is the source from which chlorine, caustic soda (sodium hydroxide), and sodium carbonate are made.

The chlor-alkali industry is based on the electrolysis of brine, which produces chlorine, hydrogen, and sodium hydroxide. In the Solvay process, sodium carbonate is produced from sodium chloride.

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bristlecone pine

the oldest living species of pine tree.

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bristletail

primitive wingless insect of the order Thysanura. Up to 2 cm/0.8 in long, bristletails have a body tapering from front to back, two long antennae, and three 'tails' at the rear end. They include the **silverfish** *Lepisma saccharina* and the **firebrat** *Thermobia domestica*. Two-tailed bristletails constitute another insect order, the Diplura. They live under stones and fallen branches, feeding on decaying material.

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bristle-worm

or polychaete

segmented worm of the class Polychaeta, characterized by having a pair of fleshy paddles (parapodia) on each segment, together with prominent bristles (setae), and a well-developed head with a pair each of eyes, antennae, and palps. Most bristle-worms are marine, and live in burrows in sand and mud or in rock crevices and under stones. More than 5,300 species are recognized.

The bristle-worms can be conveniently divided into two loosely defined groups: the **Errantia**, which are free-living (that is swimming, crawling, or actively burrowing), and the **Sedentaria**, which live within a tube or a permanent burrow.

British Standards Institution

or BSI

UK national standards body. Although government funded, the institution is independent. The BSI interprets international technical standards for the UK, and also sets its own.

The BSI was founded in 1901, taking its present name in 1931 after receiving a royal charter in 1929. For consumer goods, it sets standards which products should reach (the BS standard), as well as testing products to see that they conform to that standard, as a result of which the product may be given the BSI 'kite' mark. This symbol is used under licence on condition that the BSI is able to inspect the product or company on a regular basis to ensure standards are maintained. The BSI sets such standards in a variety of industries such as construction, electrical products, engineering, and textiles.

British thermal unit

symbol Btu

imperial unit of heat, now replaced in the SI system by the joule (one British thermal unit is approximately 1,055 joules). Burning one cubic foot of natural gas releases about 1,000 Btu of heat.

One British thermal unit is defined as the amount of heat required to raise the temperature of 0.45 kg/1 lb of water by 1°F. The exact value depends on the original temperature of the water.

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brittle-star

any member of the echinoderm class Ophiuroidea. A brittle-star resembles a starfish, and has a small, central, rounded body and long, flexible, spiny arms used for walking. The small brittle-star *Amphipholis squamata* is greyish, about 4.5 cm/2 in across, and found on sea bottoms worldwide. It broods its young, and its arms can be luminous.

About 2,000 species of brittle-stars and basket-stars, whose arms are tangled and rootlike, are included in this group.

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broadband

in computing, a type of data transmission in which a single circuit can carry several channels at once, used for example in cable television. Broadband networking is one way of supplying much greater Internet bandwidth over the existing telephone system. See also ADSL.

The term broadband refers to the method of transmitting voice, video, and data using frequency division multiplexing (FDM). Broadband is one of the fastest growing new technologies in history, with more than 200 million subscribers using it for Internet and entertainment connections in 2006, and forecasts that this would double by 2010.

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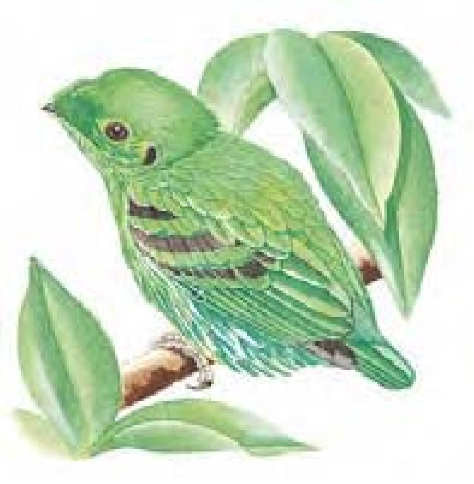
broadbill

primitive perching bird of the family Eurylaimidae, found in Africa and South Asia. Broadbills are forest birds and are often found near water. They are gregarious and noisy, have brilliant coloration and wide bills, and feed largely on insects.

broadbill



(Image © Research Machines plc)

The 14 species of broadbills are found only in the forests of South and East Africa and parts of South East Asia. Broadbills feed mainly on fruit and small invertebrates such as insects. They build domed nests usually suspended over water from tree branches.

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broadcasting

the transmission of sound and vision programs by radio and television. In the USA, broadcasting licenses are issued to public organizations and competing commercial companies by the Federal Communications Commission.

In Britain, the British Broadcasting Corporation (BBC) is a centralized body appointed by the state and responsible to Parliament, but with policy and program content not controlled by the state; in Japan, which ranks next to the USA in the number of television sets owned, there is a semigovernmental radio and television broadcasting corporation (NHK) and numerous private television companies.

Television broadcasting entered a new era with the introduction of high-powered communications satellites in the 1980s. The signals broadcast by these satellites are sufficiently strong to be picked up by a small dish aerial located, for example, on the roof of a house. Direct broadcast by satellite thus became a feasible alternative to land-based television services. See also cable television. A similar revolution is taking place as digital television becomes widely available.

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broad-leaved tree

another name for a tree belonging to the angiosperms, such as ash, beech, oak, maple, or birch. The leaves are generally broad and flat, in contrast to the needlelike leaves of most conifers. See also deciduous tree.

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broccoli

variety of cabbage. It contains high levels of the glucosinolate compound glucoraphanin. A breakdown product of this was found to neutralize damage to cells and so help to prevent cancer.

Broglie, (Louis César Victor) Maurice de (1875-1960)

6th duc de Broglie

French physicist. He worked on X-rays and gamma rays, and helped to establish the Einsteinian description of light in terms of photons. He was the brother of Louis de Broglie.

Broglie, Louis Victor Pierre Raymond de (1892-1987)

7th duc de Broglie

French theoretical physicist. He established that all subatomic particles can be described either by particle equations or by wave equations, thus laying the foundations of wave mechanics. He was awarded the Nobel Prize for Physics in 1929 for his discovery of the wavelike nature of electrons. Succeeded as Duke in 1960.

De Broglie's discovery of wave-particle duality enabled physicists to view Einstein's conviction that matter and energy are interconvertible as being fundamental to the structure of matter. The study of matter waves led not only to a much deeper understanding of the nature of the atom but also to explanations of chemical bonds and the practical application of electron waves in electron microscopes.

De Broglie, Louis

Go to site

Biographical details and a photograph of Louis de Broglie, the famous French physicist and mathematician. There are also links to de Broglie's most famous work on quantum mechanics and to many of his contemporaries.

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brolga

or **native companion**, Australian crane *Grus rubicunda*, about 1.5 m/5 ft tall, mainly grey with a red patch on the head.

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brome grass

any of several annual grasses found in temperate regions; some are used as food for horses and cattle, but many are weeds. (Genus *Bromus*, family Gramineae.)

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bromeliad

any tropical or subtropical plant belonging to the pineapple family, usually with stiff leathery leaves, which are often coloured and patterned, and bright, attractive flower spikes. There are about 1,400 species in tropical America; several are cultivated as greenhouse plants. (Family Bromeliaceae.)

Some grow in habitats ranging from scrub desert to tropical forest floor. Many, however, grow on rainforest trees. These are epiphytes: they are supported by the tree but do not take nourishment from it, using rain and decayed plant and animal remains for independent sustenance.

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bromide

salt of the halide series containing the Br^- ion, which is formed when a bromine atom gains an electron.

The term 'bromide' is sometimes used to describe an organic compound containing a bromine atom, even though it is not ionic. Modern naming uses the term 'bromo-' in such cases. For example, the compound C_2H_5Br is now called bromoethane; its traditional name, still used sometimes, is ethyl bromide.

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bromine

chemical symbol Br

(Greek bromos 'stench')

dark, reddish-brown, non-metallic element, a volatile liquid at room temperature, atomic number 35, relative atomic mass 79.904. It is a member of the halogen group, has an unpleasant odour, and is very irritating to mucous membranes. Its salts are known as bromides.

Bromine was formerly extracted from salt beds but is now mostly obtained from sea water, where it occurs in small quantities. Its compounds are used in photography and in the chemical and pharmaceutical industries.

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bromocriptine

drug that mimics the actions of the naturally occurring biochemical substance dopamine, a neurotransmitter. Bromocriptine acts on the pituitary gland to inhibit the release of prolactin, the hormone that regulates lactation, and thus reduces or suppresses milk production. It is also used in the treatment of Parkinson's disease.

Bromocriptine may also be given to control excessive prolactin secretion and to treat prolactinoma (a hormone-producing tumour). Recent research has established its effectiveness in reversing some cases of infertility.

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bronchiole

small-bore air tube found in the vertebrate lung responsible for delivering air to the main respiratory surfaces. Bronchioles lead off from the larger bronchus and branch extensively before terminating in the many thousand alveoli that form the bulk of lung tissue.

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bronchitis

inflammation of the bronchi (air passages) of the lungs, usually caused initially by a viral infection, such as a cold or flu. It is aggravated by environmental pollutants, especially smoking, and results in a persistent cough, irritated mucus-secreting glands, and large amounts of sputum.

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bronchodilator

drug that relieves obstruction of the airways by causing the bronchi and bronchioles to relax and widen. It is most useful in the treatment of asthma.

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bronchus

one of a pair of large tubes (bronchi) branching off from the windpipe (trachea) and passing into the vertebrate lung. Apart from their size, bronchi differ from the bronchioles in possessing cartilaginous rings, which give rigidity and prevent collapse during breathing movements.

Numerous glands in the wall of the bronchus secrete a slimy mucus, which traps dust and other particles; the mucus is constantly being propelled upwards to the mouth by thousands of tiny hairs or cilia. The bronchus is adversely effected by several respiratory diseases and by smoking, which damages the cilia and therefore the lung-cleansing mechanism.

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brontosaurus

former name of a type of large, plant-eating dinosaur, now better known as apatosaurus.

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bronze

alloy of copper and tin, yellow or brown in colour. It is harder than pure copper, more suitable for casting, and also resists corrosion. Bronze may contain as much as 25% tin, together with small amounts of other metals, mainly lead.

Bronze is one of the first metallic alloys known and used widely by early peoples during the period of history known as the Bronze Age. The first bronze objects date from 3000 BC.

Bell metal, the bronze used for casting bells, contains 15% or more tin.
Phosphor bronze is hardened by the addition of a small percentage of phosphorus.
Silicon bronze (for telegraph wires) and **aluminium bronze** are similar alloys of copper with silicon or aluminium and small amounts of iron, nickel, or manganese, but usually no tin.

Bronze Age

stage of prehistory and early history when copper and bronze (an alloy of tin and copper) became the first metals worked extensively and used for tools and weapons. One of the classifications of the Danish archaeologist Christian Thomsen's Three Age System, it developed out of the Stone Age and generally preceded the Iron Age. It first began in the Far East and may be dated 5000-1200 BC in the Middle East and about 2000-500 BC in Europe.

Mining and metalworking were the first specialized industries, and the invention of the wheel during this time revolutionized transport.

Agricultural productivity (which began during the New Stone Age, or Neolithic period, about 6000 BC) was transformed by the ox-drawn plough, increasing the size of the population that could be supported by farming.

In some areas, including most of Africa, there was no Bronze Age, and ironworking was introduced directly into the Stone Age economy.

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broom

any of a group of shrubs (especially species of *Cytisus* and *Spartium*), often cultivated for their bright yellow flowers. (Family Leguminosae.)

Broom

Go to site

Large resource of information about this type of shrub. This site also contains an informative description of the plant, its history, and its habitat. It also features notes on the plant's constituents and many medicinal uses, which include treating kidney and bladder complaints as well as dropsy. There are also notes on the cultivation of broom.

Brown, Robert (1773-1858)

Scottish botanist who in 1827 discovered Brownian motion. As a botanist, his more lasting work was in the field of plant morphology. He was the first to establish the real basis for the distinction between gymnosperms (conifers) and angiosperms (flowering plants).

On an expedition to Australia (1801-05) Brown collected 4,000 plant species and later classified them using the 'natural' system of Bernard de Jussieu (1699-1777) rather than relying upon the system of Carolus Linnaeus.

---

brown dwarf

in astronomy, object less massive than a star but denser than a planet. Brown dwarfs do not have enough mass to ignite nuclear reactions at their centres, but shine by heat released during their contraction from a gas cloud. Groups of brown dwarfs have been discovered, and some astronomers believe that vast numbers of them exist throughout the Galaxy.

The first brown dwarf to be positively identified was Gliese 229B (GI229B), in the constellation Lepus, by US astronomers using images from the Hubble Space Telescope. It is about 50 times as massive as Jupiter but emits only 1% of the radiation of the smallest known star and has a surface temperature of 650°C/1,200°F. Brown dwarfs cannot exist with a mass of greater than 80 times that of Jupiter.

browser

in computing, any program that allows the user to search for and view data. Browsers usually do not permit the user to edit data, but are sometimes able to convert data from one file format to another. Web browsers allow access to the World Wide Web. Microsoft's Internet Explorer was the leading Web browser in 2006, acting as a graphical user interface to information available on the Internet - reading HTML documents and displaying them as graphical documents which may include images, video, audio, and hypertext links to other documents.

The first widespread browser for personal computers (PCs) was the text-based program Lynx. Browsers using graphical user interfaces became widely available from 1993 with the release of Mosaic.

Some Web sites contain special pages that might contain animation, 3D scenes, or a particular kind of audio file. To display these kinds of effects, the basic browser technology needs to be enhanced using plug-in technology, such as the Macromedia Flash plug-in which can display sophisticated animations and multimedia effects.

---

brucellosis

disease of cattle, goats, and pigs, also known when transmitted to humans as **undulant fever** since it remains in the body and recurs. It was named after Australian doctor David Bruce (1855-1931), and is caused by bacteria (genus *Brucella*). It is transmitted by contact with an infected animal or by drinking contaminated milk.

It has largely been eradicated in the West through vaccination of livestock and pasteurization of milk. Brucellosis is especially prevalent in the Mediterranean and in Central and South America. It can be treated with antibacterial drugs.

Brundtland Report

the findings of the World Commission on Environment and Development, published in 1987 as *Our Common Future*. It stressed the necessity of environmental protection and popularized the phrase 'sustainable development'. The commission was chaired by the Norwegian prime minister Gro Harlem Brundtland.

Brunel, Isambard Kingdom (1806-1859)

English engineer and inventor. In 1833 he became engineer to the Great Western Railway, which adopted the 2.1-m/7-ft gauge on his advice. He built the Clifton Suspension Bridge over the River Avon at Bristol and the Saltash Bridge over the River Tamar near Plymouth. His shipbuilding designs include the *Great Western* (1837), the first steamship to cross the Atlantic regularly; the *Great Britain* (1843), the first large iron ship to have a screw propeller; and the *Great Eastern* (1858), which laid the first transatlantic telegraph cable.

Brussels sprout

one of the small edible buds along the stem of a variety of cabbage. (*Brassica oleracea* var. *gemmifera*.) They are high in the glucosinolate compound sinigrin. Sinigrin was found to destroy precancerous cells in laboratory rats in 1996.

---

bryophyte

member of the Bryophyta, a division of the plant kingdom containing three classes: the Hepaticae (liverwort), Musci (moss), and Anthocerotae (hornwort). Bryophytes are generally small, low-growing, terrestrial plants with no vascular (water-conducting) system as in higher plants. Their life cycle shows a marked alternation of generations. Bryophytes chiefly occur in damp habitats and require water for the dispersal of the male gametes (antherozoids).

In bryophytes, the sporophyte, consisting only of a spore-bearing capsule on a slender stalk, is wholly or partially dependent on the gametophyte for water and nutrients. In some liverworts the plant body is a simple thallus, but in the majority of bryophytes it is differentiated into stem, leaves, and rhizoids.

BSE

abbreviation for bovine spongiform encephalopathy.

BSI

abbreviation for British Standards Institution.

BST

abbreviation for bovine somatotropin.

Btu

symbol for British thermal unit: originally it was defined as the heat required to raise the temperature of one pound of water by one degree Fahrenheit. Now defined as equal to 1,055.6 joules.

---

bubble chamber

in physics, a device for observing the nature and movement of atomic particles, and their interaction with radiation. It is a vessel filled with a superheated liquid through which ionizing particles move. The paths of these particles are shown by strings of bubbles, which can be photographed and studied. By using a pressurized liquid medium instead of a gas, it overcomes drawbacks inherent in the earlier cloud chamber. It was invented by US physicist Donald Glaser in 1952. See particle detector.

---

bubble sort

in computing, technique for sorting data. Adjacent items are continually exchanged until the data are in sequence.

---

bubonic plague

epidemic disease of the Middle Ages; see plague and Black Death.

Buchner, Eduard (1860-1917)

German chemist who was awarded the Nobel Prize for Chemistry in 1907 for his biochemical research and discovery of the process of cell-free fermentation. In 1897 he observed that fermentation could be produced mechanically, by cell-free extracts. Buchner argued that it was not the whole yeast cell that produced fermentation, but only the presence of the enzyme he named zymase.

Buck, Linda (1947-)

US neuroscientist. With US neuroscientist Richard Axel she shared the Nobel Prize for Physiology or Medicine in 2004 for her contributions to understanding how the olfactory system is able to recognize and differentiate between different smells.

Buck was awarded her half share of the Nobel Prize for work carried out initially in partnership with Axel. They determined that the mechanism that allowed the sense of smell to function involved a large gene family made up of over 10,000 different genes (or about 3% of all human genes). The genes have an equivalent number of receptors in particular cells in the lining of the nose. The researchers' work showed that each of these receptors is sensitive to only one type of odour molecule, but when activated the receptors start a chain reaction that sends a signal to the higher brain functions. This reaction can trigger a connection of the smell to a particular memory or emotion. Buck and Axel published their fundamental paper in 1991, and subsequently have worked separately in this field to clarify and define the workings of the olfactory system.

---

buckminsterfullerene

form of carbon, made up of molecules (buckyballs) consisting of 60 carbon atoms arranged in 12 pentagons and 20 hexagons to form a perfect sphere. It was named after the US architect and engineer Richard Buckminster Fuller because of its structural similarity to the geodesic dome that he designed. See fullerene.

---

buckwheat

any of a group of cereal plants. The name usually refers to *Fagopyrum esculentum*, which reaches about 1 m/3 ft in height and can grow on poor soil in a short summer. The highly nutritious black triangular seeds (groats) are eaten by both animals and humans. They can be cooked and eaten whole or as a cracked meal (kasha), or ground into flour, often made into pancakes. (Genus *Fagopyrum*, family Polygonaceae.)

Buckwheat

Go to site

Detailed information about buckwheat. Included here are detailed descriptions of the plant, its habitat, and its cultivation. This site also features notes on the plant's constituents and possible medicinal uses. There is also an introduction to other species, including false and climbing buckwheat.

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buckyballs

popular name for molecules of buckminsterfullerene.

---

bud

undeveloped shoot usually enclosed by protective scales; inside is a very short stem and numerous undeveloped leaves, or flower parts, or both. Terminal buds are found at the tips of shoots, while axillary buds develop in the axils of the leaves, often remaining dormant unless the terminal bud is removed or damaged. Adventitious buds may be produced anywhere on the plant, their formation sometimes stimulated by an injury, such as that caused by pruning.

---

budding

type of asexual reproduction in which an outgrowth develops from a cell to form a new individual. Most yeasts reproduce in this way.

In a suitable environment, yeasts grow rapidly, forming long chains of cells as the buds themselves produce further buds before being separated from the parent. Simple invertebrates, such as hydra, can also reproduce by budding.

In horticulture, the term is used for a technique of plant propagation whereby a bud (or scion) and a sliver of bark from one plant are transferred to an incision made in the bark of another plant (the stock). This method of grafting is often used for roses.

---

buddleia

any of a group of ornamental shrubs or trees with spikes of fragrant flowers. The purple or white flower heads of the butterfly bush (*Buddleia davidii*) attract large numbers of butterflies. (Genus *Buddleia*, family Buddleiaceae.)

---

budgerigar

small Australian parakeet *Melopsittacus undulatus* of the parrot family, Psittacidae, order Psittaciformes, that feeds mainly on grass seeds. In the wild, it has a bright green body and a blue tail with yellow flares; yellow, white, blue, and mauve varieties have been bred for the pet market. Budgerigars breed freely in captivity.

Budgerigars are well adapted to their desert habitat and can survive for a month without drinking. They make the most out of the unyielding terrain by living a nomadic lifestyle, but if drought is particularly severe and they are unable to locate areas of recent rain then they refrain from breeding, as the chicks would simply not survive. Normally females lay a clutch of four to six eggs, each egg being laid a day apart, with each egg hatching after 19 days.

budgerigar

Budgerigar means 'good eating' in the Aboriginal language. It is also used to symbolize the getting of wisdom in Aboriginal legend, with the young men awaiting initiation depicted as a flock of budgies.

Welcome to the World of Budgerigars and Parakeets

Go to site

Huge source of information from the American Budgerigar Society. There is comprehensive advice on how to look after and exhibit the world's favourite pet. All manner of avian illnesses and their treatment are discussed. There are links to other specialist budgie sites.

---

buffalo

either of two species of wild cattle. The Asiatic water buffalo *Bubalis bubalis* is found domesticated throughout South Asia and wild in parts of India and Nepal. It likes moist conditions. Usually grey or black, up to 1.8 m/6 ft tall, both sexes carry large horns. The African buffalo *Syncerus caffer* is found in Africa, south of the Sahara, where there is grass, water, and cover in which to retreat. There are a number of subspecies, the biggest up to 1.6 m/5 ft tall, and black, with massive horns set close together over the head. The name is also commonly applied to the North American bison.

Asiatic water buffalo

(Image © Corel)

Asiatic water buffalo are used for ploughing rice fields in Bali. They are well-adapted to use in the flooded fields, as this is their natural habitat.

buffalo

(Image © Corel)

Ploughing with Asiatic water buffalo, Guilin, China. Much agricultural work in China is carried out using traditional methods. The normal wetland habitat of the buffalo suits it to use in flooded rice paddies.

---

buffer

in chemistry, mixture of compounds chosen to maintain a steady pH. The commonest buffers consist of a mixture of a weak organic acid and one of its salts or a mixture of acid salts of phosphoric acid. The addition of either an acid or a base causes a shift in the chemical equilibrium, thus keeping the pH constant.

---

buffer

in computing, a part of the memory used to store data temporarily while it is waiting to be used. For example, a program might store data in a printer buffer until the printer is ready to print it.

Buffon, Georges-Louis Leclerc (1707-1788)

Comte de Buffon

French naturalist and author of the 18th century's most significant work of natural history, the 44-volume *Histoire naturelle génerale et particulière* (1749-67). In *The Epochs of Nature*, one of the volumes, he questioned biblical chronology for the first time, and raised the Earth's age from the traditional figure of 6,000 years to the seemingly colossal estimate of 75,000 years.

---

bug

in computing, an error in a program. It can be an error in the logical structure of a program or a syntax error, such as a spelling mistake. Some bugs cause a program to fail immediately; others remain dormant, causing problems only when a particular combination of events occurs. The process of finding and removing errors from a program is called **debugging**.

---

bug

in entomology, an insect belonging to the order Hemiptera. All these have two pairs of wings with forewings partly thickened.

They also have piercing mouthparts adapted for sucking the juices of plants or animals, the 'beak' being tucked under the body when not in use.

They include: the bedbug, which sucks human blood; the shieldbug, or stinkbug, which has a strong odour and feeds on plants; and the water boatman and other water bugs.

bug: hunting technique

The Costa Rican assassin bug (*Salyavata*) has a cunning way of luring termites to their doom. Disguised as a piece of nesting material, it grabs a passing termite and sucks its body dry. It then uses the corpse as a lure, shaking it outside a termite burial chamber while concealed in a crack in the earth.

bug: shield bug

Female shield bugs are excellent mothers. They lie over their eggs to protect them and, in some species, once the eggs have hatched, escort the young bugs as they move around to feed.

---

bugle

any of a group of low-growing plants belonging to the mint family, with spikes of white, pink, or blue flowers. The leaves may be smooth-edged or slightly toothed, the lower ones with a long stalk. They are often grown as ground cover. (Genus *Ajuga*, family Labiatae.)

Bugle, Common

Go to site

Detailed resource relating to this plant. It contains an informative description of the plant and its habitat. There are also notes on the possible medicinal uses of the common bugle, which include arresting haemorrhages and allaying irritation.

---

bugloss

any of several plants native to Europe and Asia, distinguished by their rough, bristly leaves and small blue flowers. (Genera *Anchusa*, *Lycopsis*, and *Echium*, family Boraginaceae.)

Bugloss, Viper's

Go to site

Informative resource relating to this plant. It contains a detailed description of the plant and its habitat. There are also notes on the possible medicinal uses of the Viper's Bugloss, which include alleviating headaches and fevers and acting as a diuretic.

---

bulb

underground bud with fleshy leaves containing a reserve food supply and with roots growing from its base. Bulbs function in vegetative reproduction and are characteristic of many monocotyledonous plants such as the daffodil, snowdrop, and onion. Bulbs are grown on a commercial scale in temperate countries, such as England and the Netherlands.

---

bulbil

small bulb that develops above ground from a bud. Bulbils may be formed on the stem from axillary buds, as in members of the saxifrage family, or in the place of flowers, as seen in many species of onion *Allium*. They drop off the parent plant and develop into new individuals, providing a means of vegetative reproduction and dispersal.

---

bulbul

fruit-eating bird of the family Pycnonotidae, order Passeriformes, that ranges in size from that of a sparrow to a blackbird. They are mostly rather dull coloured and very secretive, living in dense forests. They are widely distributed throughout Africa and Asia; there are about 120 species.

---

bulimia

(Greek 'ox hunger')

eating disorder in which large amounts of food are consumed in a short time ('binge'), usually followed by depression and self-criticism. The term is often used for **bulimia nervosa**, an emotional disorder in which eating is followed by deliberate vomiting and purging. This may be a chronic stage in anorexia nervosa.

---

bulldog

British breed of dog of ancient but uncertain origin, formerly bred for bull-baiting. The head is broad and square, with deeply wrinkled cheeks, small folded ears, very short muzzle, and massive jaws, the peculiar set of the lower jaw making it difficult for the dog to release its grip. Thickset in build, the bulldog grows to about 45 cm/18 in and has a smooth beige, tawny, or brindle coat. The French bulldog is much lighter in build and has large upright ears.

Bulldog

Go to site

Profile of the bulldog from the American Kennel Club. There is a history of the breed, description of the ideal breed standard, a note on the dog's temperament, and some interesting facts about bulldogs. There is also a high-resolution photo of a bulldog and advice to owners to clean facial wrinkles every day.

---

bulldozer

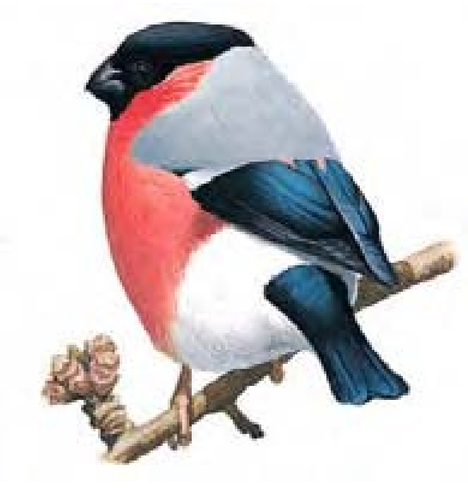
earth-moving machine widely used in construction work for clearing rocks and tree stumps and levelling a site. The bulldozer is a kind of tractor with a powerful engine and a curved, shovel-like blade at the front, which can be lifted and forced down by hydraulic rams. It usually has caterpillar tracks so that it can move easily over rough ground.

---

bullfinch

Eurasian finch with a thick head and neck, and short heavy bill, genus *Pyrrhula pyrrhula*, family Fringillidae, order Passeriformes. It is small and blue-grey or black in colour, the males being reddish and the females brown on the breast. Bullfinches are 15 cm/6 in long, and usually seen in pairs. They feed on tree buds as well as seeds and berries, and are usually seen in woodland. They also live in the Aleutians and on the Alaska mainland.

bullfinch



(Image © Research Machines plc)

The bullfinch *Pyrrhula pyrrhula* is notorious for the damage it does by eating the buds of fruit trees and flowering shrubs in spring. Bullfinches prefer to stay in the safety of trees, and are rarely seen on the ground. A bullfinch's nest is made from small twigs, moss, and lichen, lined with root fibres. The female lays a clutch of four or five eggs, two or three times per year.

bullhead

any of a North American family, Ictaluridae, of small freshwater catfish, for example, the black bullhead *Ictalurus melas*. Also, another name for the sculpin or other members of the family Cottidae.

---

bull terrier

breed of dog, originating as a cross between a terrier and a bulldog. Very powerfully built, it grows to about 40 cm/16 in tall, and has a short, usually white, coat, narrow eyes, and distinctive egg-shaped head. It was formerly used in bull-baiting. Pit bull terriers are used in illegal dog fights. The Staffordshire bull terrier is a distinct breed.

---

bulrush

any of a number of marsh plants (especially of the genus *Scirpus*) belonging to the sedge family, having long, slender, solid stems tipped with brown spikelets of tiny flowers. Bulrushes are used in basket-making and thatching.

---

bumblebee

any large bee, 2-5 cm/1-2 in, usually dark-coloured but banded with yellow, orange, or white, belonging to the genus *Bombus*.

Most species live in small colonies, usually underground, often in an old mousehole. The queen lays her eggs in a hollow nest of moss or grass at the beginning of the season. The larvae are fed on pollen and honey, and develop into workers. All the bees die at the end of the season except fertilized females, which hibernate and produce fresh colonies in the spring. Bumblebees are found naturally all over the world, with the exception of Australia, where they have been introduced to facilitate the pollination of some cultivated varieties of clover.

Bunsen, Robert Wilhelm (1811-1899)

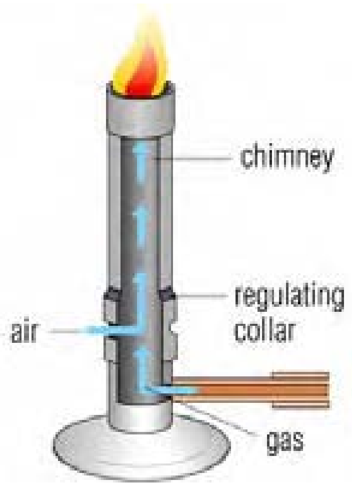
German chemist credited with the invention of the **Bunsen burner**. His name is also given to the carbon-zinc electric cell, which he invented in 1841 for use in arc lamps. In 1860 he discovered two new elements, caesium and rubidium.

Bunsen burner

gas burner used in laboratories, consisting of a vertical metal tube through which a fine jet of fuel gas is directed. Air is drawn in through airholes near the base of the tube and the mixture is ignited and burns at the tube's upper opening.

The invention of the burner is attributed to German chemist Robert von Bunsen in 1855, but English chemist and physicist Michael Faraday is known to have produced a similar device at an earlier date. A later refinement was the metal collar that can be turned to close or partially close the airholes, thereby regulating the amount of air sucked in and hence the heat of the burner's flame.

Bunsen burner



(Image © Research Machines plc)

The Bunsen burner, used for heating laboratory equipment and chemicals. The flame can reach temperatures of 1,500°C/2,732°F and is at its hottest when the collar is open.

---

bunting

any of a number of sturdy, finchlike birds with short, thick bills, of the family Emberizidae, order Passeriformes, especially the genera *Passerim* and *Emberiza*. Most of these brightly coloured birds are native to the New World.

---

buoy

floating object used to mark channels for shipping or warn of hazards to navigation. Buoys come in different shapes, such as a pole (spar buoy), cylinder (car buoy), and cone (nun buoy). Light buoys carry a small tower surmounted by a flashing lantern, and bell buoys house a bell, which rings as the buoy moves up and down with the waves. Mooring buoys are heavy and have a ring on top to which a ship can be tied.

---

buoyancy

lifting effect of a fluid on a body wholly or partly immersed in it. This was studied by Archimedes in the 3rd century BC.

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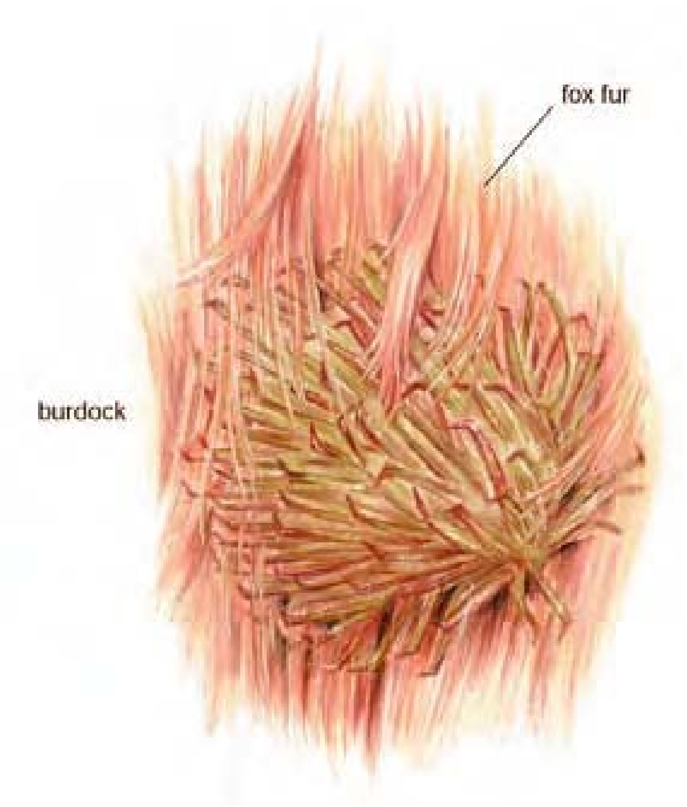
bur

or burr

in botany, a type of 'false fruit' or pseudocarp, surrounded by numerous hooks; for instance, that of burdock *Arctium*, where the hooks are formed from bracts surrounding the flowerhead. Burs catch in the feathers or fur of passing animals, and thus may be dispersed over considerable distances.

bur



(Image © Research Machines plc)

A bur entangled in a fox's fur. By the time the animal grooms itself and discards the bur it will probably have transported it some distance. A number of plants, including the burdock (shown here), disperse their seeds in this way.

---

burbot

or eelpout

long, rounded fish *Lota lota* of the cod family, the only one living entirely in fresh water. Up to 1 m/3 ft long, it lives on the bottom of clear lakes and rivers, often in holes or under rocks, throughout Europe, Asia, and North America.

burdock

any of several bushy herbs characterized by hairy leaves and ripe fruit enclosed in burs with strong hooks. (Genus *Arctium*, family Compositae.)

Burdock

Go to site

Informative resource relating to this plant. It contains a detailed description of the plant, its constituents, and its habitat. There are also notes on the cultivation of burdock, as well as on the possible medicinal uses of the plant, which include relieving inflammation and acting as a diuretic.

burn

in medicine, destruction of body tissue by extremes of temperature, corrosive chemicals, electricity, or radiation.
First-degree burns may cause reddening; **second-degree burns** cause blistering and irritation but usually heal spontaneously; **third-degree burns** are disfiguring and may be life-threatening.

Burns cause plasma, the fluid component of the blood, to leak from the blood vessels, and it is this loss of circulating fluid that engenders shock. Emergency treatment is needed for third-degree burns in order to replace the fluid volume, prevent infection (a serious threat to the severely burned), and reduce the pain. Plastic, or reconstructive, surgery, including skin grafting, may be required to compensate for damaged tissue and minimize disfigurement. If a skin graft is necessary, dead tissue must be removed from a burn (a process known as debridement) so that the patient's blood supply can nourish the graft.

Burnell, Jocelyn Bell

Northern Irish astronomer. See Bell Burnell.

burnet

herb belonging to the rose family, also known as **salad burnet**. It smells of cucumber and can be used in salads. The name is also used for other members of the genus. (*Sanguisorba minor*, family Rosaceae.)

Burnet, Great

Go to site

Informative resource relating to this plant. It contains a detailed description of the plant, its constituents, and its habitat. There are also notes on the cultivation of Great Burnet, as well as on the possible medicinal uses of the plant, which include treating haemorrhages and stopping purgings.

Burnet, (Frank) Macfarlane (1899-1985)

Australian physician, an authority on immunology and viral diseases such as influenza, poliomyelitis, and cholera, who was awarded a Nobel Prize for Physiology or Medicine in 1960, together with the immunologist Peter Medawar, for their work on acquired immunological tolerance of transplanted tissues (such as in skin grafting). He was knighted in 1969.

burning

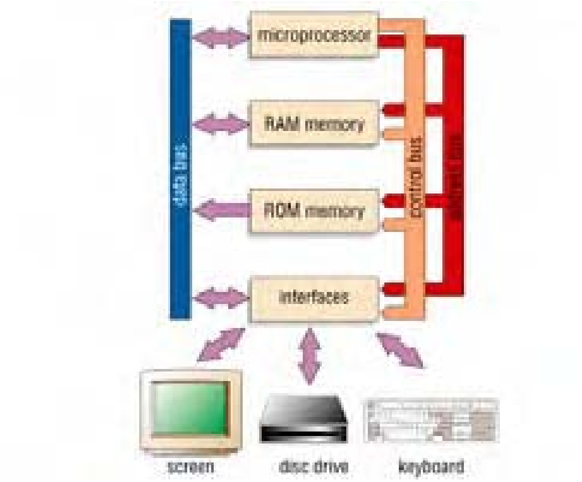
common name for combustion.

bus

in computing, the electrical pathway through which a computer processor communicates with some of its parts and/or peripherals. Physically, a bus is a set of parallel tracks that can carry digital signals; it may take the form of copper tracks laid down on the computer's printed circuit boards (PCBs), or of an external cable or connection.

A computer typically has three internal buses laid down on its main circuit board: a **data bus**, which carries data between the components of the computer; an **address bus**, which selects the route to be followed by any particular data item travelling along the data bus; and a **control bus**, which is used to decide whether data is written to or read from the data bus. An external **expansion bus** is used for linking the computer processor to peripheral devices, such as modems and printers.

bus



(Image © Research Machines plc)

The communication path used between the component parts of a computer.

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bushbaby

small nocturnal African prosimian with long feet, long, bushy tail, and large ears. Bushbabies are active tree dwellers and feed on fruit, insects, eggs, and small birds.

classification

Bushbabies are members of the loris family Lorisidae, order Primates.

---

bushbuck

antelope *Tragelaphus scriptus* found over most of Africa south of the Sahara. Up to 1 m/3 ft tall, the males have keeled horns twisted into spirals, and are brown to blackish. The females are generally hornless, lighter, and redder. All have white markings, including stripes or vertical rows of dots down the sides. Rarely far from water, bushbuck live in woods and thick brush.

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bushel

dry measure used for grain and fruit, equal to eight gallons (2,219.36 cu in/36.37 l) in the UK; some US states have different standards according to the goods measured. One bushel equals four pecks.

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bushman's rabbit

or riverine rabbit

a wild rodent *Bunolagus monticularis* found in dense riverine bush in South Africa. It lives in small populations, and individuals are only seen very occasionally; it is now at extreme risk of extinction owing to loss of habitat to agriculture. Very little is known about its life or habits.

---

bushmaster

large snake *Lachesis muta*. It is a type of pit viper, and is related to the rattlesnakes. Up to 4 m/12 ft long, it is found in wooded areas of South and Central America, and is the largest venomous snake in the New World. When alarmed, it produces a noise by vibrating its tail among dry leaves.

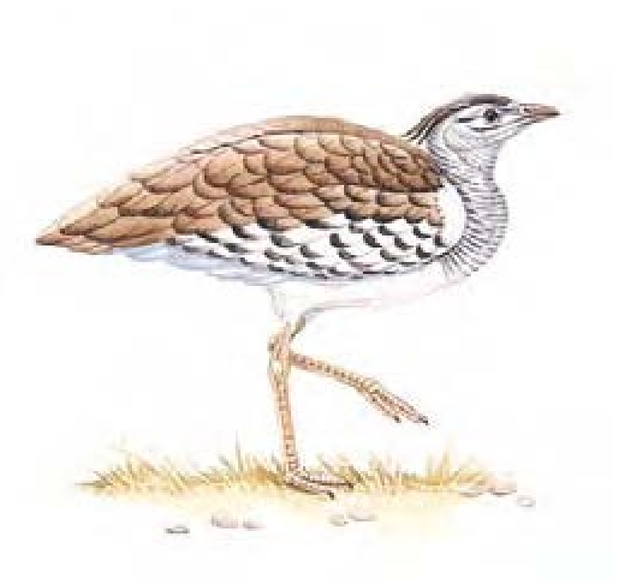
---

bustard

bird of the family Otididae, order Gruiformes, related to cranes but with a rounder body, thicker neck, and a relatively short beak. Bustards are found on the ground on open plains and fields.

The great bustard *Otis tarda* is one of the heaviest flying birds at 18 kg/40 lb, and the larger males may have a length of 1 m/3 ft and wingspan of 2.3 m/7.5 ft. It is found in northern Asia and Europe, although there are fewer than 30,000 great bustards left in Europe; two-thirds of these live on the Spanish steppes.

bustard



(Image © Research Machines plc)

The Kori bustard *Ardeotis kori* is the largest member of the bustard family, measuring 130 cm/52 in in length. Bustards live in groups on grassy plains in South and East Africa, feeding on seeds, buds, insects, and small vertebrates. In spite of being clumsy fliers, they are powerful runners.

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butane

C_4H_{10}

alkane (saturated hydrocarbon) derived from natural gas and as a product of the fractional distillation of crude oil (unrefined petroleum). Liquefied under pressure, it is used as a fuel for industrial and domestic purposes (for example, in portable cookers).

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butte

steep-sided, flat-topped hill, formed in horizontally layered sedimentary rocks, largely in arid areas. A large butte with a pronounced tablelike profile is a mesa.

Buttes and mesas are characteristic of semi-arid areas where remnants of resistant rock layers protect softer rock underneath, as in the plateau regions of Colorado, Utah, and Arizona, USA.

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buttercup

any plant of the buttercup family with divided leaves and yellow flowers. (Genus *Ranunculus*, family Ranunculaceae.)

Buttercup, Bulbous

Go to site

Informative site containing a detailed description of the plant and its characteristics. There are also notes on the possible medicinal uses of the bulbous buttercup, which include treating gout and rheumatism and curing certain headaches.

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butterfly

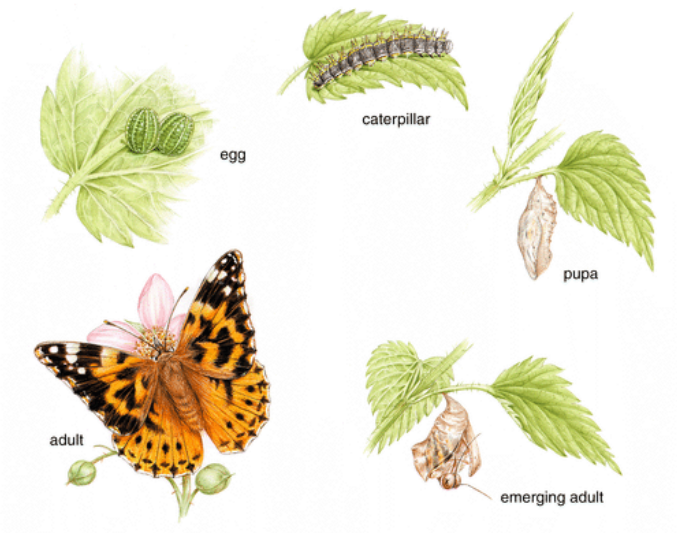
insect belonging, like moths, to the order Lepidoptera, in which the wings are covered with tiny scales, often brightly coloured. There are some 15,000 species of butterfly, many of which are under threat throughout the world because of the destruction of habitat.

The largest family, Nymphalidae, has some 6,000 species; it includes the peacock, tortoiseshells, and fritillaries. The family Pieridae includes the cabbage white, one of the few butterflies injurious to crops. The Lycaenidae are chiefly small, often with metallic coloration, for example the blues, coppers, and hairstreaks. The large blue *Lycaena arion* has a complex life history: it lays its eggs on wild thyme, and the caterpillars are then taken by Myrmica ants to their nests. The ants milk their honey glands, while the caterpillars feed on the ant larvae. In the spring, the caterpillars finally pupate and emerge as butterflies. The mainly tropical Papilionidae, or swallowtails, are large and very beautiful, especially the South American species. The world's largest butterfly is Queen Alexandra's birdwing *Ornithoptera alexandrae* of Papua New Guinea, with a body 7.5 cm/3 in long and a wingspan of 25 cm/10 in. The most spectacular migrant is the orange and black monarch butterfly *Danaus plexippus*, which may fly from northern Canada to Mexico in the autumn.

butterfly

The sensors on the feet of a red admiral butterfly are 200 times more sensitive to sugar than the human tongue.

butterfly



(Image © Research Machines plc)

The life cycle of a butterfly (painted lady *Vanessa cardui*). Eggs are laid on plants (usually the underside of leaves) and the larvae (caterpillars) feed on the plant, growing in size until ready to pupate. When the caterpillar is full-sized it forms a chrysalis in which it undergoes transformation from caterpillar to adult butterfly. The life cycle of moths is very similar.

Butterfly Web Site

Go to site

Useful link page to the world of butterflies, with graphics, articles, and discoveries, as well as information on related topics. As well as a gallery of images and a 'Frequently Asked Questions' page, this site contains sections with educational resources and a 'World watch' of butterfly populations.

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butterfly fish

any of several fishes, not all related. They include the freshwater butterfly fish *Pantodon buchholzi* of western Africa and the tropical marine butterfly fishes in family Chaetodontidae.

P. buchholzi can leap from the water and glide for a short distance on its large winglike pectoral fins. Up to 10 cm/4 in long, it lives in stagnant water, at the water surface during the day, lying beneath floating leaves. At night it hunts for insects, jumping out of the water to catch them.

The members of Chaetodontidae are brightly coloured with laterally flattened bodies, often with long snouts which they poke into crevices in rocks and coral when feeding. They have a flattened narrow body with one dorsal fin and a fairly long snout. Their bristlelike teeth are closely set in rows for feeding on small animals and green algae. The commonest colours are black, yellow, and brilliant metallic blues and greens.

classification

Chaetodontidae is in order Perciformes; *Pantodon buchholzi* is in order Osteoglossiformes; both are in class Osteichthyes.

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butterwort

insectivorous plant belonging to the bladderwort family, with purplish flowers and a rosette of flat leaves covered with a sticky substance that traps insects. (Genus *Pinguicula*, family Lentibulariaceae.)

---

buzzard

species of medium-sized hawk with broad wings, often seen soaring. Buzzards are in the falcon family, Falconidae, order Falconiformes. The **common buzzard** *Buteo buteo* of Europe and Asia is about

55 cm/1.8 ft long with a wingspan of over 1.2 m/4 ft. It preys on a variety of small animals up to the size of a rabbit.

The **rough-legged buzzard** *B. lagopus* lives in the northern tundra and eats lemmings. The **honey buzzard** *Pernis apivora* feeds largely, as its name suggests, on honey and insect larvae. It spends the summer in Europe and western Asia and winters in Africa. The **red-shouldered hawk** *B. lineatus* and **red-tailed hawk** *B. jamaicensis* occur in North America.

buzzard

(Image © Research Machines plc)

In the British Isles, the buzzard, *Buteo buteo*, is quite commonly found in Scotland, Wales, the Lake District, and southwest England. It favours forest and woodland habitats close to open country, where it can hunt. Its varied diet includes rabbits, voles, shrews, mice, lizards, and frogs, as well as worms and insects.

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by-product

substance formed incidentally during the production process of some other substance; for example, slag is a by-product of the production of iron in a blast furnace. The by-product is incidental to the main product. For industrial processes to be economical, by-products must be recycled or used in other ways as far as possible; in this example, slag is used for making roads. Another common example occurs in the petrochemical industry, where crude oil is refined principally to produce petroleum, with a number of by-products being produced, including creosote and paraffin.

Often, a poisonous by-product is removed by transforming it into another substance, which although less harmful is often still inconvenient. For example, the sulphur dioxide produced as a by-product of electricity generation can be removed from the smoke stack using flue-gas desulphurization. This process produces large amounts of gypsum, some of which can be used in the building industry.

Byron, (Augusta) Ada, Countess of Lovelace (1815-1852)

English mathematician, a pioneer in writing programs for Charles Babbage's analytical engine. In 1983 a new, high-level computer language, Ada, was named after her.

She was the daughter of the poet Lord Byron.

Byron, Ada

Go to site

Interesting biography of Ada Byron, the woman credited as the first computer programmer. This page also has links to a range of other online resources about this scientist.

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byssus

tough protein fibres secreted by the foot of sessile (fixed) bivalves, such as mussels, as a means of attachment to rocks.

The byssus of some rock creatures can be woven into fabrics. A delicate silk called byssus is made from the byssus of mussels found in the Mediterranean.

byte

sufficient computer memory to store a single character of data, such as a letter of the alphabet. The character is stored in the byte of memory as a pattern of bits (binary digits), using a code such as ASCII. A byte usually contains eight bits – for example, the capital letter F can be stored as the bit pattern 01000110.

A single byte can specify 256 values, such as the decimal numbers from 0 to 255; in the case of a single-byte pixel (picture element), it can specify 256 different colours. Three bytes (24 bits) can specify 16,777,216 values. Computer memory size is measured in **kilobytes** (1,024 bytes), **megabytes** (1,024 kilobytes), or **gigabytes** (1,024 megabytes).

°C

symbol for Celsius (temperature scale), formerly called centigrade.

C

in physics, symbol for coulomb, the SI unit of electrical charge.

C

in computing, a high-level, general-purpose programming language popular on minicomputers and microcomputers. Developed in the early 1970s from an earlier language called BCPL, C was first used as the language of the operating system Unix, though it has since become widespread beyond Unix. The original language has evolved many derivative variants, including the popular C++ and C# versions. It is useful for writing fast and efficient systems programs, such as operating systems (which control the operations of the computer).

cabbage

vegetable plant related to the turnip and wild mustard, or charlock. It was cultivated as early as 2000 BC, and the many commercial varieties include kale, Brussels sprouts, common cabbage, savoy, cauliflower, sprouting broccoli, and kohlrabi. (*Brassica oleracea*, family Cruciferae.)

cabbage butterfly

one of several butterfly species, the caterpillars of which feed on the leaves of members of the cabbage family, particularly as pests on cabbages. Ichneumon flies parasitize the caterpillars, thereby controlling their numbers.

classification

Cabbage butterflies are in genus *Pieris* in order Lepidoptera, class Insecta, phylum Arthropoda.

species

The **large white** *Pieris brassicae* is found in Europe and North Africa. The expanded wings measure 7.5 cm/3 in across, and are white with black edgings. The female, which has black spots on the upper surfaces of the wings, lays her yellow eggs in clusters on cabbage leaves. The fully grown caterpillar sometimes measures 4 cm/1.5 in, and will eat twice its own weight of leaf in 24 hours. After it has hung for some time by its tail from a ledge, it changes into a shining pale green chrysalis. The butterfly, which in the case of the autumn brood waits till winter is past before emerging, lives on nectar.

The **small white butterfly** *Pieris rapae*, has a wing expansion of about 5 cm/2 in, lays its eggs singly on the underside of vegetable leaves, and produces a velvety caterpillar which devours the hearts, instead of merely the leaves, of cabbages. The chrysalis is brownish-yellow with black spots.

A third species, the **green-veined white butterfly** *Pieris napi*, which is similar to the small white, cannot multiply so fast, because both the butterfly and its caterpillar are a favourite food of small birds.

cable car

method of transporting passengers up steep slopes by cable. In the **cable railway**, passenger cars are hauled along rails by a cable wound by a powerful winch. A pair of cars usually operates together on the funicular principle, one going up as the other goes down. The other main type is the **aerial cable car**, where the passenger car is suspended from a trolley that runs along an aerial cableway.

A cable-car system has operated in San Francisco since 1873. The streetcars travel along rails and are hauled by moving cables under the ground.

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cable length

unit of length, used on ships, originally the length of a ship's anchor cable or 120 fathoms (720 ft/219 m), but in British usage taken as one-tenth of a nautical mile (608 ft/185 m).

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cable television

distribution of broadcast signals through cable relay systems. Narrow-band systems were originally used to deliver services to areas with poor regular reception; systems with wider bands, using coaxial and fibreoptic cable, are increasingly used for distribution and development of home-based telephone and television services.

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cacao

tropical American evergreen tree, now also cultivated in West Africa and Sri Lanka. Its seeds are cocoa beans, from which cocoa and chocolate are prepared. (*Theobroma cacao*, family Sterculiaceae.)

The trees mature at five to eight years and produce two crops a year. The fruit is 17-25 cm/6.5-9.5 in long, hard, and ridged, with the beans inside. The seeds are called cocoa nibs; when left to ferment, then roasted and separated from the husks, they contain about 50% fat, part of which is removed to make chocolate and cocoa.

The Aztecs revered cacao and made a drink exclusively for the nobility from cocoa beans and chillies, which they called chocolatl. In the 16th century Spanish traders brought cacao to Europe. It was used to make a drink, which came to rival coffee and tea in popularity.

Cacao

Go to site

Informative resource relating to this tree. It contains a detailed description of the plant, its habitat, and its history. There are also notes on the many uses of cacao, which include making cocoa, preparing suppositories, and acting as a diuretic.

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cache memory

in computing, a reserved area of the immediate access memory used to increase the running speed of a computer program.

The cache memory may be constructed from SRAM, which is faster but more expensive than the normal DRAM. Most programs access the same instructions or data repeatedly. If these frequently used instructions and data are stored in a fast-access SRAM memory cache, the program will run more quickly. In other cases, the memory cache is normal DRAM, but is used to store frequently used instructions and data that would normally be accessed from backing storage. Access to DRAM is faster than access to backing storage so, again, the program runs more quickly. This type of cache memory is often called a **disk cache**.

---

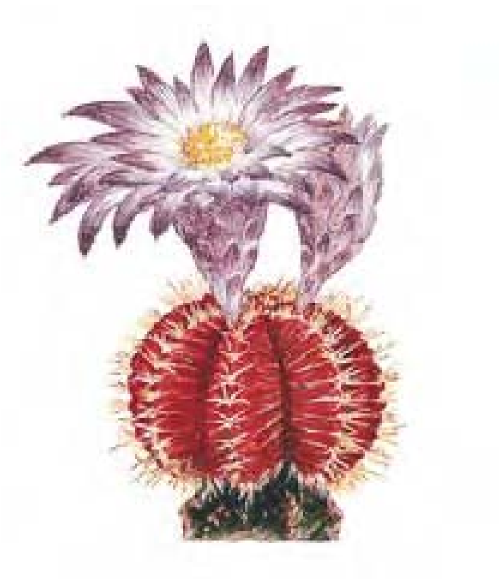
cactus

plural cacti

strictly, any plant of the family Cactaceae, although the word is commonly used to describe many different succulent and prickly plants. True cacti have a woody axis (central core) surrounded by a large fleshy stem, which takes various forms and is usually covered with spines (actually reduced leaves). They are all specially adapted to growing in dry areas.

Cactus flowers are often large and brightly coloured; the fruit is fleshy and often edible, as in the case of the prickly pear. The Cactaceae are a New World family and include the treelike saguaro and the night-blooming cereus with blossoms 30 cm/12 in across.

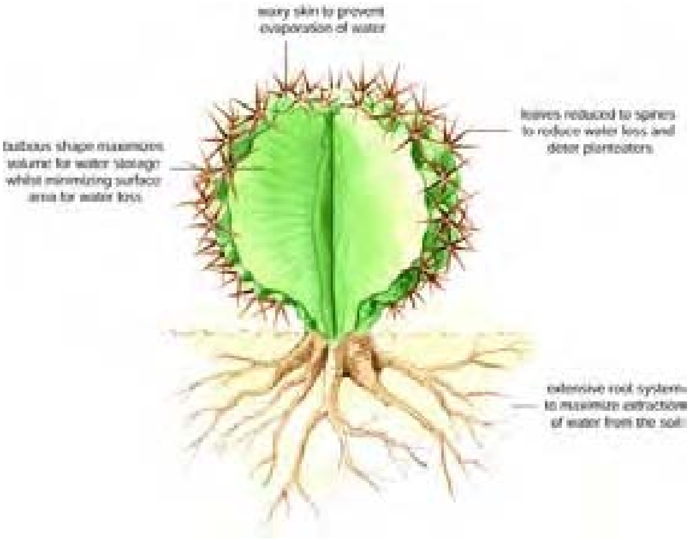
cactus



(Image © Research Machines plc)

Cactus is the ancient Greek name for a prickly plant, now applied as a general term to many different succulent and prickly plants. They vary in shape and size and have no leaves, photosynthesis occurring in green stems. The lack of leaves is an adaptation for conserving water, as is the common spherical shape.

cactus


waxy skin to prevent evaporation of water
leaves reduced to spines to reduce water loss and deter planteaters
bulbous shape maximizes volume for water storage whilst minimizing surface area for water loss
extensive root system to maximize extraction of water from the soil

(Image © Research Machines plc)

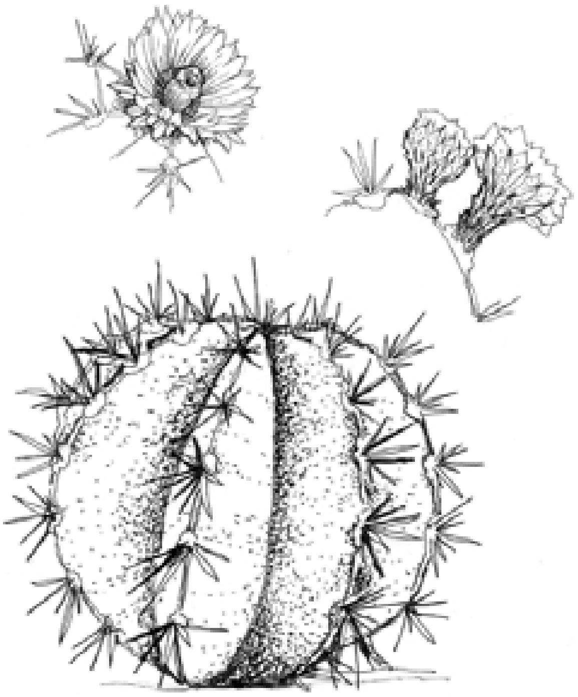
Cacti are adapted for desert life in a number of ways. They have fleshy tissue in which to store water and their leaves are reduced to spines to lessen water loss by transpiration. Cactus roots are branching and shallow, adapted to gathering surface water from a large area.

cactus

(Image © Research Machines plc)

Cacti in southern Mexico. Cacti belong to the New World Cactaceae family and are specially adapted to living in arid conditions.

cactus



(Image © Research Machines plc)

Star cactus (*Astrophytum ornatum*), also known as bishop's cap cactus. The star cactus is one of four species of spherical, spiny cactus plants that comprise the genus *Astrophytum*. During the summer the star cactus produces numerous large, daisylike yellow flowers. *Astrophytum* can grow up to 4 m/13 ft in diameter. It is native to Mexico.

Cactus and Succulent Plant Mall

Go to site

Huge source of information on cacti and how to grow them. There are also reports on conservation of cacti and succulents. There are links to a large number of international cacti associations.

Cereus, Night Blooming

Go to site

Informative resource relating to this cactus. It contains an detailed description of the plant, its habitat, and its constituents. There are also notes on the many uses of the Night Blooming Cereus, which include acting as a diuretic and as a sedative.

CAD

acronym for computer-aided design

use of computers in creating and editing design drawings. CAD also allows such things as automatic testing of designs and multiple or animated three-dimensional views of designs. CAD systems are widely used in architecture, electronics, and engineering, for example in the motor-vehicle industry, where cars designed with the assistance of computers are now commonplace. With a CAD system, picture components are accurately positioned using grid lines. Pictures can be resized, rotated, or mirrored without loss of quality or proportion.

Powerful CAD software allows designers to build virtual designs and manipulate them on screen. For example, an architect can use CAD combined with virtual reality and other graphics programmes to 'walk' people through a virtual model of a planned building. A related development is CAM (computer-aided manufacturing).

Soda Constructor

Go to site

An ingenious and enthralling site inviting the user to apply their knowledge of maths and physics, or just plain luck, to animate a two-dimensional model constructed from masses, springs, and nodes. Users can define wave (muscle) strength, gravity, and friction to make things harder for their construction.

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caddis fly

insect of the order Trichoptera. Adults are generally dull brown, mothlike, with wings covered in tiny hairs. Mouthparts are poorly developed, and many caddis flies do not feed as adults. They are usually found near water.

The larvae are aquatic, and many live in cases, open at both ends, which they make out of sand or plant remains. Some species make silk nets among aquatic vegetation to help trap food.

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cadmium

chemical symbol Cd

(ancient Greek kadmeia)

soft, silver-white, ductile, and malleable metallic element, atomic number 48, relative atomic mass 112.40. Cadmium occurs in nature as a sulphide or carbonate in zinc ores. It is a toxic metal that, because of industrial dumping, has become an environmental pollutant. It is used in batteries, electroplating, and as a constituent of alloys used for bearings with low coefficients of friction; it is also a constituent of an alloy with a very low melting point.

Cadmium is also used in the control rods of nuclear reactors, because of its high absorption of neutrons. It was named in 1817 by the German chemist Friedrich Strohmeyer (1776–1835) after the ancient Greek word *kadmeia* for certain zinc ores used to make brass.

---

caecilian

tropical amphibian of wormlike appearance. There are about 170 species known in the family Caeciliidae, forming the amphibian order Apoda (also known as Caecilia or Gymnophiona). Caecilians have a grooved skin that gives a 'segmented' appearance; they have no trace of limbs or pelvis. The body is 20–130 cm/8-50 in long, beige to black in colour. The eyes are very small and weak or blind. They eat insects and small worms. Some species bear live young, others lay eggs.

Caecilians live in burrows in damp ground in the tropical Americas, Africa, Asia, and the Seychelles.

---

caecum

in the digestive system of animals, a blind-ending tube branching off from the first part of the large intestine, terminating in the appendix. It has no function in humans but is used for the digestion of cellulose by some grass-eating mammals.

The rabbit caecum and appendix contains millions of bacteria that produce cellulase, the enzyme necessary for the breakdown of cellulose to glucose. In order to be able to absorb nutrients released by the breakdown of cellulose, rabbits pass food twice down the intestine. They egest soft pellets which are then re-eaten. This is known as coprophagy.

Caesarean section

surgical operation to deliver a baby by way of an incision in the mother's abdominal and uterine walls. It may be recommended for almost any obstetric complication implying a threat to mother or baby.

Caesarean section was named after the Roman emperor Julius Caesar, who was said to have been born this way. In medieval Europe, it was performed mostly in attempts to save the life of a child whose mother had died in labour. The Christian Church forbade cutting open the mother before she was dead.

Caesarean Section - A Brief History

Go to site

Despite the title this is a fairly comprehensive history of the Caesarean section operation. Starting with the early history of the operation, this Web site advances through to modern day medicine, charting progress with concise text and many diagrams. Also included are several text references for further reading. The material here is taken from a brochure issued to accompany an exhibition at the US National Library of Medicine in Bethesda, Maryland, USA.

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caesium

chemical symbol Cs

(Latin caesius 'bluish-grey')

soft, silvery-white, ductile metallic element, atomic number 55, relative atomic mass 132.905. It is one of the alkali metals that form Group 1 of the periodic table of the elements. The alkali metals increase in reactivity down the group, and caesium, with only the short-lived radioactive francium below it, is the most reactive of them all. In air it ignites spontaneously, and it reacts violently with water. It is the most electropositive of all the elements. It is used in the manufacture of photocells.

The rate of vibration of caesium atoms has been used as the standard of measuring time. Its radioactive isotope Cs-137 (half-life 30.17 years) is a product of fission in nuclear explosions and in nuclear reactors; it is one of the most dangerous waste products of the nuclear industry, being a highly radioactive biological analogue of potassium.

---

caffeine

alkaloid organic substance found in tea, coffee, and kola nuts; it stimulates the heart and central nervous system. When isolated, it is a bitter crystalline compound, $C_8H_{10}N_4O_2$. Too much caffeine (more than six average-size cups of tea or coffee a day) can be detrimental to health.

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caiman

or cayman

large reptile, related to the alligator.

All caimans are found only in Central and South America.

types of caiman

The black caiman *Melanosuchus niger* is the largest South American predator, reaching 6 m in length. Cuvier's dwarf caiman *Paleosuchus palpebrosus* may be as little as 1.2 m in length when fully grown (females). Schneider's dwarf caiman *Paleosuchus trigonatus* reaches 1.7 m and is reasonably common in the Amazonian rainforests. Broad-snouted caiman *Caiman latirostris* is found is found mainly in freshwater swamps and grows up to 3.5 m. Common caiman *Caiman crocodilus* is found from southern Mexico to northern Argentina and can grow up to 3 m.

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cairn

Scottish breed of terrier. Shaggy, short-legged, and compact, it can be sandy, greyish brindle, or red. It was formerly used for flushing out foxes and badgers.

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caisson

hollow cylindrical or boxlike structure, usually of reinforced concrete, sunk into a riverbed to form the foundations of a bridge.

An **open caisson** is open at the top and at the bottom, where there is a wedge-shaped cutting edge. Material is excavated from inside, allowing the caisson to sink. A **pneumatic caisson** has a pressurized chamber at the bottom, in which workers carry out the excavation. The air pressure prevents the surrounding water entering; the workers enter and leave the chamber through an airlock, allowing for a suitable decompression period to prevent decompression sickness (the so-called bends).

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cal

symbol for calorie.

CAL

acronym for computer-assisted learning

use of computers in education and training: the computer displays instructional material to a student and asks questions about the information given; the student's answers determine the sequence of the lessons.

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calabash

tropical South American evergreen tree with gourds (fruits) 50 cm/20 in across, whose dried skins are used as water containers. The Old World tropical-vine bottle gourd (*Lagenaria siceraria*, of the gourd family Cucurbitaceae) is sometimes also called a calabash, and it produces equally large gourds. (*Crescentia cujete*, family Bignoniaceae.)

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calamine

$Zn_4Si_2O_7(OH)_2.H_2O$

native zinc silicate, an ore of zinc. The term also refers to a pink powder of zinc oxide mixed with 0.5% ferric oxide, used in lotions and ointments as a topical astringent.

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calceolaria

plant with brilliantly coloured slipper-shaped flowers. Native to South America, calceolarias were introduced to Europe and the USA in the 1830s. (Genus *Calceolaria*, family Scrophulariaceae.)

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calcification

in medicine, the deposition of calcium salts in bone cells as part of the growth process. Bone is comprised of fibrous tissue and a matrix containing calcium phosphate and calcium carbonate. Bones grow in thickness from the fibrous tissue and the calcium salts deposited in their cells by calcification.

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calcination

oxidation of substances by roasting in air.

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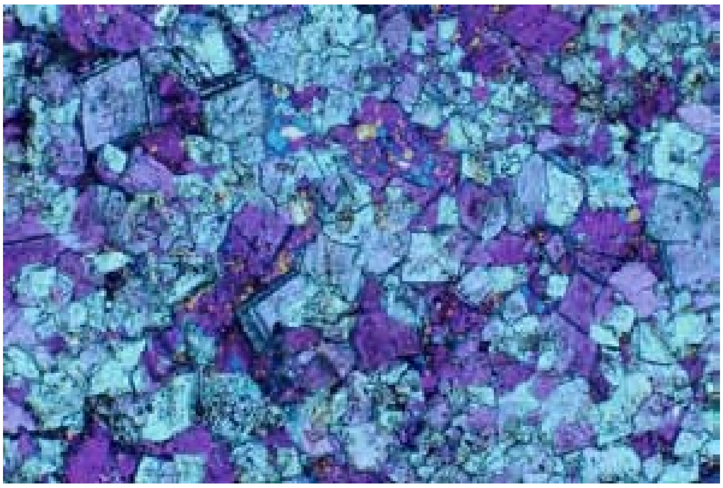
calcite

colourless, white, or light-coloured common rock-forming mineral, calcium carbonate, $CaCO_3$. It is the main constituent of limestone and marble and forms many types of invertebrate shell.

Calcite often forms stalactites and stalagmites in caves and is also found deposited in veins through many rocks because of the ease with which it is dissolved and transported by groundwater; oolite is a rock consisting of spheroidal calcite grains. It rates 3 on the Mohs scale of hardness. Large crystals up to 1 m/3 ft have been found in Oklahoma and Missouri, USA. Iceland spar is a transparent form of calcite used in the optical industry; as limestone it is used in the building industry.

calcite



(Image © Corel)

Calcite through a polarized microscope. Calcite is the main constituent of limestone and marble.

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calcium

chemical symbol Ca

(Latin calcis 'lime')

soft, silvery-white metallic element, atomic number 20, relative atomic mass 40.08. It is one of the alkaline-earth metals. It is the fifth most abundant element (the third most abundant metal) in the Earth's crust. It is found mainly as its carbonate $CaCO_3$, which occurs in a fairly pure condition as chalk and limestone (see calcite). Calcium is an essential component of bones, teeth, shells, milk, and leaves, and it forms 1.5% of the human body by mass.

Calcium ions in animal cells are involved in regulating muscle contraction, blood clotting, hormone secretion, digestion, and glycogen metabolism in the liver. It is acquired mainly from milk and cheese, and its uptake is facilitated by vitamin D. Calcium deficiency leads to chronic muscle spasms (tetany); an excess of calcium may lead to the formation of stones (calculi) in the kidney or gall bladder.

The element was discovered and named by the English chemist Humphry Davy in 1808. Its compounds include slaked lime (calcium hydroxide, $Ca(OH)_2$); plaster of Paris (calcium sulphate, $CaSO_4.1/2H_2O$); calcium phosphate ($Ca_3(PO_4)_2$), the main constituent of animal bones; calcium hypochlorite ($CaOCl_2$), a bleaching agent; calcium nitrate ($Ca(NO_3)_2.4H_2O$), a nitrogenous fertilizer; calcium carbide (CaC_2), which reacts with water to give ethyne (acetylene); calcium cyanamide ($CaCN_2$), the basis of many pharmaceuticals, fertilizers, and plastics, including melamine; calcium cyanide ($Ca(CN)_2$), used in the extraction of gold and silver and in electroplating; and others used in baking powders and fillers for paints.

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calcium carbonate

$CaCO_3$

white solid, found in nature as limestone, marble, and chalk. It is a valuable resource, used in the making of iron, steel, cement, glass, slaked lime, bleaching powder, sodium carbonate and bicarbonate, and many other industrially useful substances.

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calcium hydroxide

or slaked lime; $Ca(OH)_2$

white solid, slightly soluble in water. A solution of calcium hydroxide is called limewater and is used in the laboratory to test for the presence of carbon dioxide.

It is manufactured industrially by adding water to calcium oxide (quicklime) in a strongly exothermic reaction:

$$CaO + H_2O \rightarrow Ca(OH)_2$$

It is used to reduce soil acidity and as a cheap alkali in many industrial processes.

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calculus

(Latin 'pebble')

branch of mathematics which uses the concept of a derivative (see differentiation) to analyse the way in which the values of a function vary. Calculus is probably the most widely used part of mathematics. Many real-life problems are analysed by expressing one quantity as a function of another - position of a moving object as a function of time, temperature of an object as a function of distance from a heat source, force on an object as a function of distance from the source of the force, and so on - and calculus is concerned with such functions.

There are several branches of calculus. Differential and integral calculus, both dealing with small quantities which during manipulation are made smaller and smaller, compose the **infinitesimal calculus**. **Differential equations** relate to the derivatives of a set of variables and may include the variables. Many give the mathematical models for physical phenomena such as simple harmonic motion. Differential equations are solved generally by integration, depending on their degree. If no analytical processes are available, integration can be performed numerically. Other branches of calculus include calculus of variations and calculus of errors.

Rise of Calculus

Go to site

History of the development of calculus, from the time of the Greeks to the works of Cauchy in the 19th century. The site includes links to the biographical details of the mathematicians responsible for the rise of calculus, and also a brief list of reference publications for further information. Also included are several mathematical demonstrations on the use of calculus.

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caldera

in geology, a very large basin-shaped crater. Calderas are found at the tops of volcanoes, where the original peak has collapsed into an empty chamber beneath. The basin, many times larger than the original volcanic vent, may be flooded, producing a crater lake, or the flat floor may contain a number of small volcanic cones, produced by volcanic activity after the collapse.

Typical calderas are Kilauea, Hawaii; Crater Lake, Oregon, USA; and the summit of Olympus Mons, on Mars. Some calderas are wrongly referred to as craters, such as Ngorongoro, Tanzania.

Calderón, Alberto P (1920-1998)

Argentine mathematician who specialized in Fourier analysis and partial differential equations.

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calendar

division of the year into months, weeks, and days and the method of ordering the years. From year one, an assumed date of the birth of Jesus, dates are calculated backwards (BC'before Christ' or BCE 'before common era') and forwards (AD, Latin *anno Domini* 'in the year of the Lord', or CE 'common era'). The **lunar month** (period between one new moon and the next) naturally averages 29.5 days, but the Western calendar uses for convenience a **calendar month** with a complete number of days, 30 or 31 (February has 28). For adjustments, since there are slightly fewer than six extra hours a year left over, they are added to February as a 29th day every fourth year (**leap year**), century years being excepted unless they are divisible by 400. For example, 1896 was a leap year; 1900 was not.

The **month names** in most European languages were probably derived as follows: January from Janus, Roman god; February from *Februar*, Roman festival of purification; March from Mars, Roman god; April from Latin *aperire*, 'to open'; May from Maia, Roman goddess; June from Juno, Roman goddess; July from Julius Caesar, Roman general; August from Augustus, Roman emperor; September, October, November, December (originally the seventh to tenth months) from the Latin words meaning seventh, eighth, ninth, and tenth, respectively.

The **days of the week** are Monday named after the Moon; Tuesday from Tiu or Tyr, Anglo-Saxon and Norse god; Wednesday from Woden or Odin, Norse god; Thursday from Thor, Norse god; Friday from Freya, Norse goddess; Saturday from Saturn, Roman god; and Sunday named after the Sun.

All early calendars except the ancient Egyptian were lunar. The word calendar comes from the Latin *Kalendae* or *calendae*, the first day of each month on which, in ancient Rome, solemn proclamation was made of the appearance of the new moon.

The **Western** or **Gregorian calendar** derives from the **Julian calendar** instituted by Julius Caesar in 46 BC. It was adjusted in 1582 by Pope Gregory XIII, who eliminated the accumulated error caused by a faulty calculation of the length of a year and avoided its recurrence by restricting century leap years to those divisible by 400. Other states only gradually changed from Old Style to New Style; Britain and its colonies adopted the Gregorian calendar in 1752, when the error amounted to 11 days, and 3 September 1752 became 14 September (at the same time the beginning of the year was put back from 25 March to 1 January). Russia did not adopt it until the October Revolution of 1917, so that the event (then 25 October) is currently celebrated on 7 November.

The **Jewish calendar** is a complex combination of lunar and solar cycles, varied by considerations of religious observance. A year may have 12 or 13 months, each of which normally alternates between 29 and 30 days; the New Year (Rosh Hashanah) falls between 5 September and 5 October. The calendar dates from the hypothetical creation of the world (taken as 7 October 3761 BC).

The **Chinese calendar** is lunar, with a cycle of 60 years. Both the traditional and, from 1911, the Western calendar are in use in China.

The **Muslim calendar**, also lunar, has 12 months of alternately 30 and 29 days, and a year of 354 days. This results in the calendar rotating around the seasons in a 30-year cycle. The era is counted as beginning on the day Muhammad fled from Mecca in AD 622.

Days of the week

The names of the days are based on the seven heavenly bodies used in traditional astrology: the Sun, the Moon, Mars, Mercury, Jupiter, Venus, and Saturn. These bodies were believed at the time (about 1100 to 1500) to revolve around the Earth and influence its events. The seven-day week became part of the Roman calendar in AD 321.

English	Latin	Saxon	German	French	Italian	Spanish
Sunday	Dies Solis	Sunnandaeg - Sun's Day	Sonntag	dimanche	domenica	domingo
Monday	Dies Lunae	Monandaeg - Moon's Day	Montag	lundi	lunedì	lunes
Tuesday	Dies Martis	Tiwesdaeg - Tiw's Day[1]	Dienstag	mardi	martedì	martes
Wednesday	Dies Mercurii	Wodnesdaeg - Woden's Day[2]	Mittwoch	mercredi	mercoledì	miércoles
Thursday	Dies Jovis	Thunresdaeg - Thor's Day[3]	Donnerstag	jeudi	giovedì	jueves
Friday	Dies Veneris	Frigedaeg - Frigg's Day[4]	Freitag	vendredi	venerdì	viernes
Saturday	Dies Saturni	Saetern-daeg - Saturn's Day	Samstag	samedi	sabato	sábado

[1] Tiw: Anglo-Saxon name for Nordic Tyr, son of Odin and god of war, closest to Mars (Greek Ares), son of Roman god Jupiter (Greek Zeus).

[2] Woden: Anglo-Saxon name for Odin, Nordic dispenser of victory, closest to Mercury (Greek Hermes), Roman messenger of victory.

[3] Thor: Nordic god of thunder, eldest son of Odin, closest to Roman Jupiter (Greek Zeus).

[4] Frigg (or Freyja): wife of Odin, the Nordic goddess of love, equivalent to Roman Venus (Greek Aphrodite).

Months of the Jewish calendar

Jewish month	Number of days	Gregorian equivalent
Tishri	30	September-October
Heshvan	29 or 30	October-November
Kislev	29 or 30	November-December
Tebet	29	December-January
Shebat	30	January-February
Adar	29 or 30	February-March
Nisan	30	March-April
Iyar	29	April-May
Sivan	30	May-June
Tammuuz	29	June-July
Ab	30	July-August
Elul	29	August-September

Year equivalents for the Islamic and Gregorian calendars

AH = Anno Hegirae, the first year of the Islamic calendar, when the prophet Muhammad travelled from Mecca to Medina.

Islamic year (AH)	Gregorian equivalent
1427	31 January 2006-19 January 2007
1428	20 January 2007-9 January 2008
1429	10 January 2008-28 December 2008
1430	29 December 2008-17 December 2009
1431	18 December 2009-8 December 2010
1432	9 December 2010-26 November 2011
1433	27 November 2011-14 November 2012
1434	15 November 2012-4 November 2013
1435	5 November 2013-24 October 2014
1436	25 October 2014-14 October 2015

Gregorian Calendar

Go to site

Very detailed essay that explains the history of calculating and quantifying time, from the Egyptian calendar to the Gregorian calendar.

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calibration

the preparation of a usable scale on a measuring instrument. A mercury thermometer, for example, can be calibrated with a Celsius scale by noting the heights of the mercury column at two standard temperatures - the freezing point (0°C) and boiling point (100°C) of water - and dividing the distance between them into 100 equal parts and continuing these divisions above and below.

California current

cold ocean current in the eastern Pacific Ocean flowing southwards down the west coast of North America. It is part of the North Pacific gyre (a vast, circular movement of ocean water).

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californium

chemical symbol Cf

synthesized, radioactive, metallic element of the actinide series, atomic number 98, relative atomic mass 251. It is produced in very small quantities and used in nuclear reactors as a neutron source. The longest-lived isotope, Cf-251, has a half-life of 800 years.

It is named after the state of California, where it was first synthesized in 1950 by US nuclear chemist Glenn Seaborg and his team at the University of California at Berkeley.

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callipers

measuring instrument used, for example, to measure the internal and external diameters of pipes. Some callipers are made like a pair of compasses, having two legs, often curved, pivoting about a screw at one end. The ends of the legs are placed in contact with the object to be measured, and the gap between the ends is then measured against a rule. The slide calliper looks like an adjustable spanner, and carries a scale for direct measuring, usually with a vernier scale for accuracy.

Callisto

second-largest moon of the planet Jupiter, 4,800 km/3,000 mi in diameter, orbiting every 16.7 days at a distance of 1.9 million km/1.2 million mi. Its surface is covered with large craters.

The US space probe Galileo detected oxygen on Callisto in 1997, suggesting that its surface material contains a high proportion of water ice. In 1998 Galileo's magnetometer measured electrical currents near Callisto's surface that are consistent with the existence of a buried salty ocean beneath the icy crust.

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callus

in botany, a tissue that forms at a damaged plant surface. Composed of large, thin-walled parenchyma cells, it grows over and around the wound, eventually covering the exposed area.

In animals, a callus is a thickened pad of skin, formed where there is repeated rubbing against a hard surface. In humans, calluses often develop on the hands and feet of those involved in heavy manual work.

Calmette, (Léon Charles) Albert (1863-1933)

French bacteriologist. A student of Pasteur, he developed, with Camille Guérin, the BCG vaccine against tuberculosis in 1921.

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calomel

technical name mercury(I) chloride; Hg_2Cl_2

white, heavy powder formerly used as a laxative, now used as a pesticide and fungicide.

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calorie

c.g.s. unit of heat, now replaced by the joule (one calorie is approximately 4.2 joules). It is the heat required to raise the temperature of one gram of water by 1°C. In dietetics, the Calorie or kilocalorie is equal to 1,000 calories.

The kilocalorie measures the energy value of food in terms of its heat output: 28 g/1 oz of protein yields 120 kilocalories, of carbohydrate 110, of fat 270, and of alcohol 200.

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calorific value

amount of heat generated by a given mass of fuel when it is completely burned. It is measured in joules per kilogram. Calorific values are measured experimentally with a bomb calorimeter.

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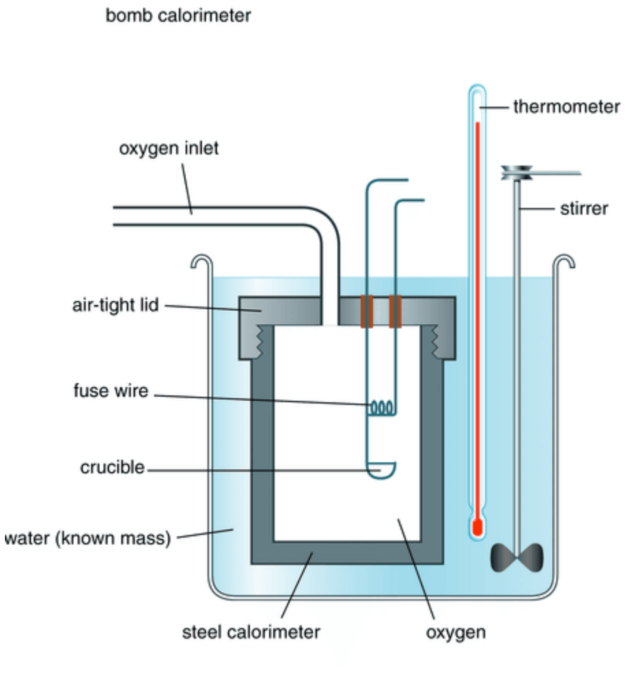
calorimeter

instrument used in physics to measure various thermal properties, such as heat capacity or the heat produced by fuel. A simple calorimeter consists of a heavy copper vessel that is polished (to reduce heat losses by radiation) and covered with insulating material (to reduce losses by convection and conduction).

In a typical experiment, such as to measure the heat capacity of a piece of metal, the calorimeter is filled with water, whose temperature rise is measured using a thermometer when a known mass of the heated metal is immersed in it. Chemists use a bomb calorimeter (so called from its sturdy pressure-resistant casing, which somewhat resembles the casing of a bomb) to measure the heat produced by burning a fuel completely in oxygen.

calorimeter



(Image © Research Machines plc)

A bomb calorimeter is used to measure the energy that is given out when one mole of a substance is completely burned in oxygen. A known amount of the substance is placed in the crucible, oxygen is added at 20 atmospheres pressure, and then the substance is ignited using the heated wire. As the calorimeter heats, it heats the water. The rise in water temperature is measured and from this the heat generated by the burning substance is calculated.

calotype

paper-based photograph using a wax paper negative, the first example of the negative/positive process invented by the English photographer Fox Talbot around 1834.

Calvin, Melvin (1911-1997)

US chemist who was awarded the Nobel Prize for Chemistry in 1961 for his study of the assimilation of carbon dioxide by plants. Using radioactive carbon-14 as a tracer, he determined the biochemical processes of photosynthesis, in which green plants use chlorophyll to convert carbon dioxide and water into sugar and oxygen.

calyptra

in mosses and liverworts, a layer of cells that encloses and protects the young sporophyte (spore capsule), forming a sheathlike hood around the capsule. The term is also used to describe the root cap, a layer of parenchyma cells covering the end of a root that gives protection to the root tip as it grows through the soil. This is constantly being worn away and replaced by new cells from a special meristem, the calyptrogen.

calyx

the collective term for the sepals of a flower, forming the outermost whorl of the perianth. It surrounds the other flower parts and protects them while in bud. In some flowers, for example, the catchflies *Silene* of the pink family, the sepals are fused along their sides, forming a sticky tubular calyx.

CAM

acronym for computer-aided manufacturing

use of computers to control production processes; in particular, the control of machine tools and robots in factories. In some factories, the whole design and production system is automated by linking CAD (computer-aided design) to CAM.

Linking flexible CAD/CAM manufacturing to computer-based sales and distribution methods, creating a computer integrated manufacturing system, makes it possible to produce semi-customized goods cheaply and in large numbers. Computers are commonly used to control industrial processes in many industries, from petrochemicals and steel, to electronic engineering and food processing.

cam

part of a machine that converts circular motion to linear motion or vice versa. The **edge cam** in a car engine is in the form of a rounded projection on a shaft, the camshaft. When the camshaft turns, the cams press against linkages (plungers or followers) that open the valves in the cylinders.

A **face cam** is a disc with a groove in its face, in which the follower travels. A **cylindrical cam** carries angled parallel grooves, which impart a to-and-fro motion to the follower when it rotates.

cambium

in botany, a layer of actively dividing cells (lateral meristem), found within stems and roots, that gives rise to secondary growth in perennial plants, causing an increase in girth. There are two main types of cambium: **vascular cambium**, which gives rise to secondary xylem and phloem tissues, and **cork cambium** (or phellogen), which gives rise to secondary cortex and cork tissues (see bark).

Cambrian period

period of geological time roughly 570–510 million years ago; the first period of the Palaeozoic Era. All invertebrate animal life appeared, and marine algae were widespread. The **Cambrian Explosion** 530–520 million years ago saw the first appearance in the fossil record of modern animal phyla; the earliest fossils with hard shells, such as trilobites, date from this period.

The name comes from Cambria, the medieval Latin name for Wales, where Cambrian rocks are typically exposed and were first described.

Cambrian Period: Life Goes for a Spin

Go to site

Part of a larger site maintained by *Scientific American*, this page reports on the research of Joseph Kirschvink of the California Institute of Technology which suggests that the so-called 'Cambrian Explosion' resulted from a sudden shifting of the Earth's crust. The text includes hyperlinks to further information, and there is also a list of related links, including one to figures, diagrams, and information from Kirschvink's research paper.

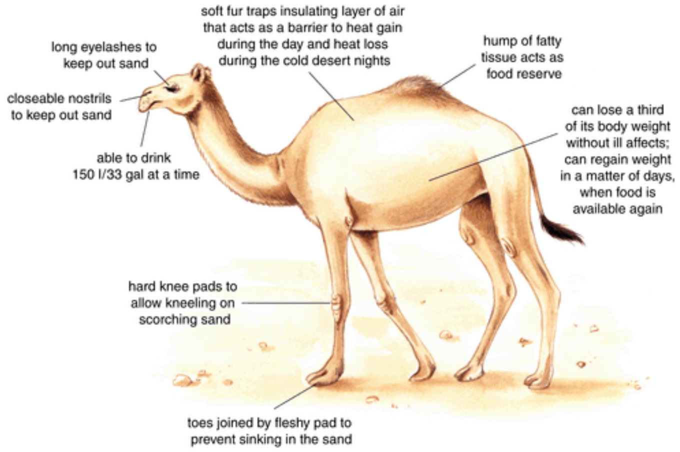
camcorder

another name for a video camera.

camel

large cud-chewing mammal with two toes which have broad soft soles for walking on sand, and hooves resembling nails. Part of the even-toed hoofed order Artiodactyla, it is a ruminant, although it differs from most ruminants in having, only a three-chambered stomach. There are two species, the single-humped **Arabian camel**, or dromedary, *Camelus dromedarius* and the twin-humped **bactrian camel** *C. bactrianus* from Asia. They carry a food reserve of fatty tissue in the hump, can go without drinking for long periods, can feed on salty vegetation, and withstand extremes of heat and cold, thus being well adapted to desert conditions.

camel


soft fur traps insulating layer of air that acts as a barrier to heat gain during the day and heat loss during the cold desert nights
long eyelashes to keep out sand
hump of fatty tissue acts as food reserve
closeable nostrils to keep out sand
can lose a third of its body weight without ill affects; can regain weight in a matter of days, when food is available again
able to drink 150 l/33 gal at a time
hard knee pads to allow kneeling on scorching sand
toes joined by fleshy pad to prevent sinking in the sand

(Image © Research Machines plc)

The Arabian camel does not actually store water in its hump, although it can do so in the lining of its stomach. During protracted periods without water, the camel can lose up to 27% of its body weight without causing harm.

camel

(Image © Research Machines plc)

Camel in Sinai, Egypt. Camels are well-adapted to desert conditions as they can withstand extreme weather conditions and go for long periods without drinking. There are two species of camel, the single-humped Arabian camel (pictured), and the twin-humped Bactrian camel from Asia.

camel

(Image © Research Machines plc)

Camel market in Cairo. While camels have been largely replaced by jeeps and trucks across much of Arabia, they are still bought and sold at markets in North Africa, such as this one in Cairo, and in India (where the famous Pushkar camel market and festival is now promoted as a tourist attraction).

camel

To distinguish between the two species of camel:

A camel I am it's plain to see
But am I a **B**actrian or **D**romedary?
Lay down the **B** and then the **D**
And which I am is plain as can be

Dromedary Camel

Go to site

Illustrated guide to the dromedary camel including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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camellia

any oriental evergreen shrub with roselike flowers belonging to the tea family. Many species, including *Camellia japonica* and *C. reticulata*, have been introduced into Europe, the USA, and Australia; they are widely cultivated as ornamental shrubs. (Genus *Camellia*, family Theaceae.)

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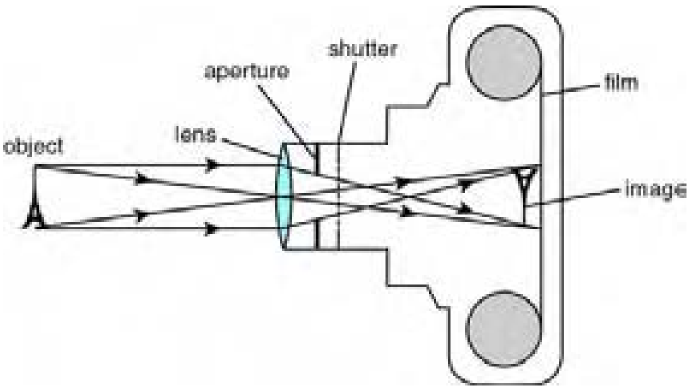
camera

apparatus used in photography, consisting of a lens system set in a light-proof box inside of which a sensitized film or plate can be placed. The lens collects rays of light reflected from the subject and brings them together as a sharp image on the film. The opening or hole at the front of the camera, through which light enters, is called an aperture. The aperture size controls the amount of light that can enter. A shutter controls the amount of time light has to affect the film. There are small-, medium-, and large-format cameras; the format refers to the size of recorded image and the dimensions of the image obtained.

A simple camera has a fixed shutter speed and aperture, chosen so that on a sunny day the correct amount of light is admitted. More complex cameras allow the shutter speed and aperture to be adjusted; most have a built-in exposure meter to help choose the correct combination of shutter speed and aperture for the ambient conditions and subject matter. The most versatile camera is the single lens reflex (SLR) which allows the lens to be removed and special lenses attached. A pin-hole camera has a small (pin-sized) hole instead of a lens. It must be left on a firm support during exposures, which are up to ten seconds with slow film, two seconds with fast film and five minutes for paper negatives in daylight. The pin-hole camera gives sharp images from close-up to infinity.

camera



(Image © Research Machines plc)

The basic parts of a camera. The film is only exposed to light when the shutter is opened to take a photograph and then the aperture controls the amount of light entering the camera. The lens position is adjustable so that objects at varying distances can be brought into focus. The rays of light reflected from the object are brought together by the lens and form a sharp inverted image on the film.

Cameras: The Technology of Photographic Imaging

Go to site

General presentation of the camera collection at the Museum of the History of Science, Oxford, UK. Of the many highlights, perhaps the most distinguished are some very early photographs, the photographic works of Sarah A Acland, and the cameras of T E Lawrence.

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camera obscura

('dark room')

darkened box with a tiny hole for projecting the inverted image of the scene outside on to a screen inside. For its development as a device for producing photographs, see photography.

Cameron, Julia Margaret (1815-1879)

born Julia Margaret Pattle

British photographer. She made lively and dramatic portraits of the Victorian intelligentsia, often posed as historical or literary figures. Her sitters included her friends the English astronomer Sir John Herschel, the poet Alfred Lord Tennyson, whose *Idylls of the King* she illustrated in 1872, and Charles Darwin. She used a large camera, five-minute exposures, and wet plates.

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camouflage

colours or structures that allow an animal to blend with its surroundings to avoid detection by other animals. Camouflage can take the form of matching the background colour, of countershading (darker on top, lighter below, to counteract natural shadows), or of irregular patterns that break up the outline of the animal's body. More elaborate camouflage involves closely resembling a feature of the natural environment, as with the stick insect; this is closely akin to mimicry. Camouflage is also important as a military technique, disguising either equipment, troops, or a position in order to conceal them from an enemy.

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camphor

$C_{10}H_{16}O$

volatile, fragrant, ketone substance obtained from the camphor tree *Cinnamomum camphora*. It is distilled from chips of the wood, and is used in insect repellents and medicinal inhalants and liniments, and in the manufacture of celluloid.

The camphor tree, a member of the family Lauraceae, is native to China, Taiwan, and Japan.

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campion

several plants of the genera *Lychnis* and *Silene*, belonging to the pink family (Caryophyllaceae), which include the garden campion *L. coronaria*, introduced from Europe, and the catchflies (genus *Silene*) of eastern North America.

Campylobacter

genus of bacteria that cause serious outbreaks of gastroenteritis. The bacteria grow best at 43°C, and so are well suited to the digestive tract of birds. Poultry is therefore the most likely source of a *Campylobacter* outbreak, although the bacteria can also be transmitted via beef or milk. *Campylobacter* can survive in water for up to 15 days, so may be present in drinking water if supplies are contaminated by sewage or reservoirs are polluted by seagulls.

Childhood Infections - Campylobacter Infections

Go to site

Useful information about campylobacter infections. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

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canal

artificial waterway constructed for drainage, irrigation, or navigation.
Irrigation canals carry water for irrigation from rivers, reservoirs, or wells, and are designed to maintain an even flow of water over the whole length.
Navigation and ship canals are constructed at one level between locks, and frequently link with rivers or sea inlets to form a waterway system. The Suez Canal in 1869 and the Panama Canal in 1914 eliminated long trips around continents and dramatically shortened shipping routes.

irrigation canals

The River Nile has fed canals to maintain life in Egypt since the earliest times. The division of the waters of the Upper Indus and its tributaries, which form an extensive system in Pakistan and Punjab, India, was, for more than ten years, a major cause of dispute between India and Pakistan, settled by a treaty in 1960. The Murray basin, Victoria, Australia, and the Imperial and Central Valley projects in California, USA, are examples of 19th- and 20th-century irrigation-canal development. Excessive extraction of water for irrigation from rivers and lakes can cause environmental damage.

ship canals

Probably the oldest ship canal to be still in use, as well as the longest, is the Grand Canal in China, which links Tianjin and Hangzhou and connects the Huang He (Yellow River) and Chang Jiang. It was originally built in three stages: the first was finished around 486 BC, the second (linking the Chang Jiang and Huang He) was constructed from 605 to 610, and the third between 1282 and 1292. It reaches a total length of approximately 1,600 km/1,000 mi. Large sections silted up in later years, but the entire system was dredged, widened, and rebuilt between 1958 and 1964 in conjunction with work on flood protection, irrigation, and hydroelectric schemes. It carries millions of tonnes of freight every year.

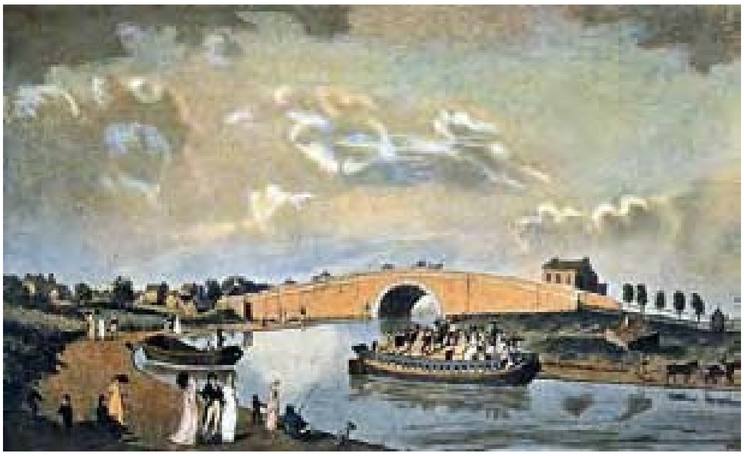
Where speed is not a prime factor, the cost-effectiveness of transporting goods by canal has encouraged a revival; Belgium, France, Germany, and the states of the former USSR are among countries that have extended and streamlined their canals. The Baltic-Volga waterway links the Lithuanian port of Klaipeda with Kahovka, at the mouth of the Dnieper on the Black Sea, a distance of 2,430 km/1,510 mi. A further canal cuts across northern Crimea, thus shortening the voyage of ships from the Dnieper through the Black Sea to the Sea of Azov. In Central America, the Panama Canal (1904-14) links the Atlantic and Pacific oceans (64 km/40 mi). In North America, the Erie Canal (1825) links the Great Lakes with the Hudson River and opened up the northeast and Midwest to commerce; the St Lawrence Seaway (1954-59) extends from Montréal to Lake Ontario (290 km/180 mi) and, with the deepening of the Welland Ship Canal and some of the river channels, provides a waterway that enables ocean-going vessels to travel (during the ice-free months) between the Atlantic and Duluth, Minnesota, USA, at the western end of Lake Superior, some 3,770 km/2,342 mi.

canal

(Image © Research Machines plc)

A canal flowing smoothly through Dublin, Republic of Ireland. The Grand Canal and the Royal Canal encircle the older part of the city.

canal



(Image © Philip Sauvain Picture Collection)

View of the Paddington Canal, London, a stretch of the Grand Junction Canal. The Grand Junction, which extended from Paddington to Uxbridge, opened in 1801 at the height of the canal-building boom.

Major navigation canals and waterways of the world

Canal	Route	Year opened	Length	
			km	mi
Karakum Canal, Turkmenistan	Caspian Sea inland	1954-81	1,100	683
Volga-Baltic, Russia	River Volga to Baltic Sea	1964	850	528
New York State Barge Canal (Erie Canal), USA	Lake Erie to Hudson River	1918	873	520
Rajasthan Canal, India	River Indus (Punjab) to Myajlan	1955	649	403
St Lawrence Seaway, Canada-USA[1]	Montreal to Lake Ontario	1959	304	189
Main-Danube Canal, Germany	Main River (Bamberg) to Danube River	1992	171	106
Suez Canal, Egypt	Mediterranean Sea to Red Sea	1869	162	101
Albert Canal, Belgium	River Meuse (Maes) to River Scheld	1939	129	80
Volga-Don, Russia	River Volga to Black Sea	1952	101	63
Kiel Canal, Germany	North Sea to Baltic Sea	1895	99	62
Alfonso XIII Canal, Spain	Seville to Gulf of Cadiz	1926	85	53
Panama Canal, Panama	Pacific Ocean to Caribbean Sea	1914	81	50
Sabine-Neches Waterway, USA[2]	Beaumont to Gulf of Mexico	1916	72	45
Houston Ship Canal, USA	Houston to Gulf of Mexico	1914	69	43
Manchester Ship Canal, UK	Manchester to Mersey estuary	1894	58	36

Welland Canal, Canada	Lake Ontario to Lake Erie	1933	44	28
North Sea Canal (Noordzeekanaal), Netherlands	Amsterdam to Ijmuiden on the North Sea	1876	27	17
Chesapeake and Delaware Canal, USA	Chesapeake Bay to Delaware River	1829	22	14

[1] The canalized section of the St Lawrence Seaway enables shipping to sail 3,769 km/2,342 mi from the North Atlantic up the St Lawrence estuary and through the Great Lakes to Duluth (MN).

[2] This is part of a series of artificial and natural channels, collectively called the Gulf Intercoastal Waterway with a total length of 1,770 km/1,100 mi, providing a discontinuous navigation, linking the Texan Gulf coast ports with the Mississippi Delta and Florida.

British Waterways

Go to site

Information about the canal system and boating holidays in Britain. The development of the canal system in the UK, and details of waterway traditions, are also discussed.

Canaries current

cold ocean current in the North Atlantic Ocean flowing southwest from Spain along the northwest coast of Africa. It meets the northern equatorial current at a latitude of 20° N.

canary

bird (*Serinus canaria*) of the finch family Fringillidae, found wild in the Canary Islands and Madeira. In its wild state the plumage is green, sometimes streaked with brown. The wild canary builds its nest of moss, feathers, and hair in thick high shrubs or trees, and produces two to four broods in a season.

Canaries have been bred as cage birds in Europe since the 15th century, and many domestic varieties are yellow or orange as a result of artificial selection.

Some canaries were used in mines as detectors of traces of poison gas in the air.

Canary FAQ

Go to site

Answers to frequently asked questions about canaries provide a wealth of information on all breeds of these cage birds. Every conceivable aspect of caring for canaries is covered and there are useful links to other canary sites.

cancel

in mathematics, to simplify a fraction or ratio by dividing both numerator and denominator by the same number (which must be a common factor of both of them). For example, $5x/25$ cancels to $x/5$ when divided top and bottom by five.

cancer

group of diseases characterized by abnormal proliferation of cells. Cancer (malignant) cells are usually degenerate, capable only of reproducing themselves (tumour formation). Malignant cells tend to spread from their site of origin by travelling through the bloodstream or lymphatic system. Cancer kills about 6 million people a year worldwide.

causes

There are more than 100 types of cancer. Some, such as lung or bowel cancer, are common; others are rare. The likely causes remain unexplained. Triggering agents (carcinogens) include chemicals such as those found in cigarette smoke, other forms of smoke, asbestos dust, vehicle exhaust fumes, and many industrial chemicals. Some viruses can also trigger the cancerous growth of cells (see oncogene), as can X-rays and radioactivity. Dietary factors are important in some cancers; for example, lack of fibre in the diet may predispose people to bowel cancer and a diet high in animal fats and low in fresh vegetables and fruit can increase the risk of breast cancer. Psychological stress may also increase the risk of cancer, more so if the person concerned is not able to control the source of the stress.

cancer genes

In some families there is a genetic tendency towards a particular type of cancer. In 1993 researchers isolated the first gene that predisposes individuals to cancer. About 1 in 200 people in the West carry the gene. If the gene mutates, those with the altered gene have a 70% chance of developing colon cancer, and female carriers have a 50% chance of developing cancer of the uterus.

Cancer: The Discovery of Oncogenes

research

Whatever its cause, a cancer takes several years to develop. The event or change in the living cell responsible may be triggered by ionizing radiation, a carcinogenic chemical, or a virus. But between this event and the appearance of the cancer cells forming a tumour, the tissue involved will have renewed itself several times over. So the question that struck cancer researchers was: how did the cancer cell perpetuate itself?

looking within the genes

It seemed likely that there must be some clue in the genes – within the DNA (deoxyribonucleic acid) of a cancer cell. The chromosomes, which are the gene carriers of the cell, should show characteristic abnormalities in some cancers. Towards the end of the 1970s, three separate teams of US researchers undertook a series of experiments to verify this hypothesis: Robert Weinberg of the Center for Cancer Research, a branch of the Massachusetts Institute of Technology; Geoffrey Cooper of the Sydney Forbes Cancer Institute of Boston; and Michael Wigler of the Cold Springs Laboratory on Long Island. They took the DNA from human cancer cells and, using cultured mouse cells (tissue culture), grafted the DNA onto them. Some of the cultured cells became cancerous and these were isolated.

The DNA from these cells was extracted, and reduced selectively into fragments with restriction enzymes. The scientists again found that some of the cultured cells became cancerous when the DNA fragments were grafted to them. By repeating these procedures, it became clear that a particular segment of human DNA could be linked to cancer. But how and why?

oncogene

One cancer-causing gene (oncogene) was isolated and analysed nucleotide by nucleotide, and an unusual sequence of bases (the molecules that define the genetic code) was discovered. The oncogene concerned caused cancer of the bladder. It was found to comprise 930 bases and had only one small difference from the normal gene: at one point a single base was out of position. This one difference in the gene was enough to cause cancer. For the first time, a genetic change leading to cancer had been identified.

The discovery of oncogenes cannot be presented as the only key to cancer, but full understanding of how oncogene activity leads to abnormal cell growth may well lead to new therapies.

Breast Cancer Awareness

Go to site

Promotes awareness of this disease through a library of frequently asked questions about breast cancer and mammograms, as well as a glossary of common terms and access to support groups. There is also information about fundraising activities and recipients of awards for people and groups seen to be contributing the most to the fight against this disease. The Web site is sponsored by the make-up company Avon.

Cancer Research UK

Go to site

Offers an introduction to the types and causes of cancer, and the research that is being carried out and that is still needed to provide effective treatment for the different kinds of cancer.

Cancer: The Facts

Go to site

Information on cancer from the Cancer Research UK, with a simple explanation of what cancer is. The 'specific cancers' link on the accompanying menu bar takes the viewer to information on the different types of cancer – bowel, leukaemia, lung, pancreatic, skin, and multiple myeloma cancers, as well as cancers specific to either men or women, or prevalent within families. There are also links to cancer statistics.

OncoLink – The University of Pennsylvania Cancer Centre Resource

Go to site

As the title of this page says, a broad resource of cancer-related information for sufferers and their families. It includes sections on 'Causes, screening, and prevention', 'Clinical trials', and 'Conferences and meetings'.

Cancer

faintest of the zodiacal constellations (its brightest stars are fourth magnitude). It lies in the northern hemisphere between Leo and Gemini, and is represented as a crab. The Sun passes through the constellation during late July and early August. In astrology, the dates for Cancer are between about 22 June and 22 July (see precession).

Cancer's most distinctive feature is the open star cluster Praesepe, popularly known as the Beehive, visible to the naked eye as a nebulous patch.

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candela

symbol cd

SI unit of luminous intensity, which replaced the former units of candle and standard candle. It measures the brightness of a light itself rather than the amount of light falling on an object, which is called **illuminance** and measured in lux.

One candela is defined as the luminous intensity in a given direction of a source that emits monochromatic radiation of frequency 540 × 10^{-12} Hz and whose radiant energy in that direction is 1/683 watt per steradian.

Candida albicans

yeastlike fungus present in the human digestive tract and in the vagina, which causes no harm in most healthy people. However, it can cause problems if it multiplies excessively, as in vaginal candidiasis or thrush, the main symptom of which is intense itching.

The most common form of thrush is oral, which often occurs in those taking steroids or prolonged courses of antibiotics.

Newborn babies may pick up the yeast during birth and suffer an infection of the mouth and throat. There is also some evidence that overgrowth of *Candida* may occur in the intestines, causing diarrhoea, bloating, and other symptoms such as headache and fatigue, but this is not yet proven. Occasionally, *Candida* can infect immunocompromised patients, such as those with AIDS. Treatment for candidiasis is based on antifungal drugs.

candidiasis

in medicine, infections due to the fungus *Candida albicans*.

candy

confectionery made mainly from sucrose sugar. Other ingredients include glucose, milk, nuts, fat (animal and vegetable), and fruit. Boiled-sugar candy contains sugar, glucose, color, and flavoring, and is boiled, cooled, and shaped.
Chewing gum consists of synthetic or vegetable gum with color, flavoring, and sometimes sweetener added. **Toffee** and **caramel** are made from sugar, glucose, animal fat, milk, and cream or vegetable fat, heated and shaped. The USA is the biggest producer of candy, though the UK has the highest consumption, with millions of pounds spent each year on advertising.

cane

reedlike stem of various plants such as the sugar cane, bamboo, and, in particular, the group of palms called rattans, consisting of the genus *Calamus* and its allies. Their slender stems are dried and used for making walking sticks, baskets, and furniture.

Canes Venatici

constellation of the northern hemisphere near Ursa Major, identified with the hunting dogs of Boötes, the herder. Its stars are faint. However, it contains the spectacular Whirlpool galaxy (M51), the first spiral galaxy to be recognized.

The constellation contains many other objects of telescopic interest, including the relatively bright globular cluster M3. The brightest star, a third magnitude double, is called Cor Caroli or Alpha Canum Venaticorum.

cane toad

toad of the genus *Bufo marinus*, family Bufonidae. Also known as the giant or marine toad, the cane toad is the largest in the world. It acquired its name after being introduced to Australia from South America in 1935 to eradicate the cane beetle, which had become a serious pest there. However, having few natural enemies, the cane toad itself has now become a pest in Australia.

The cane toad's defence system consists of highly developed glands on each side of its neck which can squirt a poisonous fluid to a distance of around 1 m/3.3 ft.

Cane Toad

Go to site

Profile of the world's largest toad, its unwise introduction to Australia, and the damage it has wrought.
It includes photographs and a complete bibliography of books and articles written about *Bufo marinus*. Linked is a detailed information leaflet, with a background to the amphibian's diet, behaviour and breeding cycle, and its venom which is capable of killing a small animal within 15 minutes of the animals making contact.

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canine

in mammalian carnivores, any of the long, often pointed teeth found at the front of the mouth between the incisors and premolars. Canine teeth are used for catching prey, for killing, and for tearing flesh. They are absent in herbivores such as rabbits and sheep, and are much reduced in humans.

Canis Major

brilliant constellation of the southern hemisphere, represented (with Canis Minor) as one of the two dogs following at the heel of Orion. Its main star, Sirius, is the brightest star in the night sky.

Epsilon Canis Majoris is also of the first magnitude, and there are three second magnitude stars.

Canis Minor

small constellation along the celestial equator (see celestial sphere), represented as the smaller of the two dogs of Orion (the other dog being Canis Major). Its brightest star is the first magnitude Procyon.

Procyon and Beta Canis Minoris form what the Arabs called 'the Short Cubit', in contrast to 'the Long Cubit' formed by Castor and Pollux (Alpha and Beta Geminorum).

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canning

food preservation in hermetically sealed containers by the application of heat. Originated by Nicolas Appert in France in 1809 with glass containers, it was developed by Peter Durand in England in 1810 with cans made of sheet steel thinly coated with tin to delay corrosion. Cans for beer and soft drinks are now generally made of aluminium.

Canneries were established in the USA before 1820, but the US canning industry expanded considerably in the 1870s when the manufacture of cans was mechanized and factory methods of processing were used. The quality and taste of early canned food was frequently inferior but by the end of the 19th century, scientific research made greater understanding possible of the food-preserving process, and standards improved. More than half the aluminium cans used in the USA are now recycled.

Cannizzaro, Stanislao (1826-1910)

Italian chemist who revived interest in the work of Avogadro that had, in 1811, revealed the difference between atoms and molecules, and so established atomic and molecular weights as the basis of chemical calculations.

Cannizzaro also worked in aromatic organic chemistry. In 1853 he discovered reactions (named after him) that make benzyl alcohol and benzoic acid from benzaldehyde.

Cannon, Annie Jump (1863-1941)

US astronomer. She carried out revolutionary work on the classification of stars by examining their spectra. Her system, still used today, has spectra arranged according to temperature into categories labelled O, B, A, F, G, K, M, R, N, and S. O-type stars are the hottest, with surface temperatures ranging from 25,000 to 50,000 K (from 24,700°C/44,450°F to 49,700°C/89,500°F).

Studying photographs of the spectra of stars, Cannon discovered 300 new variable stars. In 1901 she published a catalogue of the spectra of more than 1,000 stars, using her new classification system. She went on to classify the spectra of over 300,000 stars. Most of this work was published in a ten-volume set which was completed 1924. It described almost all stars with magnitudes greater than nine. Her later work included classification of the spectra of even fainter stars.

Canopus

or Alpha Carinae

second-brightest star in the night sky (after Sirius), with magnitude -0.7, lying in the southern constellation Carina. It is a yellow-white supergiant about 100 light years from the Sun, and thousands of times more luminous than the Sun.

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cantilever

beam or structure that is fixed at one end only, though it may be supported at some point along its length;

for example, a diving board. The cantilever principle, widely used in construction engineering, eliminates the need for a second main support at the free end of the beam, allowing for more elegant structures and reducing the amount of materials required. Many large-span bridges have been built on the cantilever principle.

A typical cantilever bridge consists of two beams cantilevered out from either bank, each supported part way along, with their free ends meeting in the middle. The multiple-cantilever Forth Rail Bridge (completed 1890) across the Firth of Forth in Scotland has twin main spans of 521 m/1,710 ft.

Cantor, Georg Ferdinand Ludwig Philipp (1845-1918)

German mathematician who followed his work on number theory and trigonometry by considering the foundations of mathematics. He defined real numbers and produced a treatment of irrational numbers using a series of transfinite numbers. Cantor's set theory has been used in the development of topology and real function theory.

Cantor, Georg Ferdinand Ludwig Philipp

Go to site

Site devoted to the life and work of the German mathematician Georg Cantor. There are links to people who influenced him, including Weierstrass, Kummer and Kronecker. Click to find out about his work on set theory and topology, and to view reference material.

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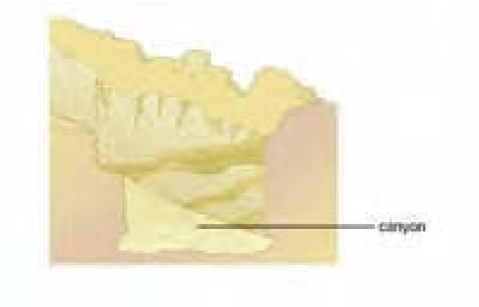
canyon

(Spanish cañon 'tube')

deep, narrow valley or gorge running through mountains. Canyons are formed by stream down-cutting, usually in arid areas, where the rate of down-cutting is greater than the rate of weathering, and where the stream or river receives water from outside the area.

There are many canyons in the western USA and in Mexico, for example the Grand Canyon of the Colorado River in Arizona, the canyon in Yellowstone National Park, and the Black Canyon in Colorado.

canyon



(Image © Research Machines plc)

Cross section of a canyon. Canyons are formed in dry regions where rivers maintain a constant flow of water over long periods of time. The Grand Canyon, for example, was first cut around 26 million years ago, in Miocene times.

CAP

abbreviation for Common Agricultural Policy.

Capa, Robert (1913-1954)

adopted name of André Friedmann

US photographer, born in Hungary. He specialized in war photography. He covered the Spanish Civil War as a freelance and World War II for *Life* and *Collier's* magazines. His pictures emphasize the human tragedy of war. He was a founder member of the Magnum photographic agency. He died while on an assignment in Vietnam.

Requiem - Robert Capa

Go to site

Tribute to the war photographer. It features the last pictures taken by Capa moments before stepping on the land mine in Vietnam which killed him. A fellow photojournalist describes what it was about Capa that inspired his colleagues.

capacitance, electrical

property of a capacitor that determines how much charge can be stored in it for a given potential difference between its terminals. It is equal to the ratio of the electrical charge stored to the potential difference. The SI unit of capacitance is the farad, but most capacitors have much smaller capacitances, and the microfarad (a millionth of a farad) is the commonly used practical unit.

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capacitor

or condenser

device for storing electric charge, used in electronic circuits; it consists of two or more metal plates separated by an insulating layer called a dielectric (see capacitance).

Its **capacitance** is the ratio of the charge stored on either plate to the potential difference between the plates.

Cape Canaveral

formerly Cape Kennedy (1963-73)

rocket launch site used by NASA, a promontory on the Atlantic coast of Florida, 367 km/228 mi north of Miami. The Kennedy Space Center is nearby.

In the 50 years since the first rocket launch from Cape Canaveral, in July 1950, over 3,000 missiles and rockets were launched from the site. These included lift-offs to the Moon during the *Apollo* project, for which a new launch complex was constructed on 324 sq km/126 sq mi of land, doubling the size of the Cape Canaveral site.

Capella

or Alpha Aurigae

brightest star in the constellation Auriga and the sixth-brightest star in the night sky. It is a visual and spectroscopic binary that consists of a pair of yellow-giant stars 42 light years from the Sun, orbiting each other every 104 days.

Its Latin name means the 'the Little Nanny Goat': its kids are the three adjacent stars Epsilon, Eta, and Zeta Aurigae.

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caper

trailing shrub native to the Mediterranean. Its flower buds are preserved in vinegar as a condiment. (*Capparis spinosa*, family Capparidaceae.)

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capercaillie

or wood-grouse or cock of the wood

(Scottish Gaelic capull coille 'cock of the wood')

large bird *Tetrao uroqallus* of the grouse type, family Tetraonidae, order Galliformes. Found in coniferous woodland in Europe and northern Asia, it is about the size of the turkey and resembles the blackcock in appearance and polygamous habit. The general colour of the male is blackish-grey above, black below, with a dark green chest, and rounded tail which is fanned out in courtship. The female is smaller, mottled, and has a reddish breast barred with black. The feathers on the legs and feet are longest in winter time, and the toes are naked. The capercaillie feeds on insects, worms, berries, and young pine-shoots. At nearly 1 m/3 ft long, the male is the biggest gamebird in Europe. The female is about 60 cm/2 ft long.

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capillarity

spontaneous movement of liquids up or down narrow tubes, or capillaries. The movement is due to unbalanced molecular attraction at the boundary between the liquid and the tube. If liquid molecules near the boundary are more strongly attracted to molecules in the material of the tube than to other nearby liquid molecules, the liquid will rise in the tube. If liquid molecules are less attracted to the material of the tube than to other liquid molecules, the liquid will fall.

capillarity

To remember the principles of capillary action:

Water rises to the tops of plants by **c**apillary **a**ction (CA), which depends upon **c**ohesive and **a**dhesive (C +A) properties of water

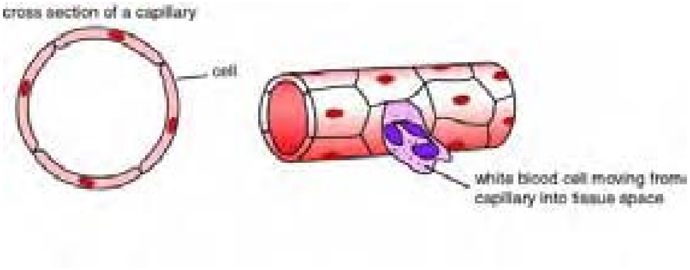
---

capillary

in biology, narrowest blood vessel in vertebrates measuring 0.008-0.02 mm in diameter, barely wider than a red blood cell. Capillaries are distributed as **beds**, complex networks connecting arteries and veins. The function of capillaries is to exchange materials with their surroundings. For this reason, capillary walls are extremely thin, consisting of a single layer of cells through which nutrients, dissolved gases, and waste products can easily pass. This makes the capillaries the main area of exchange between the fluid (lymph) bathing body tissues and the blood. They provide a large surface area in order to maximize diffusion.

All body cells lie close to capillaries so they can receive the food and oxygen they require from the capillaries. Networks of capillaries are especially extensive in certain parts of the body. For example, in the lungs they surround the air sacs (alveoli), taking up oxygen and releasing carbon dioxide. They are also found in the lining of the gut - in little finger-like projections called villi - where they absorb the products of the digestion of food.

capillary


cross section of a capillary
cell
white blood cell moving from capillary into tissue space

(Image © Research Machines plc)

The structure of a blood capillary. Capillaries are only one cell thick and white blood cells, which can move independently of the other blood components, can squeeze through them into tissue spaces.

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capillary

in physics, a very narrow, thick-walled tube, usually made of glass, such as in a thermometer. Properties of fluids, such as surface tension and viscosity, can be studied using capillary tubes.

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capitulum

in botany, a flattened or rounded head (inflorescence) of numerous, small, stalkless flowers. The capitulum is surrounded by a circlet of petal-like bracts and has the appearance of a large, single flower.

Capricornus

zodiacal constellation in the southern hemisphere next to Sagittarius. It is represented as a sea-goat, and its brightest stars are third magnitude. The Sun passes through it from late January to mid-February. In astrology, the dates for Capricornus (popularly known as Capricorn) are between about 22 December and 19 January (see precession).

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capsicum

any of a group of pepper plants belonging to the nightshade family, native to Central and South America. The different species produce green to red fruits that vary in size. The small ones are used whole to give the hot flavour of chilli, or ground to produce cayenne or red pepper; the large pointed or squarish pods, known as sweet peppers or pimientos (green, red, or yellow peppers), are mild-flavoured and used as a vegetable. (Genus *Capsicum*, family Solanaceae.)

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capsule

in botany, a dry, usually many-seeded fruit formed from an ovary composed of two or more fused carpels, which splits open to release the seeds. The same term is used for the spore-containing structure of mosses and liverworts; this is borne at the top of a long stalk or seta.

Capsules burst open (dehisce) in various ways, including lengthwise, by a transverse lid - for example, scarlet pimpernel *Anagallis arvensis* – or by a number of pores, either towards the top of the capsule, as in the poppy *Papaver*, or near the base, as in certain species of bellflower *Campanula*.

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captured rotation

or synchronous rotation

in astronomy, circumstance in which one body in orbit around another, such as the moon of a planet, rotates on its axis in the same time as it takes to complete one orbit. As a result, the orbiting body keeps one face permanently turned towards the body about which it is orbiting. An example is the rotation of our own Moon, which arises because of the tidal effects of the Earth over a long period of time.

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capuchin

monkey of the genus *Cebus* found in Central and South America, so called because the hairs on the head resemble the cowl of a Capuchin monk. Capuchins live in small groups, feed on fruit and insects, and have a long tail that is semiprehensile and can give support when climbing through the trees.

There are now thought to be only 800 yellow-breasted capuchins left in the wild, found only in the Atlantic forest in Bahía state, Brazil.

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capybara

world's largest rodent *Hydrochoerus hydrochaeris*, up to 1.3 m/4 ft long and 50 kg/110 lb in weight. It is found in South America, and belongs to the guinea-pig family. The capybara inhabits marshes and dense vegetation around water. It has thin, yellowish hair, swims well, and can rest underwater with just eyes, ears, and nose above the surface.

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caracal

cat *Felis caracal* related to the lynx. It has long black ear tufts, a short tail, and short reddish-fawn fur. It lives in bush and desert country in Africa, Arabia, and India, hunting birds and small mammals at night. Head and body length is about 75 cm/2.5 ft.

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carambola

small evergreen tree of Southeast Asia. The fruits, called **star fruit**, are yellowish, about 12 cm/4 in long, with a five-pointed star-shaped cross-section. They can be eaten raw, cooked, or pickled, and are juicily acidic. The juice is also used to remove stains from hands and clothes. (*Averrhoa carambola*, family Averrhoaceae.)

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carapace

protective covering of many animals, particularly the arched bony plate characteristic of the order Chelonia (tortoises, terrapins, and turtles), and the shield that protects the fore parts of crustaceans, such as crabs.

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carat

unit for measuring the mass of precious stones, derived from the Arabic word *quirrat*, meaning 'seed'. Originally, 1 carat was the weight of a carob seed; it is now taken as 0.00705 oz/0.2 g, and is part of the troy system of weights. Also, an alternative spelling of karat.

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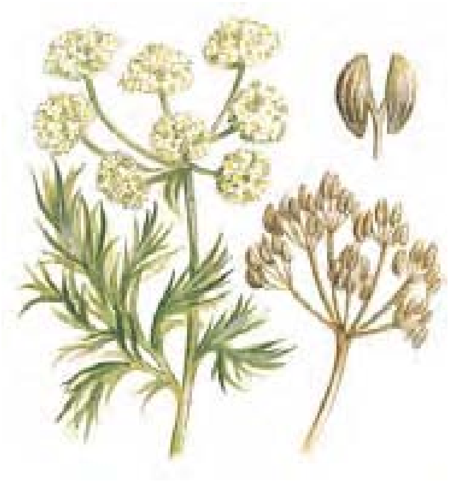
caraway

herb belonging to the carrot family. Native to northern temperate regions of Europe and Asia, it is grown for its spicy, aromatic seeds, which are used in cookery, medicine, and perfumery. (*Carum carvi*, family Umbelliferae.)

caraway



(Image © Research Machines plc)

The caraway is a member of the parsley family and closely related to fennel and dill. It grows up to 60 cm/2 ft high and is cultivated in many parts of Europe and the USA. Caraway seeds are small, oval, and ribbed.

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carbide

compound of carbon and one other chemical element, usually a metal, silicon, or boron.

Calcium carbide (CaC_2) can be used as the starting material for many basic organic chemical syntheses, by the addition of water and generation of ethyne (acetylene). Some metallic carbides are used in engineering because of their extreme hardness and strength. Tungsten carbide is an essential ingredient of carbide tools and high-speed tools. The 'carbide process' was used during World War II to make organic chemicals from coal rather than from oil.

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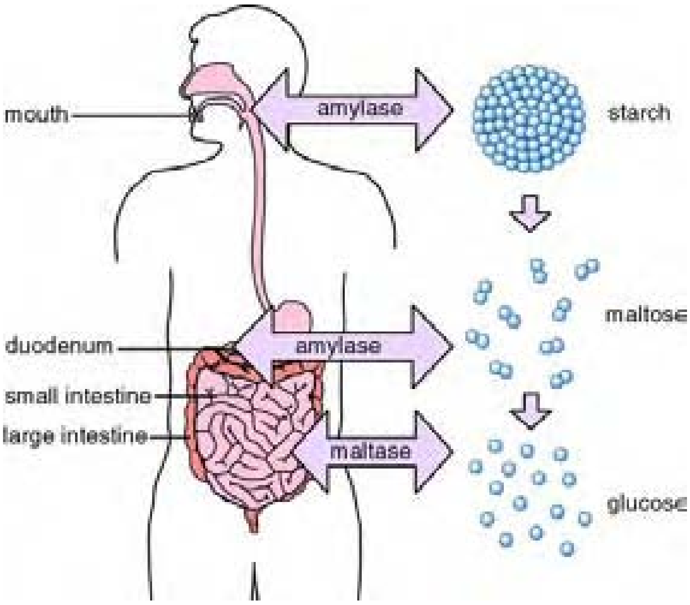
carbohydrate

chemical compounds composed of carbon, hydrogen, and oxygen, with the basic formula $C_m(H_2O)_n$, and related compounds with the same basic structure but modified functional groups. They are important to living organisms and, as sugar and starch, are an important part of a balanced human diet, providing energy for life processes including growth and movement. Excess carbohydrate intake can be converted into fat and stored in the body.

The simplest carbohydrates are sugars (**monosaccharides**, such as glucose and fructose, and **disaccharides**, such as sucrose), which are soluble compounds, some with a sweet taste. When these basic sugar units are joined together in long chains or branching structures they form **polysaccharides**, such as starch and glycogen.

The simple sugar called glucose is used in living organisms in respiration to release energy that can be used for life processes. The sugar we use to sweeten foods is a complex sugar called sucrose. Starch is used by plants as a way of storing energy-rich food, and animals that eat plants take advantage of this. It is a common part of the human diet because it is major constituent of wheat, rice, potatoes, and maize. Humans use a carbohydrate called glycogen as an energy store. This is also made from glucose. It is stored in the liver and muscles and can be broken down to supply body cells with glucose. The hormone insulin regulates this process, causing glucose to be taken in the bloodstream to the liver to be converted to glycogen.

carbohydrate



(Image © Research Machines plc)

The digestion of carbohydrate. The complex polysaccharide starch is broken down into glucose by the enzymes amylase and maltase (secreted by the small intestine).

carbolic acid

common name for the aromatic compound phenol.

carbon

chemical symbol C

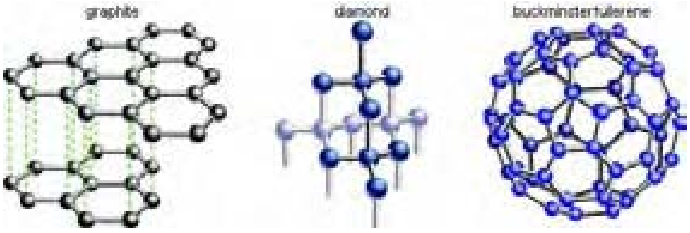
(Latin carbo, carbonaris 'coal')

non-metallic element, atomic number 6, relative atomic mass 12.011. It occurs on its own as diamond, graphite, and as fullerenes (the allotropes), as compounds in carbonaceous rocks such as chalk and limestone, as carbon dioxide in the atmosphere, as hydrocarbons in petroleum, coal, and natural gas, and as a constituent of all organic substances.

In its amorphous form, it is familiar as coal, charcoal, and soot. The atoms of carbon can link with one another in rings or chains, giving rise to innumerable complex compounds. Of the inorganic carbon compounds, the chief ones are **carbon dioxide** (CO_2), a colourless gas formed when carbon is burned in an adequate supply of air; and **carbon monoxide** (CO), formed when carbon is oxidized in a limited supply of air. **Carbon disulphide** (CS_2) is a dense liquid with a sweetish odour when pure. Another group of compounds is the **carbon halides**, including carbon tetrachloride (tetrachloromethane, CCl_4).

When added to steel, carbon forms a wide range of alloys with useful properties. In pure form, it is used as a moderator in nuclear reactors; as colloidal graphite it is a good lubricant and, when deposited on a surface in a vacuum, reduces photoelectric and secondary emission of electrons. Carbon is used as a fuel in the form of coal or coke. The radioactive isotope carbon-14 (half-life 5,730 years) is used as a tracer in biological research and in radiocarbon dating. Analysis of interstellar dust has led to the discovery of discrete carbon molecules, each containing 60 carbon atoms. The C_{60} molecules have been named buckminsterfullerenes because of their structural similarity to the geodesic domes designed by US architect and engineer Richard Buckminster Fuller.

carbon



(Image © Research Machines plc)

Carbon has three allotropes: diamond, graphite, and the fullerenes. Diamond is strong because each carbon atom is linked to four other carbon atoms. Graphite is made up of layers that slide across one another (giving graphite its qualities as a lubricator); each layer is a giant molecule. In the fullerenes, the carbon atoms form spherical cages. Buckminsterfullerene (shown here) has 60 atoms. Other fullerenes, with 28, 32, 50, 70, and 76 carbon atoms, have also been identified.

Exploring the Material World: Three Classroom Teaching Modules

Go to site

Attractive presentation on materials, including an interactive tour of current research in the materials sciences. Choose a module to learn how graphite and diamonds can both be forms of the same element, about Kevlar (the material so strong it can stop bullets), and about the delicate chemical balance of marshes and wetlands.

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carbonate

CO_3^{2-}

ion formed when carbon dioxide dissolves in water; any salt formed by this ion and another chemical element, usually a metal.

Carbon dioxide (CO_2) dissolves sparingly in water (for example, when rain falls through the air) to form carbonic acid (H_2CO_3), which unites with various basic substances to form carbonates. Calcium carbonate ($CaCO_3$) (chalk, limestone, and marble) is one of the most abundant carbonates known, being a constituent of mollusc shells and the hard outer skeletons of crustaceans.

Carbonates give off carbon dioxide when heated or treated with dilute acids.

$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

$CaCo_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

The latter reaction is used as the laboratory test for the presence of the ion, as it gives an immediate effervescence, with the gas turning limewater (a solution of calcium hydroxide, $Ca(OH)_2$) milky.

See calcium carbonate.

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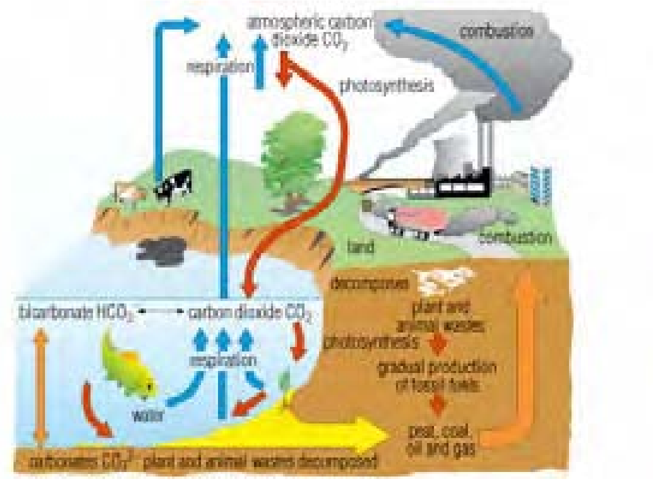
carbon cycle

sequence by which carbon circulates and is recycled through the natural world. Carbon is usually found in a carbon compound of one sort or another and so the carbon cycle is really about the cycling of carbon compounds. Carbon dioxide is released into the atmosphere by most living organisms as a result of respiration. The CO_2 is taken up and converted into high-energy chemicals – glucose and other carbohydrates – during photosynthesis by plants; the oxygen component is released back into the atmosphere. Some glucose is used by the plant and some is converted into other carbon compounds, making new tissues. However, some of these compounds can be transferred to other organisms. An animal may eat the plant and that animal may be eaten and so on down the food chain. Carbon is also released through the decomposition of dead plant and animal matter, and the burning of fossil fuels such as coal and oil, which produce carbon dioxide that is released into the atmosphere. The oceans absorb 25-40% of all carbon dioxide released into the atmosphere.

The carbon cycle is in danger of being disrupted by the increased burning of fossil fuels, and the destruction of large areas of tropical forests. The rising levels of carbon dioxide in the atmosphere are probably increasing the temperature on Earth (enhanced greenhouse effect). It is thought that by limiting the production of carbon dioxide through human activities we can slow the rate at which temperatures on Earth will rise.

carbon cycle



(Image © Research Machines plc)

The carbon cycle is necessary for the continuation of life. Since there is only a limited amount of carbon in the Earth and its atmosphere, carbon must be continuously recycled if life is to continue. Other chemicals necessary for life - nitrogen, sulphur, and phosphorus, for example - also circulate in natural cycles.

Carbon Cycle

Go to site

Part of a larger site 'Windows to the Universe', this site contains three levels of explanation of the carbon cycle. The site assumes you are an 'Intermediate' student but you can change this to 'Beginner' or 'Advanced'.

Chemical Carousel: A Trip Around the Carbon Cycle

Go to site

Captain Carbon invites you to explore the scientific process of the carbon cycle and explains the role of carbon in everyday life.

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carbon dating

alternative name for radiocarbon dating.

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carbon dioxide

CO_2

colourless, odourless gas, slightly soluble in water, and denser than air. It is formed by the complete oxidation of carbon. Carbon dioxide is produced by living things during the processes of respiration and the decomposition of organic matter, and it is used up during photosynthesis. It therefore plays a vital role in the carbon cycle.

Solid carbon dioxide is called dry ice, as it changes directly from a solid to a gas (sublimes) on warming. It is used as a coolant in its solid form and in the chemical industry.

Its increasing quantity in the atmosphere contributes to the greenhouse effect and global warming. Britain has 1% of the world's population, yet it produces 3% of CO_2 emissions; the USA has 5% of the world's population and produces 25% of CO_2 emissions. Annual releases of carbon dioxide reached 23 billion tonnes in 1997. According to a 1997 estimate by the World Energy Council, carbon dioxide emissions rose by 7.8% between 1986 and 1996.

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carbon fibre

fine, black, silky, continuous filament of pure carbon produced by heating organic fibres, such as cellulose, in an inert atmosphere, and used for reinforcing plastics, epoxy, and polyester resins. The resulting composite is very stiff and, weight for weight, has four times the strength of high-tensile steel. It is used in the aerospace industry, cars, and electrical and sports equipment.

Carboniferous period

period of geological time roughly 362.5 to 290 million years ago, the fifth period of the Palaeozoic Era. In the USA it is divided into two periods: the Mississippian (lower) and the Pennsylvanian (upper).

Typical of the lower-Carboniferous rocks are shallow-water limestones, while upper-Carboniferous rocks have delta deposits with coal (hence the name). Amphibians were abundant, and reptiles evolved during this period.

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carbon monoxide

CO

colourless, odourless gas formed when carbon is oxidized in a limited supply of air. It is a poisonous constituent of car exhaust fumes; it forms a stable compound with haemoglobin in the blood, thus preventing the haemoglobin from transporting oxygen to the body tissues.

In industry, carbon monoxide is used as a reducing agent in metallurgical processes - for example, in the extraction of iron in blast furnaces - and is a constituent of cheap fuels such as water gas. It burns in air with a luminous blue flame to form carbon dioxide:

$2CO + O_2 \rightarrow 2CO_2$

Carborundum

trademark for a very hard, black abrasive, consisting of silicon carbide (SiC), an artificial compound of carbon and silicon. It is harder than corundum but not as hard as diamond.

It was first produced in 1891 by US chemist Edward Acheson (1856-1931).

carboxyl group

-COOH

in organic chemistry, the acidic functional group that determines the properties of fatty acids (carboxylic acids) and amino acids.

carbuncle

in medicine, a collection of boils forming an abscess, caused by bacterial infection. It is usually treated with antibiotics.

carburation

any process involving chemical combination with carbon, especially the mixing or charging of a gas, such as air, with volatile compounds of carbon (petrol, kerosene, or fuel oil) in order to increase potential heat energy during combustion. Carburation applies to combustion in the cylinders of reciprocating petrol engines of the types used in aircraft, road vehicles, or marine vessels. The device by which the liquid fuel is atomized and mixed with air is called a **carburettor**.

carcinogen

any agent that increases the chance of a cell becoming cancerous (see cancer), including various chemical compounds, some viruses, X-rays, and other forms of ionizing radiation. The term is often used more narrowly to mean chemical carcinogens only.

carcinogenesis

in medicine, the means by which the changes responsible for the development of cancer are brought about.

carcinoma

malignant tumour arising from the skin, the glandular tissues, or the mucous membranes that line the gut and lungs.

cardinal number

in mathematics, one of the series of numbers 0, 1, 2, 3, 4, ... Cardinal numbers relate to quantity, whereas ordinal numbers (first, second, third, fourth, ⟩) relate to order.

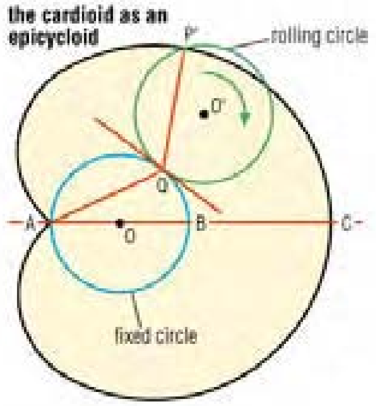
cardioid

heart-shaped curve traced out by a point on the circumference of a circle, resulting from the circle rolling around the edge of another circle of the same diameter.

The polar equation of the cardioid is of the form:

$r = a(1 + \cos \theta)$ where the polar coordinates of the point are (r, θ) and a is a constant.

cardioid



(Image © Research Machines plc)

The cardioid is the curve formed when one circle rolls around the edge of another circle of the same size. It is named after its heart shape.

caribou

the reindeer of North America.

caries

decay and disintegration, usually of the substance of teeth (cavity) or bone, caused by acids produced when the bacteria that live in the mouth break down sugars in the food. Fluoride, a low sugar intake, and regular brushing are all protective. Caries form mainly in the 45 minutes following consumption of sugary food.

Carina

constellation of the southern hemisphere, represented as a ship's keel. Its brightest star is Canopus, the second brightest in the night sky; it also contains Eta Carinae, a massive and highly luminous star embedded in a gas cloud, perhaps 8,000 light years away from the Sun.

Carina was formerly regarded as part of Argo, and is situated in one of the brightest parts of the Milky Way.

Carnac

site of prehistoric megaliths in Brittany, France, where remains of tombs and stone alignments of the period 2000 to 1500 BC (Neolithic and early Bronze Age) are found. Stones removed for local building have left some gaps in the alignments.

There are various groups of menhirs round the village of Carnac in the *département* of Morbihan, situated at Kermario (place of the dead), Kerlescan (place of burning), Erdeven, and St-Barbe. The largest of the stone alignments has 1,000 blocks of grey granite up to 4 m/13 ft high, extending over 2 km/1.2 mi. These menhirs (standing stones) are arranged in 11 parallel rows, with a circle at the western end.

Stone circles and alignments are thought to be associated with astronomical and religious ritual, and those at Carnac may possibly have been used for calculating the phases of the moon.

carnassial tooth

one of a powerful scissorlike pair of molars, found in all mammalian carnivores except seals. Carnassials are formed from an upper premolar and lower molar, and are shaped to produce a sharp cutting surface. Carnivores such as dogs transfer meat to the back of the mouth, where the carnassials slice up the food ready for swallowing.

carnation

any of a large number of double-flowered cultivated varieties of a plant belonging to the pink family. The flowers smell like cloves; they are divided into flake, bizarre, and picotees, according to whether the petals have one or more colours on their white base, have the colour appearing in strips, or have a coloured border to the petals. (*Dianthus caryophyllus*, family Carophyllaceae.)

carnauba

palm tree native to South America, especially Brazil. It produces fine timber and a hard wax, used for polishes and lipsticks. (*Copernicia cerifera*.)

carnivore

organism that eats other animals. In zoology, a mammal of the order Carnivora.

Carnivores have the greatest range of body size of any mammalian order, from the 100 g/3.5 oz weasel to the 800 kg/1,764 lb polar bear.

The characteristics of the Carnivora are sharp teeth, small incisors, a well-developed brain, a simple stomach, reduced or absent caecum, and incomplete or absent clavicles (collarbones); there are never less than four toes on each foot; the scaphoid and lunar bones are fused in the hand; and the claws are generally sharp and powerful.

Carnot, (Nicolas Léonard) Sadi (1796-1832)

French scientist and military engineer who founded the science of thermodynamics. His pioneering work was *Reflexions sur la puissance motrice du feu/On the Motive Power of Fire*, which considered the changes that would take place in an idealized, frictionless steam engine.

Carnot's theorem showed that the amount of work that an engine can produce depends only on the temperature difference that occurs in the engine. He described the maximum amount of heat convertible into work by the formula $(T_1 - T_2)/T_2$, where T_1 is the temperature of the hottest part of the machine and T_2 is the coldest part.

Carnot cycle

series of changes in the physical condition of a gas in a reversible heat engine, necessarily in the following order: (1) isothermal expansion (without change of temperature), (2) adiabatic expansion (without change of heat content), (3) isothermal compression, and (4) adiabatic compression.

The principles derived from a study of this cycle are important in the fundamentals of heat and thermodynamics.

carob

small Mediterranean tree belonging to the legume family. Its pods, 20 cm/8 in long, are used as an animal feed; they are also the source of a chocolate substitute. (*Ceratonia siliqua*, family Leguminosae.)

carotene

naturally occurring pigment of the carotenoid group. Carotenes produce the orange, yellow, and red colours of carrots, tomatoes, oranges, and crustaceans.

carotenoid

any of a group of yellow, orange, red, or brown pigments found in many living organisms, particularly in the chloroplasts of plants. There are two main types, the **carotenes** and the **xanthophylls**. Both types are long-chain lipids (fats).

Some carotenoids act as accessory pigments in photosynthesis, and in certain algae they are the principal light-absorbing pigments functioning more efficiently than chlorophyll in low-intensity light. Carotenoids can also occur in organs such as petals, roots, and fruits, giving them their characteristic colour, as in the yellow and orange petals of wallflowers *Cheiranthus*. They are also responsible for the autumn colours of leaves, persisting longer than the green chlorophyll, which masks them during the summer.

Carothers, Wallace Hume (1896-1937)

US chemist who carried out research into polymerization. He discovered that some polymers were fibre-forming, and in 1931 he produced neoprene, one of the first synthetic rubbers, and in 1935, nylon.

carotid artery

one of a pair of major blood vessels, one on each side of the neck, supplying blood to the head.

carp

fish *Cyprinus carpio* found all over the world. It commonly grows to 50 cm/1.8 ft and 3 kg/7 lb, but may be even larger. It lives in lakes, ponds, and slow rivers. The wild form is drab, but cultivated forms may be golden, or may have few large scales (mirror carp) or be scaleless (leather carp).
Koi carp are highly prized and can grow up to 1 m/3 ft long with a distinctive pink, red, white, or black colouring.

A large proportion of European freshwater fish belong to the carp family, Cyprinidae, and related fishes are found in Asia, Africa, and North America. The carp's fast growth, large size, and ability to live in still water with little oxygen have made it a good fish to farm, and it has been cultivated for hundreds of years and spread by human agency. Members of this family have a single non-spiny dorsal fin, pelvic fins well back on the body, and toothless jaws, although teeth in the throat form an efficient grinding apparatus. Minnows, roach, rudd, and many others, including goldfish, belong to this family. Chinese **grass carp** *Ctenopharyngodon idella* have been introduced (one sex only) to European rivers for weed control.

History of Koi Carp

Go to site

Origin and development of the Koi (Nishikigoi) carp in Japan, including the history of breeding them in captivity.

carpel

female reproductive unit in flowering plants (angiosperms). It usually comprises an ovary containing one or more ovules, the stalk or style, and a stigma at its top which receives the pollen. A flower may have one or more carpels, and they may be separate or fused together. Collectively the carpels of a flower are known as the gynoecium.

carpet beetle

small black or brown beetle. The larvae are covered with hairs and often known as **woolly bears**; they feed on carpets, fabrics, and hides causing damage.

The **common carpet beetle** *Anthrenus scrophularia* measures 3-4 mm/0.1-0.2 in long. It is oval, black, and has yellow scales on the shield (pronotum) and ginger red on the wing cases (elytra). This species prefers fabrics to carpets, and the larvae, which are brownish, hairy grubs, eat holes into fabrics or make slits in the carpet.

Larvae of *Anthrenus museorum* can do extensive damage to museum collections. Specimens of stuffed animals or entire insect collections, which have been inadequately treated prior to storage, can be destroyed.

classification

Carpet beetles are in the genus *Anthrenus* and *Attagenus* in the family Dermestidae of order Coleoptera, class Insecta, phylum Arthropoda.

carragheen

species of deep-reddish branched seaweed. Named after Carragheen, near Waterford, in the Republic of Ireland, it is found on rocky shores on both sides of the Atlantic. It is exploited commercially in food and medicines and as cattle feed. (*Chondrus crispus*.)

Carrel, Alexis (1873-1944)

French-born US surgeon who was awarded a Nobel Prize for Physiology or Medicine in 1912 for his work on the techniques for connecting severed blood vessels and for transplanting organs. Working at the Rockefeller Institute, New York City, he devised a way of joining blood vessels end to end (anastomosing). This was a key move in the development of transplant surgery, as was his work on keeping organs viable outside the body.

carrier

in medicine, anyone who harbours an infectious organism without ill effects but can pass the infection to others. The term is also applied to those who carry a recessive gene for a disease or defect without manifesting the condition.

carrot

hardy European biennial plant with feathery leaves and an orange tapering root that is eaten as a vegetable. It has been cultivated since the 16th century. The root has a high sugar content and also contains carotene, which is converted into vitamin A by the human liver. (*Daucus carota*, family Umbelliferae.)

Root Crops

Go to site

Informative guide to these vegetables from the Virginia Cooperative Extension. There is a guide to planting and fertilizing them, as well as the types of soil, sunlight, and moisture that yield best results. This site also features solutions to common problems and information about harvesting and storage.

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carrying capacity

in ecology, the maximum number of animals of a given species that a particular habitat can support. If the carrying capacity of an ecosystem is exceeded by overpopulation, there will be insufficient resources and one or more species will decline until an equilibrium, or balance of nature, is restored. Similarly, if the number of species in an environment is less than the carrying capacity, the population will tend to increase until it balances the available resources. Human interference frequently causes disruption to the carrying capacity of an area, for instance by the establishment of too many grazing animals on grassland, the over-culling of a species, or the introduction of a non-indigenous species into an area.

Carson, Rachel Louise (1907-1964)

US biologist, writer, and conservationist. Her book *Silent Spring* (1962), attacking the indiscriminate use of pesticides, inspired the creation of the modern environmental movement.

Carson was born in Springdale, Philadelphia, and educated at Pennsylvania College for Women and Johns Hopkins University. She worked first at the University of Maryland and the Woods Hole Marine Biological Laboratory in Massachusetts, and then as an aquatic biologist with the US Fish and Wildlife Service 1936-49, becoming its editor-in-chief until 1952. Her first book, *The Sea Around Us* (1951), was a best-seller and won several literary awards. It was followed by *The Edge of the Sea* (1955), an ecological exploration of the seashore. *Silent Spring* was a powerful condemnation of the effects of pesticides, especially DDT. While writing about broad scientific issues of pollution and ecological exploitation, she also raised important issues about the reckless squandering of natural resources by an industrial world.

Rachel Carson Homestead

Go to site

Information on the life and legacy of the pioneering ecologist from the trust preserving Carson's childhood home. There is a biography of Carson, details of books by and about Carson, and full details of the work of the conservation organizations continuing her work.

Cartesian coordinates

in coordinate geometry, components used to define the position of a point by its perpendicular distance from a set of two or more axes, or reference lines. For a two-dimensional area defined by two axes at right angles (a horizontal x-axis and a vertical y-axis), the coordinates of a point are given by its perpendicular distances from the y-axis and x-axis, written in the form (x,y). For example, a point P that lies three units from the y-axis and four units from the x-axis has Cartesian coordinates (3,4) (see abscissa and ordinate).

The Cartesian coordinate system can be extended to any finite number of dimensions (axes), and is used thus in theoretical mathematics. Coordinates can be negative numbers, or a positive and a negative; for example (-4, -7), where the point would be to the left of and below zero on the axes. In three-dimensional coordinate geometry, points are located with reference to a third, z-axis, mutually at right angles to the x and y axes.

Cartesian coordinates are named after the French mathematician, René Descartes. The system is useful in creating technical drawings of machines or buildings, and in computer-aided design (CAD).

Cartier-Bresson, Henri (1908-2004)

French photographer. He is considered one of the greatest photographic artists and photojournalists. His documentary work was shot in black and white, using a small-format Leica camera. His work is remarkable for its tightly structured composition and his ability to capture the decisive moment. He was a founder member of Magnum Photos Inc, a cooperative photographic agency that supplied leading photojournalists to cover world events.

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cartilage

flexible bluish-white connective tissue made up of the protein collagen. In cartilaginous fish it forms the skeleton; in other vertebrates it forms the greater part of the embryonic skeleton, and is replaced by bone in the course of development, except in areas of wear such as bone endings, and the discs between the backbones. It also forms structural tissue in the larynx, nose, and external ear of mammals.

Cartilage does not heal itself, so where injury is severe the joint may need to be replaced surgically. In a 1994 trial, Swedish doctors repaired damaged knee joints by implanting cells cultured from the patient's own cartilage. In 1999 US chemists created an artificial liquid cartilage for use in repairing torn tissue. The cartilage is injected into a wound or damaged joint and will harden with exposure to ultraviolet light. Clinical trials commenced in 2000.

---

cartilaginous fish

fish in which the skeleton is made of cartilage. Sharks, rays, and skates are cartilaginous. Their scales are placoid (isolated structures made of dentine resembling simple teeth) and are present all over the body surface. The scales do not continue to grow once fully formed, but are replaced by new scales as they wear out. The notochord (primitive skeletal rod) is reduced and replaced to varying degrees by cartilage.

In modern cartilaginous fish, lungs or swimbladder-like structures (which help to keep fish at a certain depth) are absent, and the fish must maintain its level in the sea by the muscular efforts of swimming. Claspers (fins modified for mating) are sometimes present in the male.

classification

There are about 900 species in the class Chondrichthyes, divided into two subclasses. Subclass Holocephali has one order of living fish, Chimaeriformes, consisting of three families of the chimaera. These have cartilaginous skeletons like sharks, but have only one gill opening with a single gill-cover, like the bony fishes.

Subclass Elasmobranchii contains the eight orders of sharks, and the superorder Batoidea, comprising the skates and rays.

---

cartography

art and practice of drawing maps, originally with pens and drawing boards, but now mostly with computer-aided drafting programs.

Mathematics of Cartography

Go to site

History of maps and details of the mathematics behind mapmaking. There are maths-related mapping problems to solve and a list of cartographical links.

Cartwright, Edmund (1743-1823)

English inventor. He patented the power loom (1785), built a weaving mill (1787), and patented a wool-combing machine (1789).

Carver, George Washington (1860-1943)

US agricultural chemist. He devoted his life to improving the economy of the US South and the condition of African-Americans. He advocated the diversification of crops, promoted peanut production, and was a pioneer in the field of plastics.

At the Tuskegee Institute, Alabama, Carver demonstrated the need for crop rotation and the use of leguminous plants, especially the peanut. Following his advice, farmers were soon making more money from the peanut and its 325 by-products (including milk, cheese, face powder, printer's ink, shampoo, and dyes) which were developed by Carver, than from tobacco and cotton.

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caryopsis

dry, one-seeded fruit in which the wall of the seed becomes fused to the carpel wall during its development. It is a type of achene, and therefore develops from one ovary and does not split open to release the seed. Caryopses are typical of members of the grass family (Gramineae), including the cereals.

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casein

main protein of milk, from which it can be separated by the action of acid, the enzyme rennin, or bacteria (souring); it is also the main protein in cheese. Casein is used as a protein supplement in the treatment of malnutrition. It is used commercially in cosmetics, glues, and as a sizing for coating paper.

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cash crop

crop grown solely for sale rather than for the farmer's own use, for example, coffee, cotton, or sugar beet. Many developing world countries grow cash crops to meet their debt repayments rather than grow food for their own people.

In 1990 Uganda, Rwanda, Nicaragua, and Somalia were the countries most dependent on cash crops for income.

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cashew

tropical American tree. Widely cultivated in India and Africa, it produces poisonous kidney-shaped nuts that become edible after being roasted. (*Anacardium occidentale*, family Anacardiaceae.)

cashew

(Image © Research Machines plc)

Cashew nut tree, Dominica. The plant can grow up to 12 m/40 ft in height. It is used principally for its kidney-shaped nuts, but also for its wood and for an oil produced between the two shells of the nut.

cashew

(Image © Research Machines plc)

Cashew nuts. The nuts are eaten either roasted or fresh. The oil of the cashew – found between the inner and outer shells of the nut – has medicinal uses, such as treating corns, warts, and cancerous ulcers, although it should be used with caution as it has toxic properties.

cashew

(Image © Research Machines plc)

Preparation of cashew nuts in Dominica. This method of roasting the nuts on burning logs can be harmful to the eyes and skin when the outer shell of the nut breaks open and releases the oil. Improved methods of roasting involve the use of roasting cylinders, which dispel the poisonous properties of the oil.

Cashew Nut

Go to site

Informative resource relating to the cashew tree and nut. It contains a detailed description of the tree, its habitat, and its constituents. There are also notes on the many uses of the tree, which include treating skin conditions and acting as a diuretic. There is even information on other species of the cashew tree.

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cassava

or manioc

plant belonging to the spurge family. Native to South America, it is now widely grown throughout the tropics for its starch-containing roots, from which tapioca and bread are made. (*Manihot utilissima*, family Euphorbiaceae.)

Cassava is grown as a staple crop in rural Africa, Asia, and South America. Altogether, it provides a staple crop for approximately 200 million people. The root cells contain the poison cyanoglucoside (converted to hydrogen cyanide in the body) but the plant's latex (milky fluid) contains enzymes that break down the poison. During the processing of cassava the two must mix; the commonest method is by fermentation, although some poison may remain. In the Democratic Republic of Congo (formerly Zaire) and Mozambique at least 10,000 women and children suffered from chronic poisoning between 1985 and 1995.

Mandioca

Go to site

Informative resource relating to mandioca, or cassava. It contains a detailed description of the plant and its habitat. There is information provided about the cultivation of mandioca, and also notes on the preparation of the plant for food and drink.

Cassegrain telescope

or Cassegrain reflector

type of reflecting telescope in which light collected by a concave primary mirror is reflected onto a convex secondary mirror, which in turn directs it back through a hole in the primary mirror to a focus behind it. As a result, the telescope tube can be kept short, allowing equipment for analysing and recording starlight to be mounted behind the main mirror. All modern large astronomical telescopes are of the Cassegrain type.

It is named after the 17th-century French astronomer Cassegrain who first devised it as an improvement to the simpler Newtonian telescope.

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cassia

bark of an aromatic Southeast Asian plant (*Cinnamomum cassia*) belonging to the laurel family (Lauraceae). It is very similar to cinnamon, and is often used as a substitute for it. *Cassia* is also a genus of pod-bearing tropical plants of the family Caesalpiniaceae, many of which have strong purgative (cleansing) properties; *C. senna* is the source of the laxative drug senna (which causes the bowels to empty).

Cassia (Cinnamon)

Go to site

Informative resource relating to cassia. It contains a detailed description of the plant, its constituents, and its habitat. There are also notes on the possible medicinal uses of the plant – such as acting as a stimulant or treating uterine haemorrhage – and on the dosages required.

Cassini, Giovanni Domenico (Jean Dominique) (1625-1712)

Italian-born French astronomer. He discovered four moons of Saturn and the gap in the rings of Saturn now called the **Cassini division**.

Cassini, Giovanni Domenico

Go to site

Devoted to the life and contributions of astronomer Giovanni Cassini, this site provides biographical information and a list of references about Cassini, as well as links to essays that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Cassini. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

Cassini-Huygens

space probe developed jointly by NASA and the European Space Agency to explore the planet Saturn. Cassini was launched on 15 October 1997 to study the planet's atmosphere, rings, and moons, and to drop off a sub-probe, Huygens, to land on Saturn's largest moon, Titan. The mission passed Saturn's moon Phoebe in June 2004 and achieved orbit insertion around Saturn on 1 July 2004.

The Huygens probe parachuted to the surface of Titan on 14 January 2005, returning images of the surface during the descent and after landing.

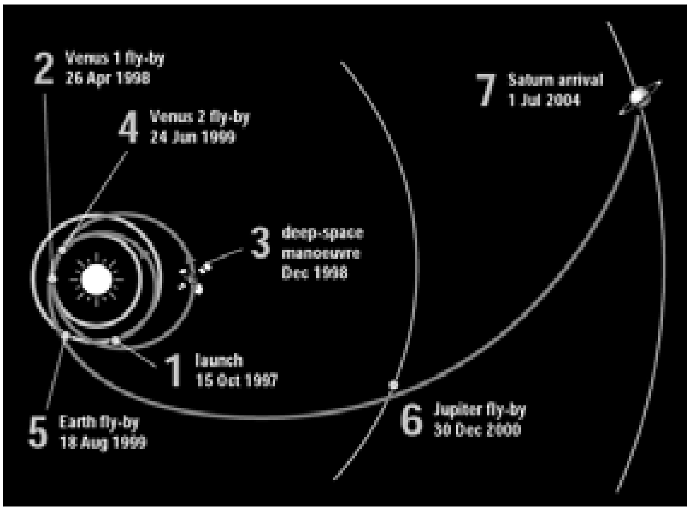
The Cassini-Huygens mission was launched on a Titan 4 rocket, with its electricity supplied by 32 kg/70 lb of plutonium. This was the largest amount of plutonium ever to be sent into space, and provoked fears of contamination should Cassini, or its rocket, malfunction.

Cassini

(Image © NASA)

Jet Propulsion Laboratory technicians about to subject the newly built Saturn probe to lengthy 'shake and bake' tests to simulate the extreme temperatures Cassini will encounter on its voyage and the forces and vibration of lift-off.

Cassini


2 Venus 1 fly-by 26 Apr 1998
4 Venus 2 fly-by 24 Jun 1999
3 deep-space manoeuvre Dec 1998
1 launch 15 Oct 1997
5 Earth fly-by 18 Aug 1999
6 Jupiter fly-by 30 Dec 2000
7 Saturn arrival 1 Jul 2004

(Image © Research Machines plc)

The gravity-assisted flight path of the Cassini space probe. After rocket-powered launch at point 1, Cassini's flight is boosted at point 2 by the gravity of Venus. It then fires its rockets at point 3 to bring it into position for the next Venus fly-by at point 4. When it reaches Earth orbit at point 5 it gains enough energy from the Earth's solar orbit to arc out towards Saturn, reducing its flight time by encountering Jupiter en route.

Cassiopeia

prominent constellation of the northern hemisphere, named after the mother of Andromeda (who was the wife of Perseus). It has a distinctive W-shape, and contains one of the most powerful radio sources in the sky, Cassiopeia A. This is the remains of a supernova (star explosion) that occurred *c.* AD 1702, too far away to be seen from Earth.

It was in Cassiopeia that Danish astronomer Tycho Brahe observed a new star in 1572, probably a supernova, since it was visible in daylight and outshone Venus for ten days.

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cassiterite

or tinstone

mineral consisting of reddish-brown to black stannic oxide (SnO_2), usually found in granite rocks. It is the chief ore of tin. When fresh it has a bright ('adamantine') lustre. It was formerly extensively mined in Cornwall, England; today Malaysia is the world's main supplier. Other sources of cassiterite are Africa, Indonesia, and South America.

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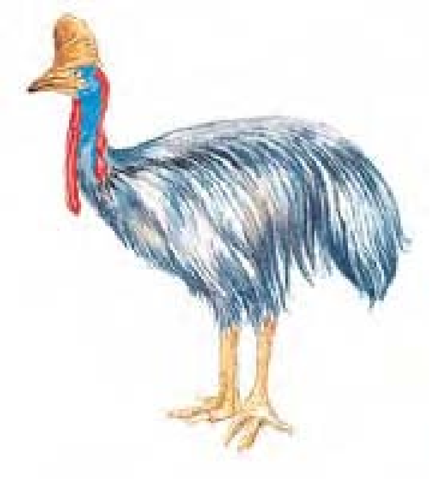
cassowary

large flightless bird, genus *Casuarius*, of the family Casuariidae, order Casuariiformes, found in New Guinea and northern Australia, usually in forests. Related to the emu, the cassowary has a bare head with a horny casque, or helmet, on top, and brightly-coloured skin on the neck. Its loose plumage is black and its wings tiny, but it can run and leap well and defends itself by kicking. Cassowaries stand up to 1.5 m/5 ft tall. They live in pairs and the male usually incubates the eggs, about six in number, which the female lays in a nest of leaves and grass.

The cassowary was put on the Australian endangered species list in 1999. It was then estimated that only 1,100 to 1,500 birds survived in north Queensland rainforests. The cassowary is also found in New Guinea.

cassowary



(Image © Research Machines plc)

The common cassowary of North Australia and New Guinea. The bird is well adapted to forest life, with long, hairlike quills that protect it from spines and prickles. The horny casque, or helmet, on the top of its head is used to force a path through thick undergrowth.

Southern Cassowary

Go to site

Good profile of this large flightless ratite. Three species of cassowary are described, but the site concentrates on the southern cassowary: its physical characteristics, diet, and breeding behaviour. The reasons for the decline in cassowary numbers as humans encroach on its habitat are clearly set out.

casting

process of producing solid objects by pouring molten material into a shaped mould and allowing it to cool. Casting is used to shape such materials as glass and plastics, as well as metals and alloys.

The casting of metals has been practised for approximately 5,000 years using first gold, copper, and bronze, then iron, and now alloys of zinc and other metals. The traditional method of casting metal is **sand casting**. Using a model of the object to be produced, a hollow mould is made in a damp sand and clay mix. Molten metal is then poured into the mould, taking its shape when it cools and solidifies. The sand mould is broken to release the casting. Permanent metal moulds called **dies** are also used for casting, in particular, small items in mass-production processes where molten metal is injected under pressure into cooled dies.
Continuous casting is a method of shaping bars and slabs that involves pouring molten metal into a hollow, water-cooled mould of the desired cross section.

cast iron

cheap but invaluable constructional material, most commonly used for car engine blocks. Cast iron is partly refined pig (crude) iron, which is very fluid when molten and highly suitable for shaping by casting; it contains too many impurities (for example, carbon) to be readily shaped in any other way. Solid cast iron is heavy and can absorb great shock but is very brittle.

Castor

or Alpha Geminorum

second-brightest star in the constellation Gemini and the 23rd brightest star in the night sky. Along with the brighter Pollux, it forms a prominent pair at the eastern end of Gemini, representing the head of the twins.

Second-magnitude Castor is 45 light years from Earth, and is one of the finest binary stars in the sky for small telescopes. The two main components orbit each other over a period of 350 years. A third, much fainter, star orbits the main pair over a period probably exceeding 10,000 years. Each of the three visible components is a spectroscopic binary, making Castor a sextuple star system.

castor-oil plant

tall tropical and subtropical shrub belonging to the spurge family. The seeds, called 'castor beans' in North America, yield the purgative castor oil (which cleans out the bowels) and also ricin, one of the most powerful poisons known. Ricin can be used to destroy cancer cells, leaving normal cells untouched. (*Ricinus communis*, family Euphorbiaceae.)

Castor-oil Plant

Go to site

Detailed description of this plant and its history. There are notes on the cultivation and preparation of the castor-oil plant. Also included here are a detailed analysis of the constituents of the plant, as well as its uses in both medicine and picture restoration.

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castration

removal of the sex glands (either ovaries or testes). Male domestic animals may be castrated to prevent reproduction, to make them larger or more docile, or to eradicate disease.

Castration of humans was used in ancient and medieval times and occasionally later to preserve the treble voice of boy singers or, by Muslims, to provide eunuchs, trustworthy harem guards. If done in childhood, it inhibits sexual development: for instance, the voice remains high, and growth of hair on the face and body is reduced, owing to the absence of the hormones normally secreted by the testes.

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casuarina

any of a group of trees or shrubs with many species in Australia and New Guinea, also found in Africa and Asia. Commonly known as she-oaks, casuarinas have taken their Latin name from the similarity of their long, drooping branchlets to the feathers of the cassowary bird (whose genus is *Casuarius*). (Genus *Casuarina*, family Casuarinaceae.)

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cat

small, domesticated, carnivorous mammal *Felis catus*, often kept as a pet or for catching small pests such as rodents. Found in many colour variants, it may have short, long, or no hair, but the general shape and size is constant – fully-grown cats range from about 51 cm/21 in to about 71 cm/28 in in length. Cats have short muzzles, strong limbs, and flexible spines that enable them to jump and climb. All walk on the pads of their toes (**digitigrade**) and have retractile claws, so are able to stalk their prey silently. They have large eyes and an acute sense of hearing. The canine teeth are long and well-developed, as are the shearing teeth in the side of the mouth.

origins

Domestic cats have a common ancestor, the **African wild cat** *Felis libyca*, found across Africa and Arabia. This is similar to the **European wild cat** *F. silvestris*. Domestic cats can interbreed with either of these wild relatives. Various other species of small wild cat live in all continents except Antarctica and Australia. Large cats, such as the lion, tiger, leopard, puma, and jaguar, also belong to the cat family Felidae.

cat

A tenth of the diet of feral cats is made up of vegetable material.

Cat breeds

The table follows the Numerical Index of Breeds. Breeds listed below are those of pedigree cats (developed through selective breeding). Cats not falling into any of these categories are known as non-pedigree or mongrel cats. They do not conform to any set standard and are referred to as either pet or working cats.

Breed		Breed number[1]	Coat	Eyes
Longhaired Cats				
Persian self black longhair		1	black	copper or deep orange
Persian self white longhair	blue-eyed white	2	white	blue
	orange-eyed white	2a	white	copper or deep orange
	odd-eyed white	2b	white	one blue, one copper or deep orange
Persian self blue longhair		3	medium to pale blue	copper or deep orange
Persian red self longhair		4	deep rich red	copper or deep orange
Persian self cream longhair		5	pale to medium cream	copper or deep orange
Black smoke longhair		6	black, with white undercoat	orange or copper
Blue smoke longhair		6a	blue, with white undercoat	orange or copper
Chocolate smoke longhair		6b	chocolate brown, with white undercoat	orange or copper
Lilac smoke longhair		6c	lilac, with white undercoat	orange or copper
Red smoke longhair		6d	red shading to white, with white undercoat	orange or copper
Tortie smoke longhair		6e	black, red, and cream, broken into patches	orange or copper
Blue-cream smoke longhair[2]		6g	blue and cream, intermingled, with white undercoat	orange or copper

Silver tabby longhair[3]		7	silver, with black markings	green or hazel
Brown tabby longhair		8	rich tawny sable, with black markings	orange or copper (no green rims)
Red tabby longhair		9	rich red, with markings of deeper rich red	orange or copper (no green rims)
Chinchilla		10	white, lightly tipped with black	emerald or blue-green
Pewter longhair		53	white, with dark tipping	orange or copper, with black rims
Golden Persian		54	apricot deepening to gold, tipped with seal brown or black	green or blue-green
Shaded silver		55	white undercoat, black tipping forming a mantle	emerald or blue-green
Tortoiseshell longhair		11	black, red, and cream, broken into patches	deep orange or copper
Chocolate tortoiseshell longhair		11b	chocolate, well broken by shades of red	deep orange or copper
Tortoiseshell-and-white longhair[4]		12 1	red, cream, black, and white, broken into patches	deep orange or copper
Bi-colour longhair		12a	blue and cream, well intermingled	deep orange or copper
Colourpoint		13b (1-20)	depending on variety[5]	blue
Birman		13c (1-20)	depending on variety[6]	deep blue
Auburn Turkish van		13d	chalk white	light amber[7]
Chocolate longhair		50b	medium to dark chocolate brown	copper or deep orange
Norwegian forest		67	all colours and patterns allowed (except chocolate, lilac, and Siamese pattern)	all colours allowed
Lilac longhair[8]		50c	lilac	copper or deep orange
Tiffanie		68	black, blue, chocolate, lilac, red, caramel tortie, or any of the Burmese silver varieties	extensive colour range
Angora		62	very extensive family; colours vary	colour should be in keeping with the coat colouring
Cameo red series	shell	51 1	sparkling silver	orange or copper (no green rims)
	shaded	51 2	white, evenly shaded with red	orange or copper (no green rims)
	tortie cameo	51 4	black, red, and cream, well broken into patches	orange or copper (no green rims)
Cameo cream series	shell	52 1	sparkling silver with cream	orange or copper (no green rims)
	shaded	52 2	white, evenly shaded with cream	orange or copper (no green rims)
	blue cream cameo	52 4	blue and cream softly intermingled	orange or copper (no green rims)
Balinese		61	extensive colour range	bright clear blue
Somali		63	28 different coats, depending on variety	mainly orange or copper
Maine coon		64	extensive colour range	extensive colour range
Ragdoll		66	seal, blue, chocolate, or lilac	extensive colour range
Exotic (shorthair)[9]		70	extensive colour range	extensive colour range
Shorthaired Cats				
British Shorthaired Cats[10]				
White shorthairs	blue-eyed white shorthair	14	pure white	intense sapphire blue
	orange-eyed white shorthair	14a	pure white	gold, orange, or copper (no green rims or flecks)
	odd-eyed white shorthair	14b	pure white	one blue, one gold, orange, or copper (no green rims or flecks)
Black shorthair		15	jet black	gold, orange, or copper
British blue shorthair		16	light to medium blue	copper, orange, or deep gold
Cream shorthair		17	pale-toned cream	copper, orange, or deep gold
Shorthaired tabbies	silver tabby shorthair	18	clean silver, with black markings	green or hazel
	red tabby shorthair	19	red, with deep red markings	brilliant orange or deep copper
	brown tabby shorthair	20	brilliant copper brown, with black markings	deep gold, copper, or orange
Tortoiseshell shorthair		21	black, rich red, and pale red, evenly intermingled	brilliant copper or orange
Tortoiseshell-and-white shorthair		22	black, rich and pale red, and white patches	deep orange or copper
Colourpointed British shorthair		40	extensive colour range[11]	extensive colour range
Manx[12]		25	all colours and patterns allowed (except the 'Siamese' pattern)	colour in keeping with coat colouring
Blue-cream shorthair		28	medium blue and pale cream, evenly intermingled	copper, orange, or deep gold
Spotted shorthair		30	any colour accepted in the British Breeds	green or hazel (silver cats with black spots)
				copper, orange, or deep gold (brown cats with black spots)

				deep orange or copper (all other cats)
Bi-colour shorthair		31	any colour accepted in the British Breeds	brilliant copper, orange, or deep gold (no green rims)
Smoke British shorthair		36	silver undercoat; top coat of any recognized self or tortie colour	copper, orange, or deep gold
British tipped shorthair		39	white undercoat; top coat of any recognized colour	green (cats with black tipping); copper, orange, or deep gold (all other cats)
Foreign Shorthaired Cats				
Russian blue		16a	clear blue	vivid green
Abyssinian	usual	23	rich golden brown	amber, hazel, or green
	sorrel	23a	lustrous copper red	
	blue	23c	blue-grey	
Burmese	brown	27	rich warm seal brown	any shade of yellow, from chartreuse to amber (golden yellow preferred)
	blue	27a	soft silver grey	
	chocolate	27b	warm milk chocolate	
	lilac	27c	pale dove-grey	
	red	27d	light tangerine	
	brown (normal) tortie	27e	mixture of brown and red	
	cream	27f	rich cream	
	blue tortie (blue cream)	27g	mixture of blue and cream	
	chocolate tortie	27h	mixture of chocolate and red	
	lilac tortie (lilac cream)	27j	lilac with shades of cream	
Tonkinese[13]		74	extensive colour range	extensive colour range
Oriental Shorthairs				
Havana[14]		29	rich warm brown	clear, vivid green
Oriental lilac		29c	frosty grey with pinkish tone	clear green
Foreign white		35	pure white	clear, brilliant blue
Oriental black		37	jet black	green
Cornish rex		33	all colours allowed	colour in keeping with coat colouring
Devon rex		33a	all colours allowed	colour in keeping with coat colouring
Korat		34	any shade of blue, with silver topping	brilliant green (amber acceptable)
Oriental tabby		38, 41, 44, 45[15]	extensive colour range	extensive colour range
Oriental smoke		42	any colour recognized for Oriental shorthairs	clear green
Asian Group				
Asian self		72	eight self colours, and five torties	colour in keeping with coat colouring
Burmilla		72 43	extensive colour range (standard and silver varieties)	colour in keeping with coat colouring
Asian smoke		72 42	as for Asian selfs	colour in keeping with coat colouring
Asian tabbies	spotted	72 38	extensive colour range	any colour
	classic	72 41		
	mackerel	72 44		
	ticked	72 45		
Siamese Cats[16]				
Seal-point Siamese		24	cream, with seal brown points	pale green
Blue-point Siamese		24a	glacial white, with blue points	clear vivid blue
Chocolate-point Siamese		61b	ivory, with milk chocolate points	green
Lilac-point Siamese		24c	magnolia-white, with pinkish grey points	vivid blue
Tabby-point Siamese[17]		32	extensive colour range	extensive colour range
Red-point Siamese		32a	warm white, with reddish gold points	brilliant intense blue
Tortie-point Siamese		32b (1-4, 7-9)	extensive colour range	extensive colour range
Cream-point Siamese		32c	creamy white	brilliant intensive blue

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[1] According to the Numerical Index of Breeds.

[2] Chocolate tortie smoke and lilac tortie smoke (both breed number 6j) are also recognized.

[3] Other recognized tabby longhairs are: blue tabby (breed number 8a), chocolate tabby (8b), lilac tabby (8c), tortie tabby (8e), blue tortie tabby (8g), chocolate tortie tabby (8h), and lilac tortie tabby (8j).

[4] Related varieties are: blue-tortoiseshell-and-white (breed number 12 2), chocolate tortie-and-white (12 3), lilac tortie-and-white (12 4). A recently recognized group, the tortie tabby-and-white, comprises: tortie tabby-and-white (breed number 12a6t), blue tortie tabby-and-white (12a8t), chocolate tortie tabby-and-white (12a9t), and lilac tortie tabby-and-white (12a10t).

[5] Seal-point (breed number 13b1): creamy-white, seal brown points; blue-point (13b2): white, blue points; chocolate-point (13b3): ivory-white, chocolate points; lilac-point (13b4): magnolia-white, lilac points; red-point (13b5): apricot-white, rich red points; seal tortie-point (13b6): cream, seal brown, and red points; cream-point (13b7): creamy-white, cream toning points; blue cream-point (13b8): glacial to creamy-white, blue, and cream points; lilac cream-

point (13b9): magnolia to creamy-white, chocolate and red points; chocolate tortie-point (13b10): ivory to apricot-white, chocolate, and red points. Tabby point colours (13b11-13b15 and 13b17) follow the above breeds 13b1-13b5 and 13b7. Tortie-tabby point colours (13b16 and 13b18-13b20) follow the above breeds 13b6 and 13b8-13b10.

[6] Seal-point (breed number 13c1), blue-point (13c2), chocolate (13c3), lilac (13c4), red (13c5), cream-point (13c7); tabby-points (13c11-17 excluding 16); seal tortie-points (13c6-10); tortie tabby-points (13c16-20).

[7] Other varieties of auburn Turkish van: blue-eyed variety (breed number 13dbl): blue; odd-eyed variety (13d odd): one blue and one light amber; three varieties of cream Turkish van (13df) also include amber-, blue-, and odd-eyed.

[8] Related varieties with provisional standards: lilac-cream longhair and chocolate-tortoiseshell longhair (both copper-eyed).

[9] Its coat is longer than that of other shorthairs; the breed technically belongs to longhairs.

[10] Apart from the most popular varieties listed in the table, the following have been recognized: chocolate British shorthair (breed number 15b), lilac (15c), and red self shorthair (15d).

[11] A large family of recognized cats conforming to the general type standard (selfs, tabby, tortie, and tortie tabby-pointed colours).

[12] Absolute taillessness is the most essential feature of this breed.

[13] The result of crossing the Siamese with the Burmese.

[14] Until 1970 known as the chestnut brown foreign.

[15] There are 128 varieties of the oriental tabby, from brown spotted tabby (breed number 38) to fawn tortie silver ticked tabby (45ys).

[16] In addition to varieties listed in the table, the following are now recognized: cinnamon-points (warm cinnamon brown on ivory), caramel-points (brownish grey on magnolia-white), and fawn-points (warm pale rosy mushroom on magnolia-white).

[17] Until 1966 known as the shadow- or Lynx-point.

Bengal Cat

Go to site

Lots of information about this very attractive new breed of domestic cat. The beginner's introduction describes the origins of the breed and its appearance. Click on the home button to access pages about the Bengal's wild ancestor, the Asian leopard cat, pictures of the Bengal's different patterning, a description of its special personality, as well as advice on care, breeding, and how to prepare for a cat show. There are also links to developments in the USA and Holland, and to information about UK breeding standards and registration.

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catabolism

in biology, the destructive part of metabolism where living tissue is changed into energy and waste products.

It is the opposite of anabolism. It occurs continuously in the body, but is accelerated during many disease processes, such as fever, and in starvation.

---

catalepsy

in medicine, an abnormal state in which the patient is apparently or actually unconscious and the muscles become rigid.

There is no response to stimuli, and the rate of heartbeat and breathing is slow. A similar condition can be drug-induced or produced by hypnosis, but catalepsy as ordinarily understood occurs spontaneously in epilepsy, schizophrenia, and other nervous disorders. It is associated with catatonia.

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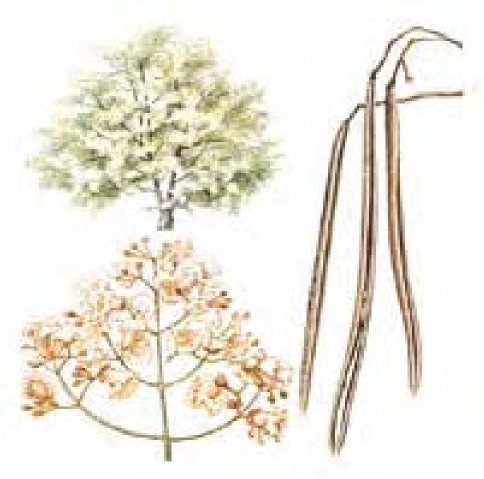
catalpa

any of a group of trees belonging to the trumpet creeper family, found in North America, China, and the West Indies. The northern catalpa (*Catalpa speciosa*) of North America grows to 20 m/65 ft and has heart-shaped deciduous leaves and tubular white flowers with purple borders. (Genus *Catalpa*, family Bignoniaceae.)

catalpa



(Image © Research Machines plc)

The catalpa tree is widely cultivated in the southern United States as an ornamental shade tree. The white tubular flowers, tinged with purple, are succeeded by long, beanlike pods.

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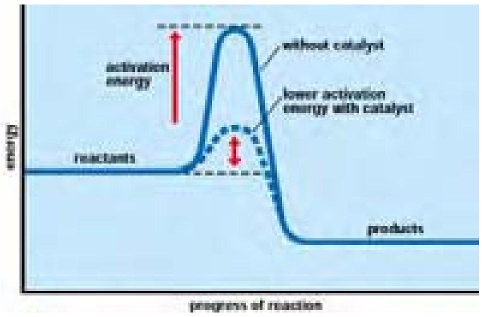
catalyst

substance that alters the speed of, or makes possible, a chemical or biochemical reaction but remains unchanged at the end of the reaction. Enzymes are natural biochemical catalysts. In practice most catalysts are used to speed up reactions.

The catalysts used in the chemical industry are often transition metals or their compounds. According to the collision theory, particles must collide before they can react, and the colliding particles must contain enough energy to cause bonds to break. Catalysts increase the rate of reaction by lowering the amount of energy needed for a successful collision. Therefore, more collisions will be successful.

catalyst



(Image © Research Machines plc)

A graph showing how a reaction speeds up with the addition of a catalyst.

Catalysts

Go to site

Clear explanation of catalysts and what they do. Designed to help GCSE chemists with their revision, this page is part of a larger site of scientific revision aids. The clearly written text includes definitions of important terms such as absorption and intermediate compounds.

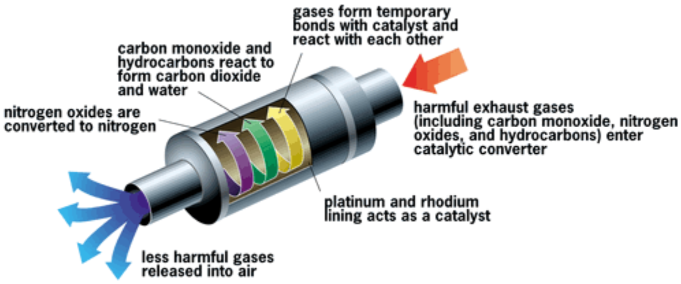
---

catalytic converter

device fitted to the exhaust system of a motor vehicle in order to reduce toxic emissions from the engine. It converts the harmful exhaust products that cause air pollution to relatively harmless ones.

It does this by passing them over a mixture of catalysts coated on a metal or ceramic honeycomb (a structure that increases the surface area and therefore the amount of active catalyst with which the exhaust gases will come into contact).
Oxidation catalysts (small amounts of precious palladium and platinum metals) convert hydrocarbons (unburnt fuel) and carbon monoxide into carbon dioxide and water, but do not affect nitrogen oxide emissions.
Three-way catalysts (platinum and rhodium metals) also convert nitrogen oxide gases into nitrogen and oxygen.

catalytic converter


gases form temporary bonds with catalyst and react with each other
carbon monoxide and hydrocarbons react to form carbon dioxide and water
nitrogen oxides are converted to nitrogen
harmful exhaust gases (including carbon monoxide, nitrogen oxides, and hydrocarbons) enter catalytic converter
platinum and rhodium lining acts as a catalyst
less harmful gases released into air

(Image © Research Machines plc)

A cross section of a car's catalytic converter. Catalytic converters convert harmful exhaust gases (including carbon monoxide, nitrogen oxide, and hydrocarbons) into less harmful gases for release back into the air.

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catamaran

(Tamil 'tied log')

twin-hulled sailing vessel, based on the native craft of South America and the Indies, made of logs lashed together, with an outrigger. A similar vessel with three hulls is known as a trimaran. Car ferries with a wave-piercing catamaran design are also in use in parts of Europe and North America. They have a pointed main hull and two outriggers and travel at a speed of 35 knots (84.5 kph/52.5 mph).

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cataract

eye disease in which the crystalline lens or its capsule becomes cloudy, causing blindness. Fluid accumulates between the fibres of the lens and gives place to deposits of albumin. These coalesce into rounded bodies, the lens fibres break down, and areas of the lens or the lens capsule become filled with opaque products of degeneration. The condition is estimated to have blinded more than 25 million people worldwide, and 150,000 in the UK.

The condition nearly always affects both eyes, usually one more than the other. In most cases, the treatment is replacement of the opaque lens with an artificial implant.

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catarrh

inflammation of any mucous membrane, especially of the nose and throat, with increased production of mucus.

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catastrophe theory

mathematical theory developed by René Thom in 1972, in which he showed that the growth of an organism proceeds by a series of gradual changes that are triggered by, and in turn trigger, large-scale changes or 'catastrophic' jumps. It also has applications in engineering - for example, the gradual strain on the structure of a bridge that can eventually result in a sudden collapse - and has been extended to economic and psychological events.

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catchment area

in earth sciences, the area from which water is collected by a river and its tributaries. In the social sciences the term may be used to denote the area from which people travel to obtain a particular service or product, such as the area from which a school draws its pupils.

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catecholamine

chemical that functions as a neurotransmitter or a hormone. Dopamine, adrenaline (epinephrine), and noradrenaline (norepinephrine) are catecholamines.

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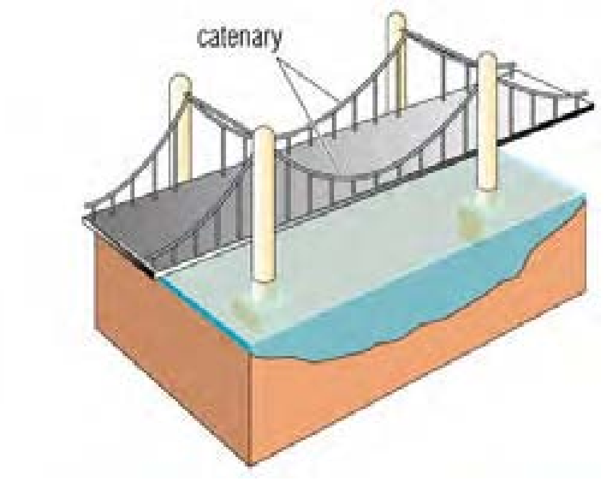
catenary

curve taken up by a flexible cable suspended between two points, under gravity; for example, the curve of overhead suspension cables that hold the conductor wire of an electric railway or tramway.

catenary



(Image © Research Machines plc)

Construction utilizing the form of a catenary can be seen in this suspension bridge.

caterpillar

larval stage of a butterfly or moth. Wormlike in form, the body is segmented, may be hairy, and often has scent glands. The head has strong biting mandibles, silk glands, and a spinneret.

Many caterpillars resemble the plant on which they feed, dry twigs, or rolled leaves. Others are highly coloured and rely for their protection on their irritant hairs, disagreeable smell, or on their power to eject a corrosive fluid. Yet others take up a 'threat attitude' when attacked. Caterpillars emerge from eggs that have been laid by the female insect on the food plant and feed greedily, increasing greatly in size and casting their skins several times, until the pupal stage is reached. The abdominal segments bear a varying number of 'prolegs' as well as the six true legs on the thoracic segments.

caterpillar: defence

When confronted by a predator the mother-of-pearl caterpillar *Pleurotya ruralis* somersaults backwards at 39 times its walking speed.

caterpillar: disguise

The caterpillars of some swallowtail butterflies deter predators by their uncanny resemblance to fresh bird droppings.

caterpillar: droppings

The caterpillar of the Brazilian butterfly *Eunica bechina* does not waste its droppings. It glues them into a long chain at the edge of its leaf, and then uses this chain of droppings as an escape route if threatened by predator ants.

caterpillar: nutrition

The caterpillars of the southern African emperor moth (mopane worms) are nutritionally excellent. Two-thirds of their dried body weight is protein, so 135 g/4.8 oz of dried mopane worms provides the average human adult with the full daily protein requirement.

Rearing Caterpillars

Go to site

Lots of information about how to rear your caterpillar into a butterfly or moth. There are tips on how to obtain them, housing, feeding, pupation, and emergence. This illustrated page is part of the Bug Club site and includes links to other bug pets, newsletter, pen pals, and books.

caterpillar track

trade name for an endless flexible belt of metal plates on which certain vehicles such as tanks and bulldozers run, which takes the place of ordinary tyred wheels and improves performance on wet or uneven surfaces.

A track-laying vehicle has a track on each side, and its engine drives small cogwheels that run along the top of the track in contact with the ground. The advantage of such tracks over wheels is that they distribute the vehicle's weight over a wider area and are thus ideal for use on soft and waterlogged as well as rough and rocky ground.

catfish

fish belonging to the order Siluriformes, in which barbels (feelers) on the head are well-developed, so giving a resemblance to the whiskers of a cat. Catfishes are found worldwide, mainly but not exclusively in fresh water, and are plentiful in South America.

The Eastern European **giant catfish** or **wels** *Silurus glanis* grows to 1.5 m/5 ft long or more. It has been introduced to several places in Britain. The unrelated marine **wolffish** *Anarhicas lupus*, a deep-sea relative of the blenny, growing 1.2 m/4 ft long, is sometimes called a catfish.

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catheter

fine tube inserted into the body to introduce or remove fluids. The urinary catheter, passed by way of the urethra (the duct that leads urine away from the bladder) was the first to be used. In today's practice, catheters can be inserted into blood vessels, either in the limbs or trunk, to provide blood samples and local pressure measurements, and to deliver drugs and/or nutrients directly into the bloodstream.

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cathode

in an electrolytic cell, the negative electrode, towards which positive particles (cations), usually in solution, are attracted. See electrolysis. The cathode is given its negative charge by connecting it to the negative side of an external electrical supply.

In a thermionic valve, cathode ray tube, or similar device, the cathode is the negative electrode, from which electrons are emitted.

In these cases, the flow of electrons is **into** the device at the cathode. The term is also inconsistently applied in some other cases to electrodes at which the flow of electrons is **out of** the device - for example, to the negative terminal of a battery.

---

cathode

in electronics, the part of an electronic device in which electrons are generated. In a thermionic valve, electrons are produced by the heating effect of an applied current; in a photocell, they are produced by the interaction of light and a semiconducting material. The cathode is kept at a negative potential relative to the device's other electrodes (anodes) in order to ensure that the liberated electrons stream away from the cathode and towards the anodes.

---

cathode ray

stream of fast-moving electrons that travel from a cathode (negative electrode) towards an anode (positive electrode) in a vacuum tube. They carry a negative charge and can be deflected by electric and magnetic fields. Cathode rays focused into fine beams of fast electrons are used in cathode-ray tubes, the electrons'kinetic energy being converted into light energy as they collide with the tube's fluorescent screen. The electrons are emitted from the heated metal cathode by a process called **thermionic emission**.

---

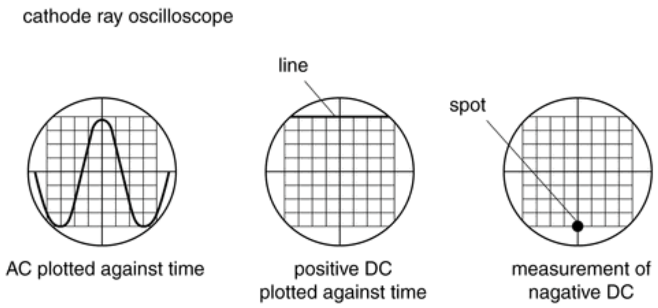
cathode-ray oscilloscope

CRO

instrument used to measure electrical potentials or voltages that vary over time and to display the waveforms of electrical oscillations or signals. Readings are displayed graphically on the screen of a cathode-ray tube.

The CRO is used as a voltmeter with any voltage change shown on screen by an up (positive) or down (negative) movement of a bright dot. This dot is produced by a beam of electrons hitting the phospor layer on the inside of the screen. Over time the dot traces a graph across the screen showing voltage change against time. If voltage remains constant the graph consists of a horizontal line.

cathode-ray oscilloscope



(Image © Research Machines plc)

The cathode-ray oscilloscope (CRO) is used to measure voltage and its changes over time. This is how the CRO screen would appear measuring AC and DC current.

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cathode-ray tube

CRT

vacuum tube in which a beam of electrons is produced and focused onto a fluorescent screen. The electrons' kinetic energy is converted into light energy as they collide with the screen. It is an essential component of one type of television receiver, of computer visual display units, and of oscilloscopes.

The screen of the CRT is coated on the inside with phosphor, which emits light when struck by an electron beam. The tube itself is glass and coated inside with a black graphite conducting paint, which is connected to one of three anodes. A heated filament heats a metal-oxide coated cathode that emits electrons which pass through a positively charged anode that is held at several thousand volts and accelerates the electrons to a high speed beam. The electrons accumulate on the phosphor of the screen and then flow into the conducting graphite paint, completing a circuit.

---

cation

ion carrying a positive charge. During electrolysis, cations in the electrolyte move to the cathode (negative electrode). Cations are formed from atoms by loss of electrons during ionic bonding. Metals form cations.

cation

To remember that **cat**ions are atoms that have lost an **e**lectron:

Cat lost an **e**ye

---

catkin

in flowering plants (angiosperms), a pendulous inflorescence, bearing numerous small, usually unisexual flowers. The tiny flowers are stalkless and the petals and sepals are usually absent or much reduced in size. Many types of trees bear catkins, including willows, poplars, and birches. Most plants with catkins are wind-pollinated, so the male catkins produce large quantities of pollen. Some gymnosperms also have catkin-like structures that produce pollen, for example, the swamp cypress *Taxodium*.

CAT scan

or CT scan; acronym for computerized axial tomography scan

sophisticated method of X-ray imaging. Quick and noninvasive, CAT scanning is used in medicine as an aid to diagnosis, helping to pinpoint problem areas without the need for exploratory surgery. It is also used in archaeology to investigate mummies.

The CAT scanner passes a narrow fan of X-rays through successive 'slices' of the suspect body part. These slices are picked up by crystal detectors in a scintillator and converted electronically into cross-sectional images displayed on a viewing screen. Gradually, using views taken from various angles, a three-dimensional picture of the organ or tissue can be built up and irregularities analysed.

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cattle

any large, ruminant, even-toed, hoofed mammal of the genus *Bos*, family Bovidae, including wild species such as the yak, gaur, gayal, banteng, and kouprey, as well as domestic breeds. Asiatic water buffaloes *Bubalus*, African buffaloes *Syncerus*, and American bison *Bison* are not considered true cattle. Cattle are bred for meat (beef cattle) or milk (dairy cattle).

Cattle were first domesticated in the Middle East during the Neolithic period, about 8000 BC. They were brought north into Europe by migrating Neolithic farmers. Fermentation in the four-chambered stomach allows cattle to make good use of the grass that is normally the main part of the diet. There are two main types of domesticated cattle: the European breeds, variants of *Bos taurus* descended from the **aurochs**, and the various breeds of **zebu** *Bos indicus*, the humped cattle of India, which are useful in the tropics for their ability to withstand the heat and diseases to which European breeds succumb. The old-established beef breeds are mostly British in origin. The Hereford, for example, is the premier English breed, ideally suited to rich lowland pastures but it will also thrive on poorer land such as that found in the US Midwest and the Argentine pampas.

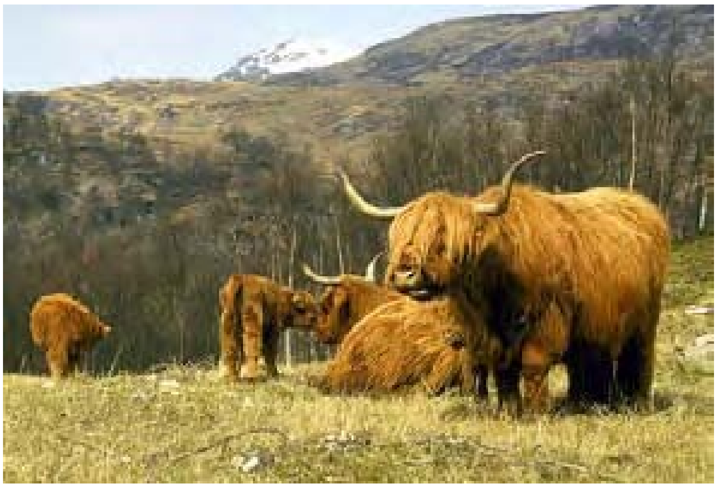
Of the Scottish beef breeds, the Aberdeen Angus, a black and hornless variety, produces high-quality meat through intensive feeding methods. Other breeds include the Devon, a hardy early-maturing type, and the Beef Shorthorn, now less important than formerly, but still valued for an ability to produce good calves when crossed with less promising cattle. In recent years, more interest has been shown in other European breeds, their tendency to have less fat being more suited to modern tastes. Examples include the Charolais and the Limousin from central France, and the Simmental, originally from Switzerland. In the USA, four varieties of zebus, called Brahmans, have been introduced. They interbreed with *B. taurus* varieties and produce valuable hybrids that resist heat, ticks, and insects. For dairying purposes, a breed raised in many countries is variously known as the Friesian, Holstein, or Black and White. It can give enormous milk yields, up to 13,000 l/3,450 gal in a single lactation, and will produce calves ideally suited for intensive beef production. Other dairying types include the Jersey and Guernsey, whose milk has a high butterfat content, and the Ayrshire, a smaller breed capable of staying outside all year.

cattle

(Image © Research Machines plc)

Farmer moving cattle in Mexico. Because of northern Mexico's dry climate, livestock are generally ranched on the open range, on areas larger than 250,000 acres. Until the 1960s, most cattle were *criollo* cattle, descended from Spanish stock of the 16th century. They now include Herefords, as well as Brahman cattle raised in the more tropical regions of the country.

Highland cattle



(Image © Corel)

Highland cattle in Glen Dochart, Perthshire, Scotland.

Cauchy, Augustin-Louis (1789-1857)

French mathematician who employed rigorous methods of analysis. His prolific output included work on complex functions, determinants, and probability, and on the convergence of infinite series. In calculus, he refined the concepts of the limit and the definite integral.

Cauchy has the credit for 16 fundamental concepts and theorems in mathematics and mathematical physics, more than any other mathematician. His work provided a basis for the calculus. He provided the first comprehensive theory of complex numbers, which contributed to the development of mathematical physics and, in particular, aeronautics.

Cauchy, Augustin Louis

Go to site

Extensive biography of the mathematician. The site contains a description of his working relationship with his contemporaries, and also includes explanations of several aspects of his work. Several literature references for further reading on the mathematician are also listed, and the Web site also features a portrait of Cauchy.

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cauliflower

variety of cabbage, with a large edible head of fleshy, cream-coloured flowers which do not fully mature. It is similar to broccoli but less hardy. (*Brassica oleracea botrytis*, family Cruciferae.)

Cole Crops or Brassicas

Go to site

Informative guide to this group of vegetables from the Virginia Cooperative Extension. There is a guide to planting them as well as the types of soil and sunlight that yield best results. This site also features solutions to common problems and information about harvesting and storage.

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caustic soda

former name for sodium hydroxide (NaOH).

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cauterization

in medicine, the use of special instruments to burn or fuse small areas of body tissue to destroy dead cells, prevent the spread of infection, or seal tiny blood vessels to minimize blood loss during surgery.

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cave

passage or tunnel – or series of tunnels – formed underground by water or by waves on a coast. Caves of the former type commonly occur in areas underlain by limestone, such as Kentucky, USA, and many Balkan regions, where the rocks are soluble in water. A **pothole** is a vertical hole in rock caused by water descending a crack; it is thus open to the sky.

Coastal caves are formed where rocks with lines of weakness, like basalt at tide level, are exposed to severe wave action. The erosion (corrasion and corrosion) of the rock layers is increased by subsidence, and the hollow in the cliff face grows still larger because of air compression in the chamber (hydraulic action). Where the roof of a cave has fallen in, the vent up to the land surface is called a blowhole. If this grows, finally destroying the cave form, the outside pillars of the cave are known as stacks or columns. The Old Man of Hoy (137 m/449 ft high), in the Orkney Islands, is a fine example of a stack.

Most inland caves are found in karst (limestone) regions, because limestone is soluble when exposed to acid water. As the water makes its way along the main joints, fissures, and bedding planes, they are constantly enlarged into potential cave passages, which ultimately join to form a complex network. Stalactites and stalagmites form due to water that is rich in calcium carbonate dripping from the roof of the cave. The collapse of the roof of a cave produces features such as **natural arches** and **steep-sided gorges**.

Cavediving

Go to site

US Web site run by a cave diving instructor. The site provides all sorts of information for those who wish to swim in cold, dark, underwater caverns. Information on how to and where to cave dive is provided along with news, articles, links, and details of where to learn how to cave dive.

Virtual Cave

Go to site

Browse the mineral wonders unique to the cave environment – from bell canopies and bottlebrushes to splattermites and stalactites.

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cave animal

animal that has adapted to life within caves. The chief characteristics of cave animals are reduced or absent eyes and consequently other well-developed sense organs, such as antennae and feelers, and their lack of colour. Most are predators, owing to the lack of vegetable matter in this dark habitat.

Cave-dwellers include several species of snails found in Austrian caves that have developed blindness as a result of their mode of life and a genus of small cockroaches in caves of the Philippine Islands where the females are blind and flightless. There are numerous species of cavefish including *Amblyopsis*, which occurs in the Mammoth Cave of Kentucky, USA. Cave-dwelling amphibians include several blind salamanders, such as the olm.

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cavefish

cave-dwelling fish, which may belong to one of several quite unrelated groups, independently adapted to life in underground waters. Cavefish have in common a tendency to blindness and atrophy of the eye, enhanced touch-sensitive organs in the skin, and loss of pigment.

The **Kentucky blindfish** *Amblyopsis spelaea*, which lives underground in limestone caves, has eyes that are vestigial and beneath the skin, and a colourless body. The Mexican **cave characin** is a blind, colourless form of *Astyanax fasciatus* found in surface rivers of Mexico.

Cavendish, Henry (1731-1810)

English physicist and chemist. He discovered hydrogen (which he called 'inflammable air') in 1766, and determined the compositions of water and of nitric acid. The Cavendish experiment (1798) enabled him to discover the mass and density of the Earth.

Cavendish demonstrated in 1784 that water is produced when hydrogen burns in air, thus proving that water is a compound and not an element. He also worked on the production of heat and determined the freezing points for many materials, including mercury.

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cavitation

in hydraulics, erosion of rocks caused by the forcing of air into cracks. Cavitation results from the pounding of waves on the coast and the swirling of turbulent river currents, and exerts great pressure, eventually causing rocks to break apart.

The process is particularly common at waterfalls, where the turbulent falling water contains many air bubbles, which burst and send shock waves into the rocks of the river bed and banks. In addition, as water is forced into cracks in the rock, air within the crack is compressed and literally explodes, helping to break down the rock.

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cavy

short-tailed South American rodent, family Caviidae, of which the guinea-pig *Cavia porcellus* is an example. Wild cavies are greyish or brownish with rather coarse hair. They live in small groups in burrows, and have been kept for food since ancient times.

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cayenne pepper

or red pepper

spice produced from the dried fruits of several species of capsicum (especially *Capsicum frutescens*), a tropical American group of plants. Its origins are completely different from black or white pepper, which comes from an East Indian plant (*Piper nigrum*).

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cayman

another name for caiman.

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cc

symbol for **cubic centimetre**; abbreviation for **carbon copy**.

CCD

abbreviation for charge-coupled device.

CD

abbreviation for compact disc; **Corps Diplomatique** (French 'Diplomatic Corps'); **certificate of deposit**.

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cd

in physics, symbol for candela, the SI unit of luminous intensity.

CD-ROM

acronym for Compact-Disc Read-Only Memory

computer storage device developed from the technology of the audio compact disc. It consists of a plastic-coated metal disk, on which binary digital information is etched in the form of microscopic pits. This can then be read optically by passing a laser beam over the disk. CD-ROMs typically hold over 600 megabytes of data, and are used in distributing large amounts of text, graphics, audio, and video, such as encyclopedias, catalogues, technical manuals, and games.

Standard CD-ROMs cannot have information written onto them by computer, but must be manufactured from a master, although recordable CDs, called CD-R disks, have been developed for use as computer disks. A compact disc, CD-RW, that can be overwritten repeatedly by a computer has also been developed.

The technology is being developed rapidly: a standard CD-ROM spins at between 240 and 1,170 rpm, but faster disks have been introduced that speed up data retrieval to many times the standard speed. Research is being conducted into high-density CDs capable of storing many gigabytes of data, made possible by using multiple layers on the surface of the disk, and by using double-sided disks. The first commercial examples of this research include DVD players and DVD-ROM computer disks launched in 1997. By 2004, DVD-ROM drives (which could also read CD-ROM disks) had become standard on high-end models of new PCs.

PhotoCD, developed by Kodak and released in 1992, transfers ordinary still photographs onto CD-ROM disks.

Quality in a Digital Age

listening

When compact disk began to oust the vinyl record from its pre-eminent position in music reproduction, hi-fi buffs warned that something special was being lost. Music broken into tiny digital steps has subliminal effects on listeners, they claimed. Music lovers risked forfeiting the musical fidelity and dynamic range of the system that had served them well for some 30 years. In its place they would find only a showy substitute - something that sounded good on a first encounter, but that would soon prove 'harsh' and a source of digital 'fatigue' for its listeners.

Enthusiasts aside, most people were unaware of this debate. For them, the CD was much tougher than scratch- and dust-prone vinyl, and the sound was cleaner and clearer. Who was right? Perhaps they both were. Hi-fi enthusiasts were thinking in terms of their expensive turntables, arms, cartridges, amplifiers, and other equipment that partly overcame the inherent disadvantages of vinyl records and their ever-diminishing spiral grooves. Everybody else played their vinyl disks on music centres or cheaper record players. For a comparable outlay, they could buy a CD system and experience a quantum leap in quality. A minority saw quality drop, but the majority saw it rise.

What happened to music reproduction is symptomatic of the 'digital effect' in other media: most people see digitization as a clear benefit, and enjoy its products, but smaller groups cry out that there is a quality 'down side'. These groups often include established media professionals. For each medium, the key question is whether this down side matters - and to whom - and what its effects will be in the longer term.

watching

It's worth mentioning that there are instances of digital techniques stopping the quality rot. Think of television cartoons. In the 1950s and 1960s, the demand for children's media 'product' spawned a mass of cheap cartoon programming in the USA. The resulting 'limited animation' shorts, with their two-dimensional feel and feeble backgrounds, were a far cry from lush, labour-intensive Hollywood cartoon features, or even the frantic shorts of Warner Brothers and others. Computer animation techniques came to the rescue, so that today's stock TV cartoons enjoy a better animation quality than many of their conventionally produced forebears. Whether the programme content of these cartoons is any better is a moot point.

It's sometimes said that digitization has removed the very bottom and very top of the quality spectrum. The very worst has gone, but the very best is often unattainable - it has disappeared along with the highly skilled people who produced it. What is left ranges from the mediocre to the near-excellent, though it is probably true that the upper reaches of this middle band are more affordable than they were in analogue days. One of the great benefits of the digital world is that it offers greatly increased accessibility to relatively high-quality media.

reading

Print media have already proved extremely susceptible to digital inroads. 'Quality' in relation to print has several dimensions, notably in judging typesetting and printing, typographical and graphic design, and the complex web of values associated with the 'text' itself.

Of course, there is more than digitization at work here - other gains in technology, and in particular in IT, have moved everything forwards. For example, it is not simply digitization that allowed us to use laser printers and photocopiers for our routine stationery. Commercial interests had to develop new, efficient implementations of xerographic technology. But digitization is the engine of modern technology, and of media technology in particular.

At first sight, everything in the world of print seems to have changed for the better. Authors can create and endlessly refine their masterpieces using powerful wordprocessors, then send the digital output by disk or wire to the publisher. Or they can self-publish in print, or via the print-analogues of the Web-page and electronic document formats such as Acrobat or Envoy. Publishers large and small - indeed, anybody with a PC and the right software - can appropriate the generations of composing and printing expertise that is allegedly built into their software to produce 'professional' leaflets, newsletters and newspapers, flyers, magazines, journals, and books.

Admittedly, some higher-end print products still need to call on commercial printing and manufacturing services, but the increase in the **accessibility** of good quality print media has been vast. And from the professional end of print media (let's not forget that digitization has radically affected professional practitioners too) there is often a higher, if superficial, 'look and feel' quality than was possible two or three decades ago.

So where is the down side? Once again, the voices of the few sound a warning to the enthusiastic many: designers and typographers can argue that increased accessibility, though a 'good thing' in itself, has put typesetting and printing capabilities into the hands of people who don't know how to use them. Much of today's printed matter is poorly designed to the point of being chaotic. And the flood of cheap typefaces available to the PC-user has severely eroded typographical discipline, aiding and accelerating the advertising-driven move away from legibility towards mere impact.

writing

Writing has changed too: entering text into a wordprocessor is significantly different from longhand writing, or bashing the keys of a finger-crunching manual typewriter. The wordprocessor has brought substantial change: authors are not just doing the same thing with a different tool, but many new and different things.

Accessible IT kicks aside quality thresholds - it's as though anybody with a wordprocessor can write, and anybody with a DTP package or Web editor can design pages. A less conspicuous but extremely important problem is the fate of editing and proofreading. Commercial publishing has good reason to be nervous here. Editorial expertise is leaking out of mainstream publishing at an alarming rate. New editors often lack basic training in editorial intervention, or even an awareness of its potential and importance.

Add commercial pressures that attempt to trim or sidestep editorial fixed costs, and the ease of editor-less self-publishing, and you have a recipe that threatens the long-term survival of publishing enterprises in their present form. To survive, publishers need to sell visibly added value to authors and readers; editorial input scales has always been a prime component of that added value.

'Quality' is not a single, measurable dimension. There are complex value-related and economic issues at stake. Whose quality standards for sound, text, design, animation . . . are at issue, and how are these standards justified?

quality costs money

Who cares? Market-minded economists would say that media consumers reveal their own quality standards whenever they buy media products. On these grounds, suppliers can claim that their standards are *good enough*. Quality costs money - this is as true now as it was in analogue days. Marginal quality improvements - however these are defined - will occur only if media consumers are willing to pay for them.

The immense drive of digital progress does lower the cost of products. This will certainly help to increase physical quality - scanner and imagesetter resolution, say, or transmission bandwiths and video compression techniques - but it's highly unlikely to improve the deeper quality of text and programme contents. Are we losing sight of this 'greyer' aspect of quality - hedged round as it is with subjectivity, multiple viewpoints, and vested interests?

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cedar

any of an Old World group of coniferous trees belonging to the pine family. The cedar of Lebanon (*Cedrus libani*) grows to great height and age in the mountains of Syria and Asia Minor. Of the historic forests on Mount Lebanon itself, only a few groups of trees remain. (Genus *Cedrus*, family Pinaceae.)

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celandine

either of two plants belonging to different families, and resembling each other only in their bright yellow flowers. The greater celandine *Chelidonium majus* belongs to the poppy family (Papaveraceae) and is a common introduced European weed on wooded slopes in the USA. The lesser celandine *Ranunculus ficaria* is a European member of the buttercup family.

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celeriac

variety of garden celery belonging to the carrot family, with an edible turniplike root and small bitter stems. (*Apium graveolens* var. *rapaceum*, family Umbelliferae.)

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celery

Old World plant belonging to the carrot family. It grows wild in ditches and salt marshes and has a coarse texture and sharp taste. Cultivated varieties of celery are grown under cover to make the edible stalks less bitter. (*Apium graveolens*, family Umbelliferae.)

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celestial mechanics

branch of astronomy that deals with the calculation of the orbits of celestial bodies, their gravitational attractions (such as those that produce the Earth's tides), and also the orbits of artificial satellites and space probes. It is based on the laws of motion and gravity laid down by 17th-century English physicist and mathematician Isaac Newton.

Celestial Mechanics

Go to site

A to Z directory of terms and theorems in celestial mechanics, part of Eric Weisstein's Treasure Trove of Physics. Many of the entries are detailed, with equations, diagrams, and references.

Celestial Police

group of astronomers in Germany between 1800 and 1815, who set out to discover a supposed missing planet thought to be orbiting the Sun between Mars and Jupiter, a region now known to be occupied by types of asteroid. Although they did not discover the first asteroid (found in 1801), they discovered the second, Pallas (1802), third, Juno (1804), and fourth, Vesta (1807).

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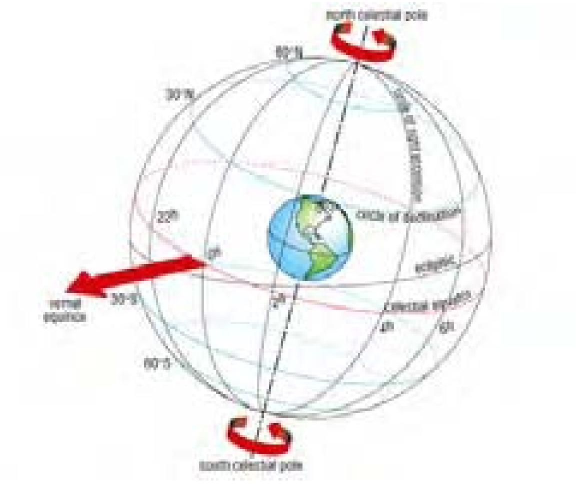
celestial sphere

imaginary sphere surrounding the Earth, on which the celestial bodies seem to lie. The positions of bodies such as stars, planets, and galaxies are specified by their coordinates on the celestial sphere. The equivalents of latitude and longitude on the celestial sphere are called declination and right ascension (which is measured in hours from 0 to 24). The **celestial poles** lie directly above the Earth's poles, and the **celestial equator** lies over the Earth's Equator. The celestial sphere appears to rotate once around the Earth each day, actually a result of the rotation of the Earth on its axis.

celestial sphere



(Image © Research Machines plc)

The main features of the celestial sphere. Declination runs from 0° at the celestial equator to 90° at the celestial poles. Right ascension is measured in hours eastwards from the vernal equinox, one hour corresponding to 15° of longitude.

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celestine

or celestite

mineral consisting of strontium sulphate, $SrSO_4$, occurring as white or light blue crystals. Celestine occurs in cavity linings associated with calcite, dolomite, or fluorite. It is the principal source of strontium.

Celestine is found in small quantities in Germany, Italy, and the USA.

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cell

in biology, the basic unit of a living organism. It is the smallest unit capable of independent existence. In organisms, other than the smallest ones, the body of the organism is made up of several cells or many cells. A single cell, therefore, is the smallest unit that shows characteristic features of life, such as reproduction, growth, respiration, response to environmental stimuli, and the ability to take in mineral salts. Viruses are particles that are not cells. A virus can only reproduce by 'taking over' a cell from another organism. This cell often dies as a result of making many new virus particles.

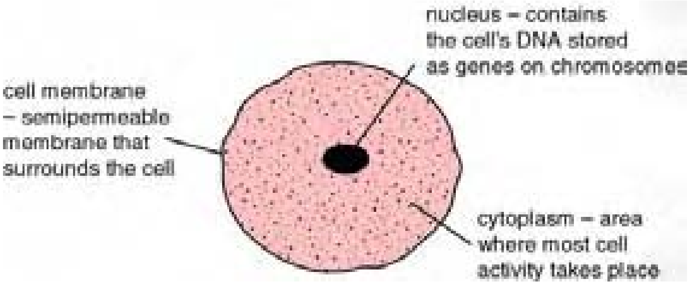
Some organisms are composed of only one cell, including many bacteria and some fungi, such as yeast. Single-cell organisms are termed **unicellular**, while plants and animals which contain many cells are termed **multicellular** organisms. Organisms such as human beings consist of billions of cells. In organisms made of many cells, groups of cells are specialized to carry out specific functions and are organized into tissues and organs.

Cells always have a cell membrane around them and cytoplasm inside, and normally a nucleus. There are differences between plant cells and animal cells; for example, plant cells have a cell wall made of cellulose outside their cell membrane. This helps to explain why plants look so different from animals.

In plants and animals, cells divide by mitosis or by meiosis when the organism carries out sexual reproduction. In both forms of cell division, the chemical carrying inherited information, DNA, has to be copied before division. Rarely, mistakes occur, causing mutations, but it is normally done accurately. Copying the DNA results in the duplication of structures called chromosomes in the nucleus. In cell division, the duplicated chromosomes are separated from each other into daughter cells. New cells produced by mitosis are needed to replace cells that die and some cells live only a short time, such as white blood cells which live for only a few days. Within the human body, about 3 billion cells die every minute. Many cells may be lost in normal activities - for example, human skin cells are constantly being worn off and have to be replaced by new cells produced by mitosis. The new cells needed during growth are also produced by mitosis.

In respiration a cell uses chemicals that it has taken in, as nutrients, and breaks them down to release energy that the cell can use for its life processes.

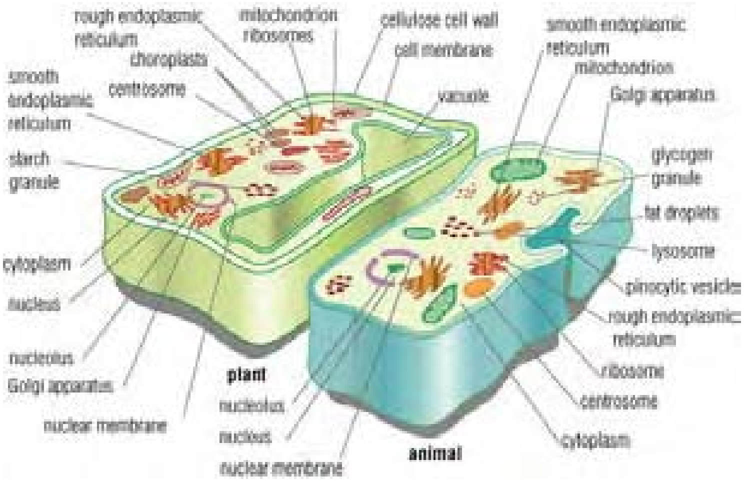
cell


nucleus – contains the cell's DNA stored as genes on chromosomes
cell membrane – semipermeable membrane that surrounds the cell
cytoplasm – area where most cell activity takes place

(Image © Research Machines plc)

A typical animal cell. Some animal cells are specialized for a particular function and may look very different (for example nerve cells and sperm cells). However, most animal cells have a nucleus containing their genetic information (red blood cells are an exception) and are made up of cytoplasm surrounded by a thin membrane. The cytoplasm contains the cell organelles, such as the mitochondria.

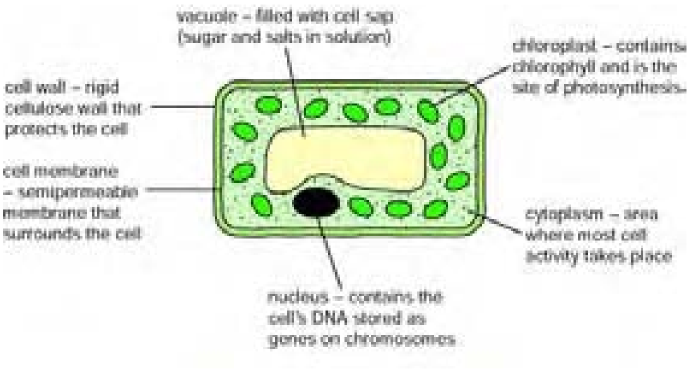
cell structure


rough endoplasmic reticulum
mitochondrion
ribosomes
cellulose cell wall
cell membrane
choroplasts
smooth endoplasmic reticulum
centrosome
vacuole
starch granule
cytoplasm
nucleus
nucleolus
Golgi apparatus
nuclear membrane
plant
nucleolus
nucleus
nuclear membrane
smooth endoplasmic reticulum
mitochondrion
Golgi apparatus
glycogen granule
fat droplets
lysosome
pinocytic vesicle
rough endoplasmic reticulum
ribosome
centrosome
cytoplasm
animal

(Image © Research Machines plc)

Typical plant and animal cell. Plant and animal cells share many structures, such as ribosomes, mitochondria, and chromosomes, but they also have notable differences: plant cells have chloroplasts, a large vacuole, and a cellulose cell wall. Animal cells do not have a rigid cell wall but have an outside cell membrane only.

cell


vacuole – filled with cell sap (sugar and salts in solution)
chloroplast – contains chlorophyll and is the site of photosynthesis
cell wall – rigid cellulose wall that protects the cell
cell membrane – semipermeable membrane that surrounds the cell
cytoplasm – area where most cell activity takes place
nucleus – contains the cell's DNA stored as genes on chromosomes

(Image © Research Machines plc)

A typical plant cell. Plant cells differ from animal cells in that they have chloroplasts (where photosynthesis takes place), a large vacuole, and a cellulose cell wall.

Cells Alive

Go to site

Well-organized collection of images, video, and text describing living human and animal cells, and their interaction with bacteria and parasites. There is also a cell-cam, which displays a growing culture of cells. Further links are available to other cell sites, such as one dealing with the common cold.

Dr NAD's Mini-Course

Go to site

Dr NAD's step-by-step mini-course uses helpful graphics and readable text to guide you through the basics of plant structure and reproduction. It provides a clear explanation of the differences between plant and animal cells.

Interactive Mitosis Tutorial

Go to site

Shockwave-enhanced explanation of mitosis, the process of cell division in non-reproductive eukaryotic cells. All terms are clearly explained. The site also provides animated GIFs for those whose connections are slow.

Leaf Section

Go to site

Part of a larger section on biology, this Web site explains the structure and form of a typical leaf. A detailed diagram is included, together with labels and definitions for the important parts. Links are contained to the rest of the site at the bottom of the page.

Membrane Transport Mechanisms

Go to site

Concise description of cell diffusion, the means by which materials travel in and out of a cell. With the help of diagrams, the page explains the related concepts of facilitated diffusion and active transport.

Mitosis and Meiosis

Go to site

Clear and detailed description of meiosis, the process of division in reproductive cells. The text is linked to a companion page on mitosis, and there is an animated comparison between the two processes.

Virtual Cell

Go to site

The Virtual Cell site provides you with a variety of options that allow you to explore the microscopic structures inside cells using only your mouse; this site also includes real electron micrographs of these tiny structures and provides some information on their function.

cell differentiation

in developing embryos, the process by which cells acquire their specialization, such as heart cells, muscle cells, skin cells, and brain cells. The seven-day-old human pre-embryo consists of thousands of individual cells, each of which is destined to assist in the formation of individual organs in the body.

Research has shown that the eventual function of a cell, in for example, a chicken embryo, is determined by the cell's position. The embryo can be mapped into areas corresponding with the spinal cord, the wings, the legs, and many other tissues. If the embryo is relatively young, a cell transplanted from one area to another will develop according to its new position. As the embryo develops the cells lose their flexibility and become unable to change their destiny.

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cell division

process by which a cell divides. Cells are the basic units of life and they carry out basic functions that are characteristic of living organisms, such as growth and reproduction. Both growth and reproduction usually involve cell division. In plants and animals reproduction can be either sexual reproduction or asexual reproduction. Both involve cell division. In sexual reproduction the cell division that is used is meiosis. In asexual reproduction it is mitosis that is used. In both forms of cell division, the chemical carrying inherited information, DNA, has to be copied before division. Rarely, mistakes occur causing mutations, but it is normally done accurately. Copying the DNA results in the duplication of structures called chromosomes in the nucleus. In cell division, the duplicated chromosomes are separated from each other into daughter cells.

In sexual reproduction male and female gametes combine. Gametes are produced by meiosis cell division. Usually the male and female gametes are produced by two different individuals. If so, sexual reproduction combines inherited information from the two parents. Most animals and plants reproduce sexually, though many plants also reproduce asexually.

The male and female sex organs of a plant are usually found in the flower. Many flowers contain both male and female organs. The male gametes of a plant are inside the pollen grains, and the female gametes are inside the ovules.

In mammals, the male gametes are called sperm and are made in the testes. The female gametes are eggs (see ovum) and are made in the ovaries.

cell division

To remember the phases of cell division:

Prime **M**inister – **a t**oad!

Prophase, **m**etaphase, **a**naphase, **t**elophase

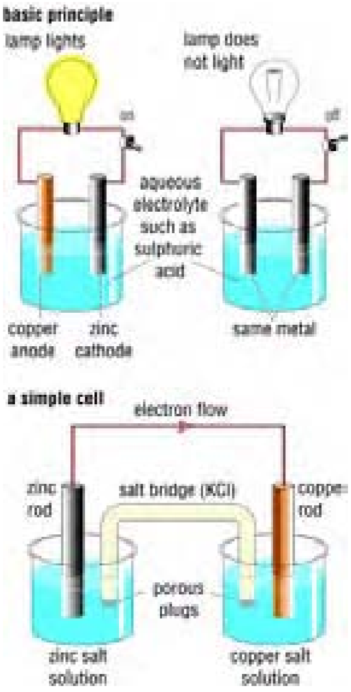
---

cell, electrical

or voltaic cell or galvanic cell

device in which chemical energy is converted into electrical energy; the popular name is 'battery', but this strictly refers to a collection of cells in one unit. The reactive chemicals of a **primary cell** cannot be replenished, whereas **secondary cells** – such as storage batteries – are rechargeable: their chemical reactions can be reversed and the original condition restored by applying an electric current. It is dangerous to attempt to recharge a primary cell.

cell, electrical


basic principle
lamp lights
lamp does not light
on
off
aqueous electrolyte such as sulphuric acid
copper anode
zinc cathode
same metal
a simple cell
electron flow
zinc rod
salt bridge (KCl)
coppe rod
porous plugs
zinc salt solution
copper salt solution

(Image © Research Machines plc)

When electrical energy is produced from chemical energy using two metals acting as electrodes in a aqueous solution, it is sometimes known as a galvanic cell or voltaic cell. Here the two metals copper (+) and zinc (-) are immersed in dilute sulphuric acid, which acts as an electrolyte. If a light bulb is connected between the two, an electric current will flow with bubbles of gas being deposited on the electrodes in a process known as polarization.

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cell, electrolytic

device to which electrical energy is applied in order to bring about a chemical reaction; see electrolysis.

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cell membrane

or plasma membrane

thin layer of protein and fat surrounding cells that keeps the cells together and controls substances passing between the cytoplasm and the intercellular space. The cell membrane is semipermeable, allowing some substances to pass through and some not. Generally, small molecules such as water, glucose, and amino acids can penetrate the membrane, while large molecules, such as starch, cannot. Substances often cross the membrane by diffusion, a spontaneous passage of molecules. Water movement across the membrane is a special case of diffusion known as osmosis.

Membranes also play a part in active transport, hormonal response (see hormones), and cell metabolism.

Transport Across Cell Membranes

Go to site

Study guide to cell membrane transport. The well-written text covers important concepts such as diffusion, osmosis, active transport, symport, and facilitated diffusion.

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cellophane

transparent wrapping film made from wood cellulose, widely used for packaging, first produced by Swiss chemist Jacques Edwin Brandenberger in 1908.

Cellophane is made from wood pulp, in much the same way that the artificial fibre rayon is made: the pulp is dissolved in chemicals to form a viscose solution, which is then pumped through a long narrow slit into an acid bath where the emergent viscose stream turns into a film of pure cellulose.

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cell sap

dilute fluid found in the large central vacuole of many plant cells. It is made up of water, amino acids, glucose, and salts. The sap has many functions, including storage of useful materials, and provides mechanical support for non-woody plants.

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cellular phone

or cellphone

see mobile phone.

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cellulite

fatty compound alleged by some dietitians to be produced in the body by liver disorder and to cause lumpy deposits on the hips and thighs. Medical opinion generally denies its existence, attributing the lumpy appearance to a type of subcutaneous fat deposit.

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cellulitis

inflammation of connective tissue. It is usually due to bacterial infection.

Childhood Infections - Cellulitis

Go to site

Useful information about cellulitis. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

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celluloid

transparent or translucent, highly flammable, plastic material (a thermoplastic) made from cellulose nitrate and camphor. It was once used for toilet articles, novelties, and photographic film, but has now been replaced by the nonflammable substance cellulose acetate.

---

cellulose

complex carbohydrate composed of long chains of glucose units, joined by chemical bonds called glycosidic links. It is the principal constituent of the cell wall of higher plants, and a vital ingredient in the diet of many herbivores. Molecules of cellulose are organized into long, unbranched microfibrils that give support to the cell wall. No mammal produces the enzyme cellulase, necessary for digesting cellulose; mammals such as rabbits and cows are only able to digest grass because the bacteria present in their gut can manufacture it.

Cellulose is the most abundant substance found in the plant kingdom. It has numerous uses in industry: in rope-making; as a source of textiles (linen, cotton, viscose, and acetate) and plastics (cellophane and celluloid); in the manufacture of nondrip paint; and in such foods as whipped dessert toppings.

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cellulose acetate

or cellulose ethanoate

chemical (an ester) made by the action of acetic acid (ethanoic acid) on cellulose. It is used in making transparent film, especially photographic film; unlike its predecessor, celluloid, it is not flammable.

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cell wall

tough outer surface of the cell in plants. It is constructed from a mesh of cellulose and is very strong and only very slightly elastic so that it protects the cell and holds it in shape. Most living cells are turgid (swollen with water; see turgor). Water is absorbed by osmosis causing the cell to expand and develop an internal hydrostatic pressure (wall pressure) that acts against the cellulose wall. The result of this turgor pressure is to give the cell, and therefore the plant, rigidity. Plants, or sections of plants, that are not woody are particularly reliant on this form of support.

The cellulose in cell walls plays a vital role in global nutrition. No vertebrate is able to produce cellulase, the enzyme necessary for the breakdown of cellulose into sugar. However, most mammalian herbivores rely on cellulose, using secretions from micro-organisms living in the gut to break it down. Humans cannot digest the cellulose of the cell walls; they possess neither the correct gut micro-organisms nor the necessary grinding teeth. However, cellulose still forms a necessary part of the human diet as fibre (roughage). Because it is not broken down it acts as a signal that the gut needs to contract to move the contents on.

The cell walls of bacteria and fungi are not made of cellulose, but are just as strong. Some antibiotics kill bacteria by weakening the cell wall. Penicillins work in this way.

Cellular Organization

Go to site

Thorough introduction to cellular biology. This academic Web site covers the size, shape, and constituent parts of various cells, with clear text illustrated by diagrams and slides. For quick reference the user may pick a topic from the contents section at the top of the page.

Structure and Function in Cell Biology

Go to site

Good basic guide to the properties of cells. This site consists of a series of links with easy-to-follow introductory explanations.

Virtual Cell

Go to site

Journey to the centre of a cell with this visually sophisticated Web site. The interactive tour allows you to cut through the membrane and see how the cell nucleus works, while accompanying text explains the components and processes involved.

Celsius

scale of temperature, previously called centigrade, in which the range from freezing to boiling of water is divided into 100 degrees, freezing point being 0 degrees and boiling point 100 degrees.

The degree centigrade (°C) was officially renamed Celsius in 1948 to avoid confusion with the angular measure known as the centigrade (one hundredth of a grade). The Celsius scale is named after the Swedish astronomer Anders Celsius, who devised it in 1742 but in reverse (freezing point was 100°; boiling point 0°).

Origin of the Celsius Temperature Scale

Go to site

Brief but comprehensive description of how Swedish astronomer Anders Celsius devised his temperature scale. The Web site is available in three languages, English, Swedish, and Dutch, and the Swedish cover of Celsius's paper on his temperature scale is also shown here.

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cement

any bonding agent used to unite particles in a single mass or to cause one surface to adhere to another. **Portland cement** is a powder which when mixed with water and sand or gravel turns into mortar or concrete.

In geology, cement refers to a chemically precipitated material such as carbonate that occupies the interstices of clastic rocks.

The term 'cement' covers a variety of materials, such as fluxes and pastes, and also bituminous products obtained from tar. In 1824 English bricklayer Joseph Aspdin (1779–1855) created and patented the first Portland cement, so named because its colour in the hardened state resembled that of Portland stone, a limestone used in building.

Cement is made by heating limestone (calcium carbonate) with clay (which contains a variety of silicates along with aluminium). This produces a grey powdery mixture of calcium and aluminium silicates. On addition of water, a complex series of reactions occurs and calcium hydroxide is produced. Cement sets by losing water.

Cenozoic Era

or Caenozoic

era of geological time that began 65 million years ago and continues to the present day. It is divided into the Tertiary and Quaternary periods. The Cenozoic marks the emergence of mammals as a dominant group, and the rearrangement of continental masses towards their present positions.

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censorship, computing

banning of certain types of information from public access. Concerns over the ready availability of material such as bomb recipes and pornography have led a number of countries to pass laws attempting to censor the Internet. The best known of these is the US Communications Decency Act 1996, but initiatives have been taken in other countries, for example Singapore, which in 1996 announced new regulations bringing the Internet under the Singapore Broadcasting Authority and requiring all access providers and users to be registered and licensed. Less formal pressures have been applied against Internet Service Providers (ISPs) in Germany and the UK to block specific types of material.

In 2006, a survey by US organization Freedom House found that 54% of countries restrict print and electronic journalists. The French monitoring service Reporters sans Frontieres has reported that the following countries totally or largely restrict Internet access: Belarus, China, Cuba, Iran, Libya, the Maldives, Myanmar, Nepal, North Korea, Saudi Arabia, Syria, Tunisia, Turkmenistan, Uzbekistan, and Vietnam. In the UK, the Regulation of Investigatory Powers Act (2000, extended in 2003) increased the rights of security services to monitor personal communication (such as telephone tapping) to include electronic mail.

Electronic Frontier Foundation

Go to site

US-based non-profit organization that aims to protect free speech on the Internet. This site includes a lot of technical legal jargon and the full text of Supreme Court decisions relating to their campaigns. However, there are also a lot of news-style pieces on issues such as encryption, privacy, and free speech which are more accessible to the casual browser.

Electronic Privacy Information Center

Go to site

With privacy and security on the Internet an increasing concern, this site attempts to focus public attention on privacy issues. News and information covering free speech on the Internet, freedom of information, 'censorware' and filtering programs, hacking, and related topics are included, along with practical tips on how to protect your personal information on the Internet.

Centaurus

large, bright constellation of the southern hemisphere, represented as a centaur. Its brightest star, Alpha Centauri, is a triple star, and contains the closest star to the Sun, Proxima Centauri, which is only 4.2 light years away from the Sun, and 0.1 light years closer than its companions, Alpha Centauri A and B. Omega Centauri, which is just visible to the naked eye as a hazy patch, is the largest and brightest globular cluster of stars in the sky, 16,000 light years away from the Sun.

Alpha and Beta Centauri are both of the first magnitude and, like Alpha and Beta Ursae Majoris, are known as 'the Pointers', as a line joining them leads to Crux.

A 'planetary nursery' in a cloudy ring around a star in Centaurus was discovered by astronomers in Hawaii and Chile in 1998. The ring, with a diameter of 18.6 billion miles, seems to be forming a solar system with planets. It is expected to give astronomers valuable information about how our own solar system was formed.

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centigrade

former name for the Celsius temperature scale.

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centipede

jointed-legged animal of the group Chilopoda, members of which have a distinct head and a single pair of long antennae. Their bodies are composed of segments (which may number nearly 200), each of similar form and bearing a single pair of legs. Most are small, but the tropical *Scolopendra gigantea* may reach 30 cm/1 ft in length.
Millipedes, class Diplopoda, have fewer segments (up to 100), but have two pairs of legs on each.

Nocturnal, frequently blind, and all carnivorous, centipedes live in moist, dark places, and protect themselves by a poisonous secretion. They have a pair of poison claws, and strong jaws with poison fangs. The bite of some tropical species is dangerous to humans. Several species live in Britain, *Lithobius forficatus* being the most common.

---

central dogma

in genetics and evolution, the fundamental belief that genes can affect the nature of the physical body, but that changes in the body (acquired character, for example, through use or accident) cannot be translated into changes in the genes.

The elements of this idea were outlined by the German biologist August Weismann in the 1880s, when he claimed that the **soma** (body) and **germ** (reproductive) parts were separate lines. In the 1950s, following the discovery of the structure of DNA, Francis Crick formulated the central dogma as we now know it, on the basis that genetic information can only flow out of DNA, not into it, because RNA (and thus proteins) can be made using DNA as a template, but not *vice versa*. The more recent discovery of retroviruses has shown this to be partly untrue: DNA can be copied from RNA. However, the fundamental idea of the central dogma is still valid. See also acquired character.

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central heating

system of heating from a central source, typically of a house, larger building, or group of buildings, as opposed to heating each room individually. Steam heat and hot-water heat are the most common systems in use. Water is heated in a furnace burning oil, gas, or solid fuel, and, as steam or hot water, is then pumped through radiators in each room. The level of temperature can be selected by adjusting a thermostat on the burner or in a room.

Central heating has its origins in the hypocaust heating system introduced by the Romans nearly 2,000 years ago. From the 18th century, steam central heating, usually by pipe, was available in the West and installed in individual houses on an ad hoc basis. The Scottish engineer James Watt heated his study with a steam pipe connected to a boiler, and Matthew Boulton installed steam heating in a friend's Birmingham house. Not until the latter half of the 20th century was central heating in general use. Central heating systems are usually switched on and off by a time switch. Another kind of central heating system uses hot air, which is pumped through ducts (called risers) to grills in the rooms. Underfloor heating (called radiant heat) is used in some houses, the heat coming from electric elements buried in the floor. New energy-efficient houses use heat from the Sun and good insulation to replace some central heating.

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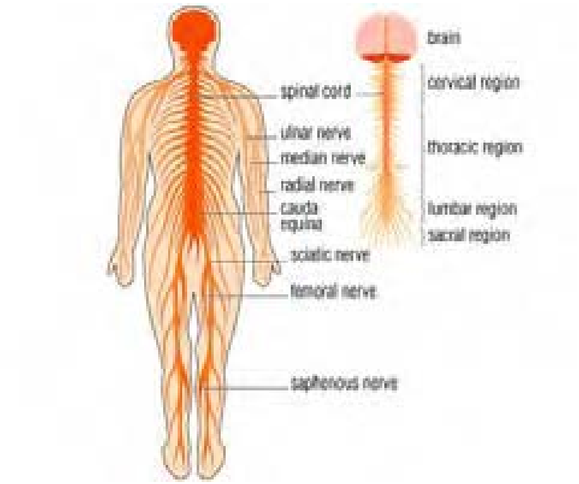
central nervous system

CNS

brain and spinal cord, as distinct from other components of the nervous system. The CNS integrates all nervous function.

In invertebrates it consists of a paired ventral nerve cord with concentrations of nerve-cell bodies, known as ganglia in each segment, and a small brain in the head. Some simple invertebrates, such as sponges and jellyfishes, have no CNS but a simple network of nerve cells called a **nerve net**.

central nervous system



(Image © Research Machines plc)

The central nervous system (CNS) with its associated nerves.

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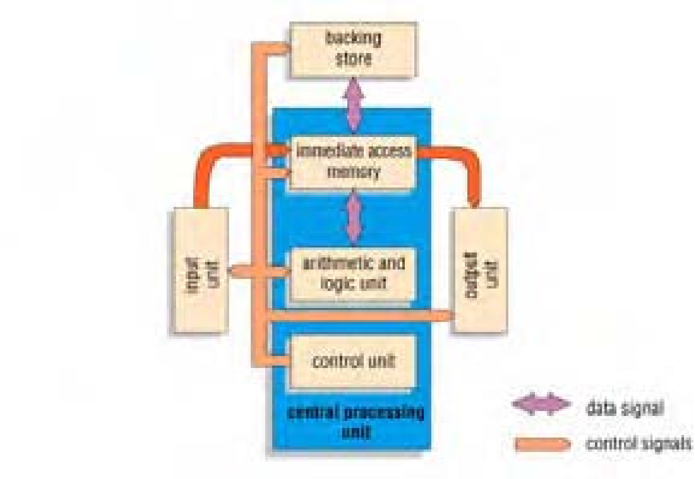
central processing unit

CPU

older name for the main component of a computer, the part that executes individual program instructions and controls the operation of other parts. It is now known simply as the processor or, when contained on a single integrated circuit, microprocessor.

central processing unit



(Image © Research Machines plc)

The relationship between the three main areas of a computer's central processing unit. The arithmetic and logic unit (ALU) does the arithmetic, using the registers to store intermediate results, supervised by the control unit. Input and output circuits connect the ALU to external memory, input, and output devices.

Illustrated Guide to CPUs

Go to site

Series of modules on central processing units (CPUs). The site introduces the design and function of the CPU since it is the key to understanding data processing methodology. It begins by asking 'What is a CPU?' and then explores the development of the CPU from the first through to the seventh generation.

PC Technology Guide

Go to site

Complete guide to the personal computer (PC). It contains comprehensive information on the component parts of a PC, what they are, and how they work. It covers topics such as 'Components', 'Storage', 'Multimedia', and 'Input/Output'. The topics are covered in detail, yet are written in way that is easy to understand.

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centre of mass

point in or near an object at which the whole mass of the object may be considered to be concentrated. A symmetrical homogeneous object such as a sphere or cube has its centre of mass at its geometrical centre; a hollow object (such as a cup) may have its centre of mass in space inside the hollow.

For an object to be in stable equilibrium, a vertical line down through its centre of mass must run within the boundaries of its base; if tilted until this line falls outside the base, the object becomes unstable and topples over.

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centrifugal force

in physics, apparent or 'fictitious' force arising for an observer moving with a rotating system. For an object of mass m moving with a velocity v in a circle of radius r, the centrifugal force F equals mv^2/r (outwards).

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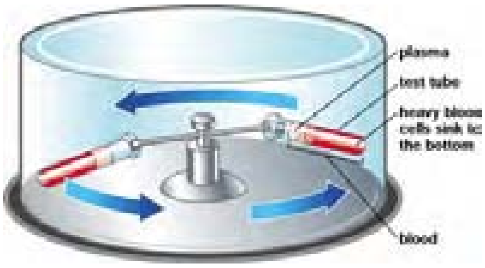
centrifuge

apparatus that rotates containers at high speeds, creating centrifugal forces. One use is for separating mixtures of substances of different densities.

A laboratory centrifuge is used to separate small amounts of suspension. Test tubes of suspension are spun around very fast so that the solid gets flung to the bottom. The mixtures are usually spun horizontally in balanced containers ('buckets'), and the rotation sets up centrifugal forces, causing their components to separate according to their densities. A common example is the separation of the lighter plasma from the heavier blood corpuscles in certain blood tests. The **ultracentrifuge** is a very high-speed centrifuge, used in biochemistry for separating colloids and organic substances; it may operate at several million revolutions per minute. The centrifuges used in the industrial separation of cream from milk, and yeast from fermented wort (infused malt), operate by having mixtures pumped through a continually rotating chamber, the components being tapped off at different points. Large centrifuges are used for physiological research - for example, in astronaut training where bodily responses to gravitational forces many times the normal level are tested.

centrifuge



(Image © Research Machines plc)

Centrifuge being used to separate the blood plasma from blood cells. As the test tubes spin the heavier blood cells sink to the bottom. Centrifuges are useful in laboratories and on an industrial scale for separating solids in suspension in liquids.

centriole

structure found in the cells of animals that plays a role in the processes of meiosis and mitosis (cell division).

centripetal force

force that acts radially inwards on an object moving in a curved path. For example, with a weight whirled in a circle at the end of a length of string, the centripetal force is the tension in the string. For an object of mass m moving with a velocity v in a circle of radius r, the centripetal force F equals mv^2/r (inwards).

cephalopod

any predatory marine mollusc of the class Cephalopoda, with the mouth and head surrounded by tentacles. Cephalopods are the most intelligent, the fastest-moving, and the largest of all animals without backbones, and there are remarkable luminescent forms that swim or drift at great depths. They have the most highly developed nervous and sensory systems of all invertebrates, the eye in some closely paralleling that found in vertebrates. Examples include squid, octopus, and cuttlefish. Shells are rudimentary or absent in most cephalopods.

Typically, they move by swimming with the mantle (fold of outer skin) aided by the arms, but can squirt water out of the siphon (funnel) to propel themselves backwards by jet propulsion. Squid, for example, can escape predators at speeds of 11 kph/7mph. Cephalopods grow very rapidly and may be mature in a year. The female common octopus lays 150,000 eggs after copulation, and stays to brood them for as long as six weeks. After they hatch the female dies, and, although reproductive habits of many cephalopods are not known, it is thought that dying after spawning may be typical.

cephalosporin

any of a class of broad-spectrum antibiotics derived from a fungus (genus *Cephalosporium*). They are similar to penicillins and are used on penicillin-resistant infections.

The first cephalosporin was extracted from sewage-contaminated water, and other naturally occurring ones have been isolated from moulds taken from soil samples. Side effects include allergic reactions and digestive upsets. Synthetic cephalosporins can be designed to be effective against a particular pathogen.

Cepheid variable

yellow supergiant star that varies regularly in brightness every few days or weeks as a result of pulsations. The time that a Cepheid variable takes to pulsate is directly related to its average brightness; the longer the pulsation period, the brighter the star.

This relationship, the **period luminosity law** (discovered by US astronomer Henrietta Leavitt), allows astronomers to use Cepheid variables as 'standard candles' to measure distances within our Galaxy and to nearby galaxies. They are named after their prototype, Delta Cephei, whose light variations were observed in 1784 by English astronomer John Goodricke.

Cepheus

constellation of the north polar region, named after King Cepheus of Greek mythology, husband of Cassiopeia and father of Andromeda. It contains the Garnet Star (Mu Cephei), a red supergiant of variable brightness that is one of the reddest-coloured stars known, and Delta Cephei, prototype of the Cepheid variables, which are important both as distance indicators and for the information they give about stellar evolution.

cereal

grass grown for its edible, nutrient-rich, starchy seeds. The term refers primarily to wheat, oats, rye, and barley, but may also refer to maize (corn), millet, and rice. Cereals contain about 75% complex carbohydrates and 10% protein, plus fats and fibre (roughage). They store well. If all the world's cereal crop were consumed as whole-grain products directly by humans, everyone could obtain adequate protein and carbohydrate; however, a large proportion of cereal production in affluent nations is used as animal feed to boost the production of meat, dairy products, and eggs.

The term also refers to breakfast foods prepared from the seeds of cereal crops. Some cereals require cooking (porridge oats), but most are ready to eat. Mass-marketed cereals include refined and sweetened varieties as well as whole cereals such as muesli. Whole cereals are more nutritious and provide more fibre than the refined cereals, which often have vitamins and flavourings added to replace those lost in the refining process.

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cerebellum

part of the brain of vertebrate animals which controls muscle tone, movement, balance, and coordination. It is relatively small in lower animals such as newts and lizards, but large in birds since flight demands precise coordination. The human cerebellum is also well developed, because of the need for balance when walking or running, and for finely coordinated hand movements.

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cerebral haemorrhage

or apoplectic fit

in medicine, a form of stroke in which there is bleeding from a cerebral blood vessel into the surrounding brain tissue. It is generally caused by degenerative disease of the arteries and high blood pressure. Depending on the site and extent of bleeding, the symptoms vary from transient weakness and numbness to deep coma and death. Damage to the brain is permanent, though some recovery can be made. Strokes are likely to recur.

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cerebral palsy

any nonprogressive abnormality of the brain occurring during or shortly after birth. It is caused by oxygen deprivation, injury during birth, haemorrhage, meningitis, viral infection, or faulty development. Premature babies are at greater risk of being born with cerebral palsy, and in 1996 US researchers linked this to low levels of the thyroid hormone thyroxine. The condition is characterized by muscle spasm, weakness, lack of coordination, and impaired movement; or there may be spastic paralysis, with fixed deformities of the limbs. Intelligence is not always affected.

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cerebrum

part of the vertebrate brain, formed from the two paired cerebral hemispheres, separated by a central fissure. In birds and mammals it is the largest and most developed part of the brain. It is covered with an infolded layer of grey matter, the cerebral cortex, which integrates brain functions. The cerebrum coordinates all voluntary activity.

Ceres

largest asteroid, 940 km/584 mi in diameter, and the first to be discovered (by Italian astronomer Giuseppe Piazzi in 1801). Ceres orbits the Sun every 4.6 years at an average distance of 414 million km/257 million mi. Its mass is about 0.014 of that of the Earth's Moon.

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cerium

chemical symbol Ce

malleable and ductile, grey, metallic element, atomic number 58, relative atomic mass 140.12. It is the most abundant member of the lanthanide series, and is used in alloys, electronic components, nuclear fuels, and lighter flints. It was discovered in 1804 by the Swedish chemists Jöns Berzelius and Wilhelm Hisinger (1766-1852), and, independently, by German chemist Martin Klaproth. The element was named after the then recently discovered asteroid Ceres.

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cermet

contraction of ceramics and metal

bonded material containing ceramics and metal, widely used in jet engines and nuclear reactors.

Cermets behave much like metals but have the great heat resistance of ceramics. Tungsten carbide, titanium, zirconium bromide, and aluminium oxide are among the ceramics used; iron, cobalt, nickel, and chromium are among the metals.

CERN

particle physics research organization founded in 1954 as a cooperative enterprise among European governments. It has laboratories at Meyrin, near Geneva, Switzerland. It houses the world's largest particle accelerator, the Large Hadron Collider (LHC), which will become operational in 2007.

CERN is the acronym of its original name, **Conseil Européen pour la Recherche Nucléaire**, but has undergone several name changes since then. Its official English name is the European Organization for Nuclear Research, though it is commonly called the European Laboratory for Particle Physics. In 1965, the original laboratory was doubled in size by extension across the border from Switzerland into France. In 1994, the 19 member nations of CERN approved the construction of the Large Hadron Collider. It is built in the tunnel previously occupied by the Large Electron Positron Collider(LEP), operational 1989-2000, with which notable advances were made in particle physics.

European Laboratory for Particle Physics

Go to site

Information about CERN, the world-class physics laboratory in Geneva. As well as presenting committees, groups, and associations hosted by the Laboratory, this official site offers important scientific material and visual evidence on the current activities and projects. Visitors will also find postings about colloquia, schools, meetings, and other services offered there. A special section is devoted to the history of the World Wide Web and the pioneering contribution of CERN in its conception and expansion.

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cervical cancer

cancer of the cervix (neck of the womb). It can be detected at an early stage through screening by cervical smear.

A vaccine for the human papillomavirus (HPV) that triggers cervical cancer is under development in the USA. Figures in 2001 showed that around 400,000 women a year develop the disease, of whom 200,000 die.

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cervical smear

in medicine, removal of a small sample of tissue from the cervix (neck of the womb) to screen for changes implying a likelihood of cancer. The procedure is also known as the **Pap test** after its originator, George Papanicolaou.

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cervix

(Latin 'neck')

abbreviation for **cervix uteri**, the neck of the womb; see uterus.

Cesalpino, Andrea (1519-1603)

Italian botanist who showed that plants could be and should be classified by their anatomy and structure. In *De plantis* (1583) Cesalpino offered the first remotely modern classification of plants. Before this plants were classed by their location – for example marsh plants, moorland plants, and even foreign plants.

Cetus

(Latin 'whale')

large constellation on the celestial equator (see celestial sphere), represented as a sea monster or a whale. Cetus contains the long-period variable star Mira, and Tau Ceti, one of the nearest stars.

It is named after the sea monster sent to devour Andromeda. Mira is sometimes the most conspicuous object in the constellation, but it is more usually invisible to the naked eye.

CFC

abbreviation for chlorofluorocarbon.

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c.g.s. system

system of units based on the centimetre, gram, and second, as units of length, mass, and time, respectively. It has been replaced for scientific work by the SI units to avoid inconsistencies in definition of the thermal calorie and electrical quantities.

chafer

beetle of the family Scarabeidae. The adults eat foliage or flowers, and the underground larvae feed on roots, chiefly those of grasses and cereals, and can be very destructive. Examples are the **cockchafer** and the **rose chafer** *Cetonia aurata*, about 2 cm/0.8 in long and bright green.

chaffinch

bird *Fringilla coelebs* of the finch family, common throughout much of Europe and West Asia. About 15 cm/6 in long, the male is olive-brown above, with a bright chestnut breast, a bluish-grey cap, and two white bands on the upper part of the wing; the female is duller. During winter they form single-sex flocks.

Chagas's disease

disease common in Central and South America, infecting approximately 18 million people worldwide. It is caused by a trypanosome parasite, *Trypanosoma cruzi*, transmitted by several species of blood-sucking insect; it results in incurable damage to the heart, intestines, and brain. It is named after Brazilian doctor Carlos Chagas (1879-1934).

It is the world's third most prevalent parasitic disease, after malaria and schistosomiasis. In its first stage symptoms resemble flu but 20-30% of sufferers develop inflammation of the heart muscles up to 20 years later.

Chain, Ernst Boris (1906-1979)

German-born British biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1945, together with Alexander Fleming and Howard Florey (Fleming for his discovery of the bactericidal effect of penicillin, and Chain and Florey for their isolation of penicillin and its development as an antibiotic drug). Chain also discovered penicillinase, an enzyme that destroys penicillin. Chain was knighted in 1969.

chain reaction

in chemistry, a succession of reactions, usually involving free radicals, where the products of one stage are the reactants of the next. A chain reaction is characterized by the continual generation of reactive substances.

A chain reaction comprises three separate stages: **initiation** - the initial generation of reactive species; **propagation** - reactions that involve reactive species and generate similar or different reactive species; and **termination** - reactions that involve the reactive species but produce only stable, nonreactive substances. Chain reactions may occur slowly (for example, the oxidation of edible oils) or accelerate as the number of reactive species increases, ultimately resulting in explosion.

chain reaction

in nuclear physics, a fission reaction that is maintained because neutrons released by the splitting of some atomic nuclei themselves go on to split others, releasing even more neutrons. Such a reaction can be controlled (as in a nuclear reactor) by using moderators to absorb excess neutrons. Uncontrolled, a chain reaction produces a nuclear explosion (as in an atom bomb).

chalaza

glutinous mass of transparent albumen supporting the yolk inside birds' eggs. The chalaza is formed as the egg slowly passes down the oviduct, when it also acquires its coiled structure.

chalcedony

form of the mineral quartz, SiO_2, in which the crystals are so fine-grained that they are impossible to distinguish with a microscope (cryptocrystalline). Agate, onyx, and carnelian are gem varieties of chalcedony.

chalcopyrite

copper iron sulphide mineral, $CuFeS_2$, the most common ore of copper. It is brassy yellow in colour and may have an iridescent surface tarnish. It occurs in many different types of mineral vein, in rocks ranging from basalt to limestone.

chalk

soft, fine-grained, whitish sedimentary rock composed of calcium carbonate, $CaCO_3$, extensively quarried for use in cement, lime, and mortar, and in the manufacture of cosmetics and toothpaste. **Blackboard chalk** in fact consists of gypsum (calcium sulphate, $CaSO_4.2H_2O$).

Chalk was once thought to derive from the remains of microscopic animals or foraminifera. In 1953, however, it was seen under the electron microscope to be composed chiefly of coccolithophores, unicellular lime-secreting algae, and hence primarily of plant origin. It is formed from deposits of deep-sea sediments called oozes.

chalk

(Image © Garret Nagle)

Soil developed on a bed of chalk. Soils develop as a result of weathering of rocks, breakdown of vegetation, and the effect of water. Chalk is an unusual rock. When it is weathered the chalk is changed to calcium bicarbonate. This is soluble and removed by running water. As a result, chalk normally does not have much material on the top of it. Chalk soils consist of a thin top soil composed of decayed vegetation.

chameleon

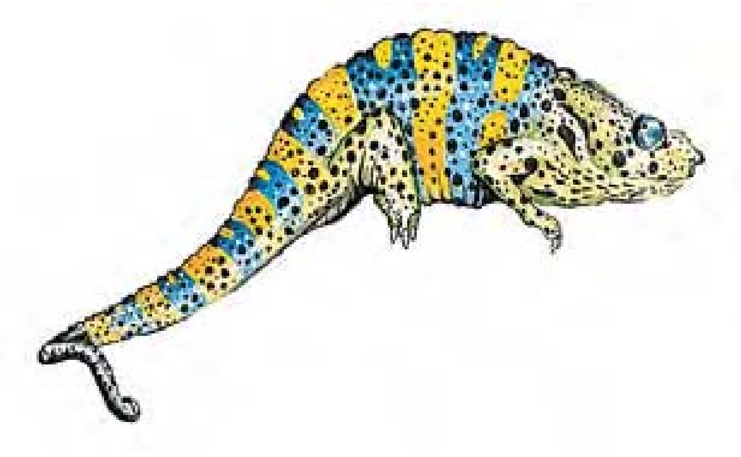
any of 80 or so species of lizard of the family Chameleontidae. Some species have highly developed colour-changing abilities, caused by stress and changes in the intensity of light and temperature, which alter the dispersal of pigment granules in the layers of cells beneath the outer skin.

The tail is long and highly prehensile, assisting the animal when climbing. Most chameleons live in trees and move very slowly.

The tongue is very long, protrusile, and covered with a viscous secretion; it can be shot out with great rapidity to 20 cm/8 in for the capture of insects. The eyes are on 'turrets', move independently, and can swivel forward to give stereoscopic vision for 'shooting'. Most live in Africa and Madagascar, but the **common chameleon** *Chameleo chameleon* is found in Mediterranean countries; two species live in southwestern Arabia, and one species in India and Sri Lanka.

Some species of chameleon, such as the African species *C. bitaeniatus* give birth to live young; the female 'gives birth' to a fully-formed young enclosed in a membrane, which is immediately shed.

chameleon



(Image © Research Machines plc)

Meller's chameleon of the savannah of Tanzania and Malawi is the largest chameleon found outside Madagascar, about 55 cm/1.7 ft long. It feeds on small birds and insects, lying in wait on branches to ambush them. Its coloration makes it very hard to see among foliage.

chameleon

(Image © Corel)

A chameleon waiting for prey. Chameleons have excellent eyesight, and a sticky pad on the end of the tongue for catching insects.

Chameleons

Go to site

Guide to the expensive and time-consuming business of looking after a pet chameleon. Would-be owners are warned not to support the trade in endangered species. Dietary and housing requirements are well explained, together with advice on what to do if your lizard is stressed, goes on hunger strike, has parasites, or does not get enough unfiltered sunlight. There are links to a number of specialist sites related to chameleons in the wild or in captivity.

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chamois

goatlike mammal *Rupicapra rupicapra* found in mountain ranges of southern Europe and Asia Minor. It is brown, with dark patches running through the eyes, and can be up to 80 cm/2.6 ft high. Chamois are very sure-footed, and live in herds of up to 30 members.

Both sexes have horns which may be 20 cm/8 in long. These are set close together and go up vertically, forming a hook at the top. Chamois skin is very soft, and excellent for cleaning glass, but the chamois is now comparatively rare and 'chamois leather' is often made from the skin of sheep and goats.

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champignon

any of a number of edible fungi (see fungus). The fairy ring champignon (*Marasmius oreades*) has this name because its fruiting bodies (mushrooms) grow in rings around the outer edge of the underground mycelium (threadlike body) of the fungus. (Family Agaricaceae.)

---

chance

likelihood, or probability, of an event taking place, expressed as a fraction or percentage. For example, the chance that a tossed coin will land heads up is 50%.

As a science, it originated when the Chevalier de Méré consulted Blaise Pascal about how to reduce his gambling losses. In 1664, in correspondence with another mathematician, Pierre de Fermat, Pascal worked out the foundations of the theory of chance. This underlies the science of statistics.

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chancroid

or soft sore

acute localized, sexually transmitted ulcer on or about the genitals, caused by the bacterium *Haemophilus ducreyi*.

It causes painful enlargement and suppuration of lymph nodes in the groin area.

Chandrasekhar, Subrahmanyan (1910-1995)

Indian-born US astrophysicist who was awarded the Nobel Prize for Physics in 1983 for his theoretical studies of the physical processes in connection with the structure and evolution of stars. The Chandrasekhar limit is the maximum mass of a white dwarf before it turns into a neutron star.

Chandrasekhar has also investigated the transfer of energy in stellar atmospheres by radiation and convection, and the polarization of light emitted from particular stars.

Chandrasekhar limit

or Chandrasekhar mass

in astrophysics, maximum possible mass of a white dwarf star. The limit depends slightly on the composition of the star but is equivalent to 1.4 times the mass of the Sun. A white dwarf heavier than the Chandrasekhar limit would collapse under its own weight to form a neutron star or a black hole. The limit is named after the Indian-born US astrophysicist Subrahmanyan Chandrasekhar, who developed the theory of white dwarfs in the 1930s.

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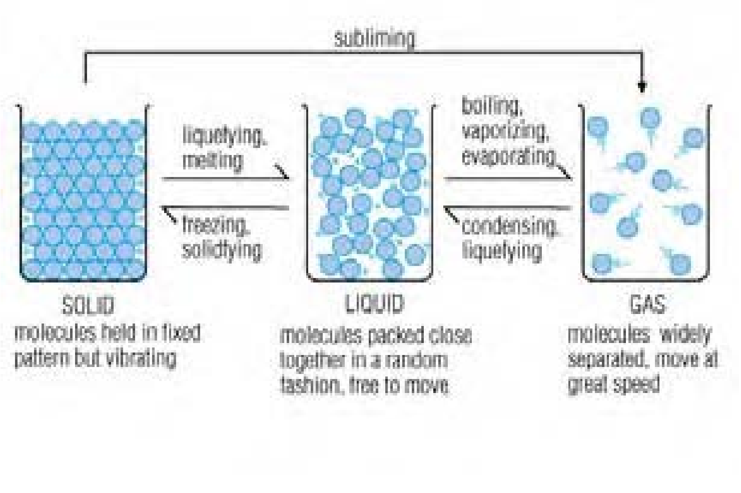
change of state

in science, change in the physical state (solid, liquid, or gas) of a material. For instance, melting, boiling, and evaporation and their opposites, solidification and condensation, are changes of state. The former set of changes are brought about by heating or decreased pressure; the latter by cooling or increased pressure.

These changes involve the absorption or release of heat energy, called latent heat, even though the temperature of the material does not change during the transition between states. See also states of matter. Changes of state can be explained by the kinetic theory of matter. In the unusual change of state called **sublimation**, a solid changes directly to a gas without passing through the liquid state. For example, solid carbon dioxide (dry ice) sublimes to carbon dioxide gas.

change of state


subliming
liquefying, melting
freezing, solidifying
boiling, vaporizing, evaporating
condensing, liquefying
SOLID
molecules held in fixed pattern but vibrating
LIQUID
molecules packed close together in a random fashion, free to move
GAS
molecules widely separated, move at great speed

(Image © Research Machines plc)

The state (solid, liquid, or gas) of a substance is not fixed but varies with changes in temperature and pressure.

Channel, English

see English Channel.

Channel Tunnel

tunnel built beneath the English Channel, linking Britain with mainland Europe. It comprises twin rail tunnels, 50 km/31 mi long and 7.3 m/24 ft in diameter, located 40 m/130 ft beneath the seabed. Construction began in 1987, and the French and English sections were linked in December 1990. It was officially opened on 6 May 1994. The shuttle train service, Le Shuttle, opened to lorries in May 1994 and to cars in December 1994. The tunnel's high-speed train service, Eurostar, linking London to Paris and Brussels, opened in November 1994.

The final cost of the tunnel was £12 billion, and left Eurotunnel plc, the Anglo-French company that built the tunnel, £9 billion in debt. In its first year, it made a loss of £925 million. Its first net profit was announced in March 1999.

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chanterelle

edible fungus that is bright yellow and funnel-shaped. It grows in deciduous woodland. (*Cantharellus cibarius*, family Cantharellaceae.)

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chaos theory

or chaology or complexity theory

branch of mathematics that attempts to describe irregular, unpredictable systems - that is, systems whose behaviour is difficult to predict because there are so many variable or unknown factors. Weather is an example of a chaotic system.

Chaos theory, which attempts to predict the *probable* behaviour of such systems, based on a rapid calculation of the impact of as wide a range of elements as possible, emerged in the 1970s with the development of sophisticated computers. First developed for use in meteorology, it has also been used in such fields as economics.

Chaos Theory: The Mathematics of Chaos

the mathematics of chaos

Why are tides predictable years ahead, whereas weather forecasts often go wrong within a few days?

Both tides and weather are governed by natural laws. Tides are caused by the gravitational attraction of the Sun and Moon; the weather by the motion of the atmosphere under the influence of heat from the Sun. The law of gravitation is not noticeably simpler than the laws of fluid dynamics; yet for weather the resulting behaviour seems to be far more complicated.

The reason for this is 'chaos', which lies at the heart of one of the most exciting and most rapidly expanding areas of mathematical research, the theory of nonlinear dynamic systems.

random behaviour in dynamic systems

It has been known for a long time that dynamic systems - systems that change with time according to fixed laws - can exhibit regular patterns, such as repetitive cycles. Thanks to new mathematical techniques, emphasizing shape rather than number, and to fast and sophisticated computer graphics, we now know that dynamic systems can also behave randomly. The difference lies not in the complexity of the formulae that define their mathematics, but in the geometrical features of the dynamics. This is a remarkable discovery: random behaviour in a system whose mathematical description contains no hint whatsoever of randomness.

Simple geometric structure produces simple dynamics. For example, if the geometry shrinks everything towards a fixed point, then the motion tends towards a steady state. But if the dynamics keep stretching things apart and then folding them together again, the motion tends to be chaotic - like food being mixed in a bowl. The motion of the Sun and Moon, on the kind of timescale that matters when we want to predict the tides, is a series of regular cycles, so prediction is easy. The changing patterns of the weather involve a great deal of stretching and folding, so here chaos reigns.

fractals

The geometry of chaos can be explored using theoretical mathematical techniques such as topology - 'rubber-sheet geometry' - but the most vivid pictures are obtained using computer graphics. The geometric structures of chaos are 'fractals': they have detailed form on all scales of magnification. Order and chaos, traditionally seen as opposites, are now viewed as two aspects of the same basic process, the evolution of a system in time. Indeed, there are now examples where both order and chaos occur naturally within a single geometrical form.

predicting the unpredictable

Does chaos make randomness predictable? Sometimes. If what looks like random behaviour is actually governed by a dynamic system, then short-term prediction becomes possible. Long-term prediction is not as easy, however. In chaotic systems any initial error of measurement, however small, will grow rapidly and eventually ruin the prediction. This is known as the butterfly effect: if a butterfly flaps its wings, a month later the air disturbance created may cause a hurricane.

Chaos can be applied to many areas of science, such as chemistry, engineering, computer science, biology, electronics, and astronomy. For example, although the short-term motions of the Sun and Moon are not chaotic, the long-term motion of the Solar System **is** chaotic. It is impossible to predict on which side of the Sun Pluto will lie in 200 million years' time. Saturn's satellite Hyperion tumbles chaotically. Chaos caused by Jupiter's gravitational field can fling asteroids out of orbit, towards the Earth. Disease epidemics, locust plagues, and irregular heartbeats are more down-to-earth examples of chaos, on a more human timescale.

making sense of chaos

Chaos places limits on science: it implies that even when we know the equations that govern a system's behaviour, we may not in practice be able to make effective predictions. On the other hand, it opens up new avenues for discovery, because it implies that apparently random phenomena may have simple, nonrandom explanations. So chaos is changing the way scientists think about what they do: the relation between determinism and chance, the role of experiment, the computability of the world, the prospects for prediction, and the interaction between mathematics, science, and nature. Chaos cuts right across traditional subject boundaries, and distinctions between pure and applied mathematicians, between mathematicians and physicists, between physicists and biologists, become meaningless when compared to the unity revealed by their joint efforts.

Chaos Club

Go to site

Introduction to chaos theory, for those with an underdeveloped mathematical background! The site includes a selection of games to illustrate the theory.

Dance of Chance

Go to site

Examination of fractal patterns in nature, including those of bacterial growth, erosion, metal deposition, and termite trails. Are they dominated by chance or are other factors involved?

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char

or charr

fish *Salvelinus alpinus* related to the trout, living in the Arctic coastal waters, and also in Europe and North America in some upland lakes. It is one of Britain's rarest fish, and is at risk from growing acidification.

Numerous variants have been described, but they probably all belong to the same species.

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characin

freshwater fish belonging to the family Characidae. There are over 1,300 species, mostly in South and Central America, but also in Africa. Most are carnivores. In typical characins, unlike the somewhat similar carp family, the mouth is toothed, and there is a small dorsal adipose fin just in front of the tail.

Characins are small fishes, often colourful, and they include tetras and piranhas.

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characteristic

in mathematics, the integral (whole-number) part of a logarithm. The fractional part is the mantissa.

For example, in base ten, $10^0 = 1$, $10^1 = 10$, $10^2 = 100$, and so on; the powers to which 10 is raised are the characteristics. To determine the power to which 10 must be raised to obtain a number between 10 and 100, say 20 (2 × 10, or log 2 + log 10), the logarithm for 2 is found (0.3010), and the characteristic 1 (log 10) added to make 1.3010.

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character set

in computing, the complete set of symbols that can be used in a program or recognized by a computer. It may include letters, digits, spaces, punctuation marks, and special symbols.

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charcoal

black, porous form of carbon, produced by heating wood or other organic materials in the absence of air. It is used as a fuel in the smelting of metals such as copper and zinc, and by artists for making black line drawings. **Activated charcoal** has been powdered and dried so that it presents a much increased surface area for adsorption; it is used for filtering and purifying liquids and gases – for example, in drinking-water filters and gas masks.

Charcoal was traditionally produced by burning dried wood in a kiln, a process lasting several days. The kiln was either a simple hole in the ground, or an earth-covered mound. Today kilns are of brick or iron, both of which allow the waste gases to be collected and used. Charcoal had many uses in earlier centuries. Because of the high temperature at which it burns (1,100°C/2,012°F), it was used in furnaces and blast furnaces before the development of coke. It was also used in an industrial process for obtaining ethanoic acid (acetic acid), in producing wood tar and wood pitch, and (when produced from alder or willow trees) as a component of gunpowder.

Charcot, Jean-Martin (1825-1893)

French neurologist who studied hysteria, sclerosis, locomotor ataxia, and senile diseases. Among his pupils was the founder of psychiatry, Sigmund Freud.

One of the most influential neurologists of his day, Charcot exhibited hysterical women at weekly public lectures, which became fashionable events. He was also fascinated by the relations between hysteria and hypnotic phenomena.

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charge

see electric charge.

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charge-coupled device

CCD

device for forming images electronically, using a layer of silicon that releases electrons when struck by incoming light. The electrons are stored in pixels and read off into a computer at the end of the exposure. CCDs are used in digital cameras, and have now almost entirely replaced photographic film for applications such as astrophotography, where extreme sensitivity to light is paramount.

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chariot

ancient two-wheeled carriage, used both in peace and war by the Egyptians, Assyrians, Babylonians, Greeks, Romans, ancient Britons, and others.

Various kinds of chariot, with different purposes, are depicted on ancient monuments and in ancient art. The most familiar is the war chariot, usually drawn by two horses. Other chariots were drawn by four horses harnessed abreast. These included the *quadriga*, or racing chariot, and the Roman *currus triumphalis*, in which victorious generals rode in triumphs (victory processions). This was round in shape and, unlike most chariots, closed behind.

Charles, Jacques Alexandre César (1746-1823)

French physicist who studied gases and made the first ascent in a hydrogen-filled balloon in 1783. His work on the expansion of gases led to the formulation of Charles's law.

Hearing of the hot-air balloons of the Montgolfier brothers, Charles and his brothers began experimenting with hydrogen balloons and made their ascent only ten days after the Montgolfiers' first flight. In later flights Charles ascended to an altitude of 3,000 m/10,000 ft.

Charles's law

law stating that the volume of a given mass of gas at constant pressure is directly proportional to its absolute temperature (temperature in kelvins). It was discovered by French physicist Jacques Charles in 1787, and independently by French chemist Joseph Gay-Lussac in 1802.

According to Charles's Law, the volume of a gas increases by 1/273 (0.003663) of its volume at 0°C for each °C rise of temperature. This means that the coefficient of expansion of all gases is the same. The law is only approximately true.

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charm

in physics, a property possessed by elementary particles, including one type of quark (very small particles found inside protons and neutrons), called the charm quark. The effects of charm are only seen in experiments with particle accelerators.

Chauvin, Yves (1930-)

French chemist, who with US chemists Robert H Grubbs and Richard R Schrock shared the Nobel Prize in Chemistry in 2005 for his contributions to the understanding of metathesis reactions (the interchange of radicals or groups of atoms in a compound) in organic chemistry.

Chauvin won his share of the Nobel Prize for his work in 1971 explaining how metathesis reactions functioned and postulating what types of metal compound would act as a catalyst for these reactions. Metathesis has since become an established method in the chemistry industry and is used routinely in the production of advanced plastics and pharmaceuticals. Chemical synthesis using metathesis reactions is widely regarded as a more efficient and environmentally friendly method than those previously used.

Chavín de Huantar

archaeological site in the Peruvian Andes, 3,135 m/10,000 ft above sea level, thought to be 'the womb of Andean civilization'. Its influence peaked between 1000 and 300 BC.

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cheetah

large wild cat *Acinonyx jubatus* native to Africa, Arabia, and southwestern Asia, but now rare in some areas. Yellowish with black spots, it has a slim lithe build. It is up to 1 m/3 ft tall at the shoulder, and up to 1.5 m/5 ft long. It can reach 103 kph/64 mph, but tires after about 400 yards. Cheetahs live in open country where they hunt small antelopes, hares, and birds.

A cheetah's claws do not retract as fully as in most cats. It is the world's fastest mammal. Cheetahs face threats both from ranchers who shoot them as vermin and from general habitat destruction that is reducing the prey on which they feed, especially gazelles. As a result the wild population is thought to have fallen by over half since the 1970s; there are now thought to be no more than 5,000-12,000 left.

cheetah

The cheetah can accelerate from zero to 72 kmph/45 mph in two seconds.

Cheetah

Go to site

Details about this fast-moving predator. The page contains information about the appearance, breeding habits, and typical height and weight of the animal.

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chelate

chemical compound whose molecules consist of one or more metal atoms or charged ions joined to chains of organic residues by two or more coordinate (or dative covalent) chemical bonds.

The parent organic compound is known as a **chelating agent** - for example, EDTA (ethylene-diaminetetra-acetic acid), used in chemical analysis. Chelating agents 'grip' the metal ion from several sides at once (six in the case of EDTA), making it extremely unlikely that random movements of any of the coordinating groups lead to a detachment of the entire molecule. This is why they are extremely effective at binding and keeping hold of suitably sized metal ions.

Chelates are used in analytical chemistry, in agriculture and horticulture as carriers of essential trace metals, in water softening, and in the treatment of thalassaemia by removing excess iron, which may build up to toxic levels in the body. Metalloproteins (natural chelates) may influence the performance of enzymes or provide a mechanism for the storage of iron in the spleen and plasma of the human body.

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chemical change

change that occurs when two or more substances (reactants) interact with each other, resulting in the production of different substances (products) with different chemical compositions. A simple example of chemical change is the burning of carbon in oxygen to produce carbon dioxide (combustion). Other types of chemical change include decomposition, oxidation, and reduction.

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chemical element

alternative name for element.

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chemical equation

method of indicating the reactants and products of a chemical reaction by using chemical symbols and formulae. A chemical equation gives two basic pieces of information: (1) the reactants (on the left-hand side) and products (right-hand side); and (2) the reacting proportions (stoichiometry) – that is, how many units of each reactant and product are involved. The equation must balance; that is, the total number of atoms of a particular element on the left-hand side must be the same as the number of atoms of that element on the right-hand side.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$

reactants →products

This equation states that one molecule of sodium carbonate combines with two molecules of hydrochloric acid to form two molecules of sodium chloride, one of carbon dioxide, and one of water. Double arrows indicate that the reaction is reversible – in the formation of ammonia from hydrogen and nitrogen, the direction of the reaction depends on the temperature and pressure of the reactants.

$3H_2 + N_2 \leftrightarrow 2NH_3$

Introduction to Chemical Equations

Go to site

Essay that introduces the concept of chemical equations to the reader. The text is accompanied by explanatory diagrams.

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chemical equilibrium

condition in which the products of a chemical reaction are formed at the same rate at which they decompose back into the reactants, so that the concentration of each reactant and product remains constant. It is a reversible reaction; the reaction can happen in both directions.

For example, in the Haber process, nitrogen and hydrogen combine to form ammonia, but as the ammonia is formed, it breaks down again into nitrogen and hydrogen.

$N_2 + 3H_2 \leftrightarrow 2NH_3$

At equilibrium, the forward and back reactions occur at the same rate. As fast as ammonia is being formed it is broken down into hydrogen and nitrogen, therefore, the amounts of nitrogen, hydrogen, and ammonia remain constant at equilibrium.

The amounts of reactant and product present at equilibrium are defined by the **equilibrium constant** for that reaction and specific temperature.

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chemical family

collection of elements that have very similar chemical and physical properties. In the periodic table of the elements such collections are to be found in the vertical columns (groups). The groups that contain the most markedly similar elements are group I, the alkali metals; group II, the alkaline-earth metals; group VII, the halogens; and group 0, the noble or rare gases.

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chemical oxygen demand

COD

measure of water and effluent quality, expressed as the amount of oxygen (in parts per million) required to oxidize the reducing substances present.

Under controlled conditions of time and temperature, a chemical oxidizing agent (potassium permanganate or dichromate) is added to the sample of water or effluent under consideration, and the amount needed to oxidize the reducing materials present is measured. From this the chemically equivalent amount of oxygen can be calculated. Since the reducing substances typically include remains of living organisms, COD may be regarded as reflecting the extent to which the sample is polluted. Compare biological oxygen demand.

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chemical weathering

form of weathering brought about by chemical attack on rocks, usually in the presence of water. Chemical weathering involves the breakdown of the original minerals within a rock to produce new minerals (such as clay minerals, bauxite, and calcite). The breakdown of rocks occurs because of chemical reactions between the minerals in the rocks and substances in the environment, such as water, oxygen, and weakly acidic rainwater. Some chemicals are dissolved and carried away from the weathering source, while others are brought in.

Material worn away from rocks by weathering, either as fragments of rock or dissolved material, may be transported and deposited as sediments, which eventually become compacted to form sedimentary rocks. Thus chemical weathering plays a part in the rock cycle.

Chemical processes involved in weathering include carbonation (breakdown by weakly acidic rainwater), hydrolysis (breakdown by water), hydration (breakdown by the absorption of water), and oxidation (breakdown by the oxygen in air and water).

The reaction of carbon dioxide gas in the atmosphere with silicate minerals in rocks to produce carbonate minerals is called the 'Urey reaction' after the chemist who proposed it, Harold Urey. The Urey reaction is an important link between Earth's climate and the geology of the planet. It has been proposed that chemical weathering of large mountain ranges like the Himalayas can remove carbon dioxide from the atmosphere by the Urey reaction (or other more complicated reactions like it), leading to a cooler climate as the greenhouse effects of the lost carbon dioxide are diminished.

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chemiluminescence

the emission of light from a substance as a result of a chemical reaction (rather than raising its temperature). See luminescence.

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chemisorption

attachment, by chemical means, of a single layer of molecules, atoms, or ions of gas to the surface of a solid or, less frequently, a liquid. It is the basis of some types of catalysis (see catalyst) and is of great industrial importance.

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chemistry

branch of science concerned with the study of the structure and composition of the different kinds of matter, the changes that matter may undergo, and the phenomena which occur in the course of these changes.

Organic chemistry is the branch of chemistry that deals with carbon compounds.
Inorganic chemistry deals with the description, properties, reactions, and preparation of all the elements and their compounds, with the exception of carbon compounds.
Physical chemistry is concerned with the quantitative explanation of chemical phenomena and reactions, and the measurement of data required for such explanations. This branch studies in particular the movement of molecules and the effects of temperature and pressure, often with regard to gases and liquids.

Chemistry

the origins of chemistry

Chemistry seems to have originated in Egypt and Mesopotamia several thousand years before Christ. Certainly by about 3000 BC the Egyptians had produced the copper-tin alloy known as bronze, by heating the ores of copper and tin together, and this new material was soon common enough to be made into tools, ornaments, armour, and weapons. The Ancient Egyptians were also skilled at extracting juices and infusions from plants, and pigments from minerals, which they used in the embalming and preserving of their dead. By 600 BC the Greeks were also becoming a settled and prosperous people with leisure time in which to think. They began to turn their attention to the nature of the universe and to the structure of its materials. They were thus the first to study the subject we now call chemical theory. The Greek philosopher Aristotle (384-322 BC) proposed that there were four elements – earth, air, fire, and water – and that everything was a combination of these four. They were thought to possess the following properties: earth was cold and dry, air was hot and moist, fire was hot and dry, and water was cold and moist. The idea of the four elements persisted for 2,000 years. The Greeks also worked out, at least hypothetically, that matter ultimately consisted of small indivisible particles, *atomos* – the origin of our word 'atom'.

From the Egyptians and the Greeks comes *khemeia*, alchemy and eventually chemistry as we know it today. The source of the word *khemeia* is debatable, but it is certainly the origin of the word chemistry. It may derive from the Egyptians' word for their country *Khem*, 'the black land'. It may come from the Greek word *khumos* (the juice of a plant), so that *khemeia* is 'the art of extracting juices'; or from the Greek *cheo* 'pour or cast', which refers to the activities of the metal workers. Whatever its origin, the art of *khemeia* soon became akin to magic and was feared by the ordinary people. One of the greatest aims of the subject involved the attempts to transform base metals such as lead and copper into silver or gold. From the four-element theory, it seemed that it should be possible to perform any such change, if only the proper technique could be found.

the Arabs and alchemy

With the decline of the Greek empire *khemeia* was not pursued and little new was added to the subject until it was embraced by the increasingly powerful Arabs in the 7th century AD. Then for five centuries *al-kimiya*, or alchemy, was in their hands. The Arabs drew many ideas from the *khemeia* of the Greeks, but they were also in contact with the Chinese – for example, the idea that gold possessed healing powers came from China. They believed that 'medicine' had to be added to base metals to produce gold, and it was this medicine that was to become the philosopher's stone of the later European alchemists. The idea that not only could the philosopher's stone heal 'sick' or base metals, but that it could also act as the elixir of life, was also originally Chinese. The Arab alchemists discovered new classes of chemicals such as the caustic alkalis (from the Arabic *al-qalíy*) and they improved technical procedures such as distillation.

Western Europe had its first contact with the Islamic world as a result of the Crusades. Gradually the works of the Arabs - handed down from the Greeks - were translated into Latin and made available to European scholars in the 12th and 13th centuries. Many people spent their lives trying in vain to change base metals into gold; and many alchemists lost their heads for failing to supply the promised gold.

the beginning of modern chemistry

A new era in chemistry began with the researches of Irish chemist Robert Boyle (1627-1691), who carried out many experiments on air. These experiments were the beginning of a long struggle to find out what air had to do with burning and breathing. From Boyle's time onwards, alchemy became chemistry and it was realized that there was more to the subject than the search for the philosopher's stone.

chemistry as an experimental science

During the 1700s the phlogiston theory gained popularity. It went back to the alchemists' idea that combustible bodies lost something when they burned. Metals were thought to be composed of a calx (different for each) combined with phlogiston, which was the same in all metals. When a candle burned in air, phlogiston was given off. It was believed that combustible objects were rich in phlogiston and what was left after combustion possessed no phlogiston and would therefore not burn. Thus wood possessed phlogiston but ash did not; when metals rusted, it was considered that the metals contained phlogiston but that its rust or calx did not. By 1780 this theory was almost universally accepted by chemists. English chemist Joseph Priestley (1733-1804) was a supporter of the theory and in 1774 he had succeeded in obtaining from mercuric oxide a new gas which was five or six times purer than ordinary air. It was, of course, oxygen but Priestley called it 'dephlogisticated air' because a smouldering splint of wood thrust into an atmosphere of this new gas burst into flames much more readily than it did in an ordinary atmosphere. He took this to mean that the gas must be without the usual content of phlogiston, and was therefore eager to accept a new supply.

It was French chemist Antoine Lavoisier (1743-1794) who put an end to the phlogiston theory by working out what was really happening in combustion. He repeated Priestley's experiments in 1775 and named the dephlogisticated air oxygen. He realized that air was not a single substance but a mixture of gases, made up of two different gases in the proportion of 1 to 4. He deduced that one-fifth of the air was Priestley's dephlogisticated air (oxygen), and that it was this part only that combined with rusting or burning materials and was essential to life. Oxygen means 'acid-producer' and Lavoisier thought, erroneously, that oxygen was an essential part of all acids. He was a careful experimenter and user of the balance, and from his time onwards experimental chemistry was concerned only with materials that could be weighed or otherwise measured. All the 'mystery' disappeared and Lavoisier went on to work out a logical system of chemical nomenclature, much of which has survived to the present day.

the 19th century

Early in the 19th century many well-known chemists were active. French chemist Claude Berthollet (1748-1822) worked on chemical change and composition, and French chemist Joseph Gay-Lussac (1778-1850) studied the volumes of gases that take part in chemical reactions. Others included Berzelius, Cannizzaro, Avogadro, Davy, Dumas, Kolbe, Wöhler, and Kekulé. The era of modern chemistry was beginning.

atomic theory and new elements

An English chemist, John Dalton (1766-1844), founded the atomic theory in 1803 and in so doing finally crushed the belief that the transmutation to gold was possible. He realized that the same two elements can combine with each other in more than one set of proportions, and that the variation in combining proportions gives rise to different compounds with different properties. For example, he determined that one part (by weight) of hydrogen combined with eight parts of oxygen to form water, and if it was assumed (incorrectly) that a molecule of water consisted of one atom of hydrogen and one atom of oxygen, then it was possible to set the mass of the hydrogen atom arbitrarily at 1 and call the mass of oxygen 8 (on the same scale). In this way Dalton set up the first table of atomic weights (now called relative atomic masses), and although this was probably his most important achievement, it contained many incorrect assumptions. These errors and anomalies were researched by Swedish chemist Jöns Berzelius (1779-1848), who found that for many elements the atomic weights were not simple multiples of that of hydrogen. For many years, oxygen was made the standard and set at 16.000 until the mid-20th century, when carbon (= 12.000) was adopted. Berzelius suggested representing each element by a symbol consisting of the first one or two letters of the name of the element (sometimes in Latin) and these became the chemical symbols of the elements as still used today.

At about the same time, in 1808, English chemist Humphry Davy (1778-1829) was using an electric current to obtain from their oxides elements that had proved to be unisolatable by chemical means: potassium, sodium, magnesium, barium, and calcium. His assistant, English physicist Michael Faraday (1791-1867), was to become even better known in connection with this technique, electrolysis. By 1830, more than 50 elements had been isolated; chemistry had moved a long way from the four elements of the ancient Greeks, but their properties seemed to be random. In 1829 the German chemist Johann Döbereiner (1780-1849) thought that he had observed some slight degree of order. He wondered if it was just coincidence that the properties of the element bromine seemed to lie between those of chlorine and iodine, but he went on to notice a similar gradation of properties in the triplets calcium, strontium, and barium and with sulphur, selenium, and tellurium. In all of these examples, the atomic weight of the element in the middle of the set was about half-way between the atomic weights of the other two elements. He called these groups 'triads', but because he was unable to find any other such groups, most chemists remained unimpressed by his discovery. Then in 1864 English chemist John Newlands (1837-1898) arranged the elements in order of their increasing atomic weights and found that if he wrote them in horizontal rows, and started a new row with every eighth element, similar elements tended to fall in the same vertical columns. Döbereiner's three sets of triads were among them. Newlands called this his 'Law of Octaves' by analogy with the repeating octaves in music. Unfortunately there were many places in his chart where obviously dissimilar elements fell together and so it was generally felt that Newland's similarities were not significant but probably only coincidental. He did not have his work published.

In 1862 a German chemist, Julius Lothar Meyer (1830-1895), looked at the volumes of certain fixed weights of elements, and talked of atomic volumes. He plotted the values of these for each element against its atomic weight, and found that there were sharp peaks in the graph at the alkali metals - sodium, potassium, rubidium, and caesium. Each part of the graph between the peaks corresponded to a 'period' or horizontal row in the table of the elements, and it became obvious where Newlands had gone wrong. He had assumed that each period contained only seven elements; in fact the later periods had to be longer than the earlier ones. By the time Meyer published his findings, he had been anticipated by the Russian chemist Dmitri Mendeleyev (1834-1907), who in 1869 published his version of the periodic table, which was more or less as we have it today. He had the insight to leave gaps in his table for three elements which he postulated had not yet been discovered, and was even able to predict what their properties would be. Chemists were sceptical, but within 15 years all three of the 'missing' elements had been discovered and their properties were found to agree with Mendeleyev's predictions.

the beginnings of physical chemistry

Until the beginning of the 19th century, the areas covered by the subjects of chemistry and physics seemed well defined and quite distinct. Chemistry studied changes where the molecular bonding structure of a substance was altered, and physics studied phenomena in which no such change occurred. Then in 1840 physics and chemistry merged in the work of Swiss-born Russian chemist Germain Hess (1802-1850). It had been realized that heat - a physical phenomenon - was produced by chemical reactions such as the burning of wood, coal, and oil, and it was gradually becoming clear that all chemical reactions involved some sort of heat transfer. Hess showed that the quantity of heat produced or absorbed when one substance was changed into another was the same no matter by which chemical route the change occurred, and it seemed likely that the law of conservation of energy was equally applicable to chemistry and physics. Thermochemistry had been founded and work was able to begin on thermodynamics. Most of this research was done in Germany and it was Latvian-born German chemist Wilhelm Ostwald (1853-1932), towards the end of the 19th century, who was responsible for physical chemistry developing into a discipline in its own right. He worked on chemical kinetics and catalysis in particular, but was the last important scientist to refuse to accept that atoms were real - there was at that time still no direct evidence to prove that they existed. Other contemporary chemists working in the new field of physical chemistry included Dutch physical chemist Jacobus van't Hoff (1852-1911) and Swedish physical chemist Svante Arrhenius (1859-1927). Van't Hoff studied solutions and showed that molecules of dissolved substances behaved according to rules analogous to those that describe the behaviour of gases. Arrhenius carried on the work which had been begun by Davy and Faraday on solutions that could carry an electric current. Faraday had called the current-carrying particles 'ions', but nobody had worked out what they were. Arrhenius suggested that they were atoms or groups of atoms which bore either a positive or a negative electric charge. His theory of ionic dissociation was used to explain many of the phenomena in electrochemistry.

gases

Towards the end of the 19th century, mainly as a result of the increasing interest in the physical side of chemistry, gases came under fresh scrutiny and some errors were found in the law that had been proposed three centuries earlier by Robert Boyle. German-born French physical chemist Henri Regnault (1810-1878), Scottish physicist James Clerk Maxwell (1831-1879) and Austrian theoretical physicist Ludwig Boltzmann (1844-1906) had all worked on the behaviour of gases, and the kinetic theory of gases had been derived. Taking all their findings into account, Dutch physicist Johannes van der Waals (1837-1923) arrived at an equation that related pressure, volume, and temperature of gases and made due allowance for the sizes of the different gas molecules and the attractions between them. By the end of the century Scottish chemist William Ramsay (1852-1916) had begun to discover a special group of gases - the inert or rare gases - which have a valency (oxidation state) of zero and which fit neatly into the periodic table between the halogens and the alkali metals.

organic chemistry becomes a separate discipline

Meanwhile the separate branches of chemistry were emerging and organic substances were being distinguished from inorganic ones. In 1807 Berzelius had proposed that substances such as olive oil and sugar, which were products of living organisms, should be called organic, whereas sulphuric acid and salt should be termed inorganic. Chemists at that time had realized that organic substances were easily converted into inorganic substances by heating or in other ways, but it was thought to be impossible to reverse the process and convert inorganic substances into organic ones. They believed in Vitalism - that somehow life did not obey the same laws as did inanimate objects and that some special influence, a 'vital force', was needed to convert inorganic substances into organic ones. Then in 1828 German chemist Friedrich Wöhler (1800-1882) succeeded in converting ammonium cyanate (an inorganic compound) into urea. In 1845 German chemist Adolf Kolbe (1818-1884) synthesized acetic acid, squashing the Vitalism theory forever. By the middle of the 19th century organic compounds were being synthesized in profusion; a new definition of organic compounds was clearly needed, and most organic chemists were working by trial and error. Nevertheless there was a teenage assistant of German organic chemist August von Hofmann (1818-1892), the English chemist William Perkin (1838-1907), who was able to retire at the age of only 35 because of a brilliant chance discovery. In 1856 he treated aniline with potassium chromate, added alcohol, and obtained a beautiful purple colour, which he suspected might be a dye (later called aniline purple or mauve). He left school and founded what became the synthetic dyestuffs industry.

Then in 1861 the German chemist Friedrich Kekulé (1829-1886) defined organic chemistry as the chemistry of carbon compounds and this definition has remained, although there are a few carbon compounds (such as carbonates) which are considered to be part of inorganic chemistry. Kekulé suggested that carbon had a valency of four, and proceeded to work out the structures of simple organic compounds on this basis. These representations of the structural formulae showed how organic molecules were generally larger and more complex than inorganic molecules. There was still the problem of the structure of the simple hydrocarbon benzene, C_6H_6, until 1865 when Kekulé suggested that rings of carbon atoms might be just as possible as straight chains. The idea that molecules might be three-dimensional came in 1874 when van't Hoff suggested that the four bonds of the carbon atom were arranged tetrahedrally. If these four bonds are connected to four different types of groups, the carbon atom is said to be asymmetric and the compound shows optical activity - its crystals or solutions rotate the plane of polarized light. German organic chemist Viktor Meyer (1848-1897) proposed that certain types of optical isomerism could be explained by bonds of nitrogen atoms. French-born Swiss chemist Alfred Werner (1866-1919) went on to demonstrate that this principle also applied to metals such as cobalt, chromium, and rhodium, and succeeded in working out the necessary theory of molecular structure, known as coordination theory. This new approach allowed there to be structural relationships within certain fairly complex inorganic molecules, which were not restricted to bonds involving ordinary valencies. It was to be another 50 years before enough was known about valency for both Kekulé's theory and Werner's to be fully understood, but by 1900 the idea was universally accepted that molecular structure could be represented satisfactorily in three dimensions.

modern synthetic organic chemistry

Kekulé's work gave the organic chemist scope to alter a structural formula stage by stage, to convert one molecule into another, and modern synthetic organic chemistry began. Practical techniques for the synthesis of organic compounds were developed. French chemists Paul Sabatier (1854-1941) and Jean Senderens (1856-1936) discovered the Sabatier-Senderens reduction, Grignard and Gilman reagents were developed by French chemist Victor Grignard (1871-1935) and US chemist Henry Gilman (1893-1986) respectively, and German organic chemists Kurt Alder (1902-1958) and Otto Diels (1976-1954) found a method to synthesize cyclic carbon compounds, an essential step in drug development. New advances continued to be made throughout the 19th century.

In 1954, the Wittig reaction, a route to produce unsaturated hydrocarbons, was developed by German chemist George Wittig (1897-1987). In the 1960s US chemist Charles Pedersen (1904-1990), French chemist Jean Marie Lehn (1939-), and US chemist Donald Cram (1919-) discovered and developed crown ethers, cryptands and crytates, versatile organic reagents with broad applications in biochemistry and organic synthesis. US chemist Elias J Corey (1928-) developed retrosynthesis, a powerful tool for building complex molecules from smaller, cheaper, and more readily available ones. Retrosynthesis can be used to picture a molecule like a jigsaw, working backwards to find reactive components to complete the puzzle. Modern chemists use retrosynthesis to design everything from insect repellents to better drugs.

Significant advances also occurred in the field of structural analysis. In 1909 German physicist Max von Laue (1879-1960) began a series of brilliant experiments. He established that crystals consist of atoms arranged in a geometric structure of regularly repeating layers, and that these layers scatter X-rays in a set pattern. In so doing, he had set the scene for X-ray crystallography to be used to help to work out the structures of large molecules for which chemists had not been able to determine formulae. This field was advanced by scientists such as English physicist Lawrence Bragg (1890-1971), English chemist and X-ray crystallographer Rosalind Franklin (1920-1958), and English biochemist Dorothy Hodgkin (1910-1994) who developed the technique to allow the determination of a wide range of crystal structures, from common salt to DNA and insulin.

German organic chemist Richard Willstätter (1872-1942) was able to work out the structure of chlorophyll and another German organic chemist, Heinrich Wieland (1877-1957), determined the structures of steroids. Russian-born Swiss chemist Paul Karrer (1889-1971) elucidated the structures of the carotenoids and other vitamins and English organic chemist Robert Robinson (1886-1975) tackled the alkaloids - he worked out the structures of morphine and strychnine. The alkaloids have found medical use as drugs, as have many other organic compounds. The treatment of disease by the use of specific chemicals is known as chemotherapy and was founded by the German bacteriologist Paul Ehrlich (1854-1915). The first anti-bacterial drug, protosil red, was discovered by German chemist Gerhard Domagk (1895-1964). A series of drugs known as the sulpha drugs were developed from his discovery. The need for drugs to combat disease and infection during World War II spurred on research, and by 1945 the antibiotic penicillin, first isolated by Australian-born British bacteriologist Howard Florey (1898-1968) and German-born British biochemist Ernst Chain (1906-1979), was being produced in quantity. Other antibiotics such as streptomycin and the tetracyclines soon followed.

In 1912, Polish-born US biochemist Casimir Funk (1884-1967) isolated vitamin B from yeast. A year later US biochemist Elmer McCollum (1884-1967) discovered vitamin A and found vitamin D in 1920. Hungarian-born US biochemist Albert Szent-Györgyi (1893-1986) isolated vitamin C from cabbages. Vitamin E was isolated by US chemists soon afterwards. Once the vitamins had been isolated in pure form, their structure could be determined. The structure of vitamin B_1 was determined in 1934 and, by the 1940s, most of the vitamins we know today had been found, isolated, and synthesized in laboratories.

Some organic molecules contain thousands of atoms; some, such as rubber, are polymers and others, such as haemoglobin, are proteins. German organic chemist Hermann Staudinger (1881-1965) pioneered the concept of macromolecules and his theories formed the foundation of polymer science. Synthetic polymers have been made which closely resemble natural rubber; the leader in this field was US organic chemist Wallace Carothers (1896-1937), who also invented nylon. German organic chemist Karl Ziegler (1898-1973) and Italian chemist Giulio Natta (1903-1979) worked out how to prevent branching during polymerization, so that plastics, films, and fibres can now be made more or less to order. Work on the make-up of proteins had to wait for the development of chemical techniques such as chromatography (by Italian-born Russian botanist Mikhail Tswett (1872-1919) and by English biochemists Archer Martin (1910-) and Richard Synge (1914-1994)) and electrophoresis (by Swedish chemist Arne Tiselius (1902-1971)). In the forefront of molecular biological research are English biochemists Frederick Sanger (1918-), John Kendrew (1917-1997), and Austrian-born British molecular biologist Max Perutz (1914-).

the rise of the chemical industry

The 20th century was a time of advancement and discovery for the chemical industry. German chemists Fritz Haber (1868-1934) and Carl Bosch (1874-1940) developed industrial techniques using high pressures, catalysts, and high temperatures to manufacture chemicals that could not be produced economically in the 19th century, notably nitrogen fixation which lead the development of modern artificial fertilisers and explosives. The 19th century chemical industry had been based on the conversion of coal to chemicals. This was superseded by developments in the USA in the 20th century. Pioneers such as US chemist William Burton (1865-1964), French-born US inventor Eugene Houdry (1892-1962),and US chemical engineer Warren K Lewis (1882-1975) developed techniques for the conversion of petroleum oil and natural gas into chemicals. Compounds produced in this way are called petrochemicals. This route allowed chemicals to be produced cheaper and in greater quantities than ever before. Petroleum also provided the chemical industry with a variety of previously unavailable feedstocks which lead to the development of plastics, synthetic rubber, and synthetic fibres. Materials such as nylon, Teflon, Lycra, and neoprene rubber were developed from the 1930s onwards.

modern atomic theory

In 1897 English physicist J J Thomson (1856-1940) proved the existence of the first subatomic particle, the negatively charged electron. New Zealand-born British physicist Ernest Rutherford (1871-1937) deduced that the unit of positive charge was a particle quite different from the electron, which was the unit of negative charge, and in 1920 he suggested that this fundamental positive particle be called the proton. In 1895 German physicist Wilhelm Röntgen (1845-1923) discovered X-rays, but other known radiation components

- alpha and beta rays - were found to be made up of protons and electrons.

1n 1911, Rutherford evolved his theory of the nuclear atom, which suggested that sub-atomic particles made up the atom. Rutherford's model of the atom had most of its mass located in a small positively charged core called a nucleus surrounded by a mist of electrons which occupied almost all of the space. Why the negatively charged electrons were not drawn into the nucleus was explained by Danish physicist Niels Bohr (1885-1962), who postulated that the electrons orbited the nucleus in stable orbits called shells.

In about 1902 it was proved, contrary to all previous ideas, that radioactive elements changed into other elements, and by 1912 the complicated series of changes of these elements had been worked out. In the course of this research, English chemist Frederick Soddy (1877-1956) realized that there could be several atoms differing in mass but having the same properties. They were called isotopes and we now know that they differ in the number of neutrons which they possess, although the neutron was not to be discovered until 1932, by the English physicist James Chadwick (1891-1974). The question now was, how did the nuclear atom of one element differ from that of another?

In 1913 the young English scientist Henry Moseley (1887-1915) found that there were characteristic X-rays for each element and that there was an inverse relationship between the wavelength of the X-ray and the atomic weight of the element. This relationship depended on the size of the positive charge on the nucleus of the atom, and the size of this nuclear charge is called the atomic number. Mendeleyev had arranged his periodic table, by considering the valencies of the elements, in sequence of their atomic weights, but the proper periodic classification is by atomic numbers. Scientists used this discovery to update the periodic table into the form it is used in today. It was now possible to predict exactly how many elements were still to be discovered. Since the proton is the only positively charged particle in the nucleus, the atomic number is equal to the number of protons; the neutrons contribute to the mass but not to the charge. For example, a sodium atom, with an atomic number of 11 and an atomic weight (relative atomic mass) of 23, has 11 protons and 12 neutrons in its nucleus.

isotopes and biochemistry

The new electronic atom was also of great interest to organic chemists. It enabled theoreticians such as English organic chemist Christopher Ingold (1893-1970) to try to interpret organic reactions in terms of the movements of electrons from one point to another within a molecule. Physical chemical methods were being used in organic chemistry, founding physical organic chemistry as a separate discipline. US theoretical chemist and biologist Linus Pauling (1911-1994), who was to suggest in the 1950s that proteins and nucleic acids possessed a helical shape, worked on the wave properties of electrons, and established the theory of resonance. This idea was very useful in establishing that the structure of the benzene molecule possessed 'smeared out' electrons and was a resonance hybrid of the two alternating double bond/single bond structures. The concept of isotopes was clarified by English chemist and physicist Francis Aston (1877-1945) with the mass spectrograph. This instrument used electric and magnetic fields to deflect ions of identical charge by an extent that depended on their mass - the greater the mass of the ion, the less it was deflected. He found for instance that there were two kinds of neon atoms, one of mass 20 and one of mass 22. The neon-20 was ten times as common as the neon-22, and so it seemed reasonable that the atomic weight of the element was 20.2 - a weighted average of the individual atoms and not necessarily a whole number. In some cases, the weighted average (atomic weight) of a particular atom may be larger than that for an atom of higher atomic number. This explains the relative positions of iodine and tellurium in the periodic table, which Mendeleyev had placed correctly without knowing why.

In 1931 US chemist Harold Urey (1893-1981) discovered that hydrogen was made up of a pair of isotopes, and he named hydrogen-2 deuterium. In 1934 it occurred to the Italian-born US physicist Enrico Fermi (1901-1954) to bombard uranium (element number 92, the highest atomic number known at that time) to see whether he could produce any elements of higher atomic numbers. This approach was pursued by US nuclear chemist Glenn Seaborg (1912-1999) and the transuranium elements were discovered, going up from element 94 but becoming increasingly difficult to form and decomposing again more rapidly with increasing atomic number.

In November 1994, researchers working at the GSI heavy-ion cyclotron at Darmstadt, Germany, produced element 110. The element, atomic mass 269, was produced when atoms of lead were bombarded with atoms of nickel. As is usual for super heavy atoms, the new element has a very short half-life; it decayed in less than a millisecond. A second element was discovered in December 1994. Three atoms of element 111, atomic mass 272, were detected when bismuth-209 was bombarded with nickel atoms. It decayed into two previously unknown isotopes of elements 109 and 107 after about a millisecond. In February 1996 element 112 was discovered by the same team. Elements 114, 116, and 118 were created in 1999.

the boundaries between chemistry and other sciences

The area between physics and chemistry has been replaced by a common ground where atoms and molecules are studied together with the forces that influence them. A good example is the discovery in the early 1990s of a new form of carbon, with molecules called buckyballs, consisting of 60 carbon atoms arranged in 12 pentagons and 20 hexagons to form a perfect sphere.

The boundary between chemistry and biology has also become less well defined and is now a scene of intense activity, with the techniques of chemistry being applied successfully to biological problems. Electron diffraction, chromatography, and radioactive tracers have all been used to help discover what living matter is composed of, although it is possible that these investigations in biology are only now at the stage that atomic physics was at the beginning of this century. It was Lavoisier who said that life is a chemical function, and perhaps the most important advance of all is towards understanding the chemistry of the cell. Biochemical successes of recent years include the synthesis of human hormones, the development of genetic fingerprinting, and the use of enzymes in synthesis. The entire field of genetic engineering is essentially biochemistry.

the negative face of chemistry

The advances in chemistry have come with a price. The sheer scale of the chemical industry has led to global pollution, environmental damage, and the development of chemical and biological weapons. As most chemicals are manufactured from petroleum, huge quantities of crude oil have to be transported all over the world. Accidents such as the *Exxon Valdez* oil spill in Alaska's Prince William Sound or deliberate releases such as during the Gulf War by the Iraqi forces, cause catastrophic environmental damage. Waste products from chemical manufacture have polluted water supplies and the widespread use of aerosols and chlorinated solvents was shown by US chemist F Sherwood Roland (1927-), Mexican chemist Mario Molina (1943-), and Dutch chemist Paul Crutzen (1933-) to accelerate ozone depletion in the upper atmosphere. Greenhouse gas production and acid rain are consequences of the dependence on fossil fuels to provide industry with energy. The misuse of drugs, especially antibiotics has lead to the emergence of resistant strains of bacteria, and the overuse of fertilisers has introduced levels of nitrates into the environment, poisoning water supplies and killing aquatic life. The indiscriminate use of insecticides such as DDT, highlighted in US science writer Rachel Carson's (1907-1964) influential book *Silent Spring*, have had adverse effects, such as the emergence of chemical-resistant insects and the killing of beneficial insect species. A particularly dark aspect of industrial production is the availability of poisonous chemical agents in sufficient quantities for creating a viable weapon in warfare. Widespread use of chemical weapons during World War 1 and subsequently in various countries around the world has shown that this development is here to stay despite international pressure.

chemistry in the future

The chemist of the future will have two primary roles, to continue to develop and produce the chemicals that society requires and to provide solutions to address the problems of pollution. There is still much research to do in the field of chemotherapy. Less toxic anticancer agents, antiviral drugs, and the next generation of antibiotics are all still to be developed. Already companies are developing alternatives to CFCs and other ozone-depleting chemicals. Biodegradable plastics are being developed and the understanding of the environmental impact of chemicals has become a science in its own right, environmental chemistry. Alternative sources of industrial raw materials to replace petroleum, such as biomass, are being developed to eliminate the risk of oil spillages, and operational procedures and safeguards at chemical factories are continually being improved to increase the safety of chemical production. Species-specific insecticides and pesticides are a possible development which would minimize the impact of chemicals in agricultural production and more careful management of artificial fertilisers is also an area of study. Economic ways to reduce greenhouse gas levels, such as chemically combining carbon dioxide to form inert compounds which can be safely stored, are an area of intense study. In short, the chemist of the future will be a global scientist, assessing the impact of his or her products on the environment and finding ways in which their manufacture and use can be made safer.

Chemistry in the 20th century

introduction - chemistry at the start of the 20th century

By 1900, chemistry had come a long way from its origins in medieval times with the alchemists. The understanding of the elements and chemical reactions had become a distinct science separate from natural philosophy, or physics as it is now known. The existence of the atom was still in dispute, although most scientists accepted it as a useful concept. The first subatomic particle, the electron, had been discovered, but scientists did not fully understand what they had found.

Many new elements had been discovered in the 19th century and a system for their classification had been established. It was called the periodic table and was constructed by placing the elements in order of increasing atomic weight, the assumption being that this was the property that characterized an element. The elements were arranged in columns such that similar chemical properties occurred at fixed intervals or periods. Sometimes this arrangement could not be made to work and so gaps were left in the table, anticipating the discoveries of new elements. The search for the missing elements had led to the discovery of new radioactive members of the table. However, isolating these elements for study had proven to be difficult and so little was known about them.

Also in the 19th century, chemical production had become an integral part of industrialized society. The majority of the technology had evolved in Germany where the availability of huge coal reserves had influenced the development of the industry. There, chemists had concentrated on the conversion of coal to produce chemicals. A disadvantage with this approach was that the industrial processing of crude oil, or petroleum, was totally neglected in Europe. One class of compounds that were not produced by coal-conversion were the unsaturated hydrocarbons from which synthetic plastics are produced. The development of plastics would have to wait for the rise of the mighty US petrochemical industry.

In 1828, German chemist Friedrich Wöhler (1800-1882) had produced the organic chemical urea using only inorganic starting materials, something thought impossible at the time. Synthesis, the artificial production of a substance from its constituents, had been restricted to inorganic compounds, but now new doors had been opened to the chemist. Progress was hampered by having no reliable techniques to examine how a substance was chemically constructed, leaving the synthetic chemist to stumble blindly through the jungle of chemical preparations, occasionally stumbling onto the correct path. Progress relied on individual breakthroughs rather than systematic development. Consequently, by the start of the 20th century, synthetic dyes were the only organic compound in full commercial production.

Chemistry was on the brink of a scientific and industrial explosion of development, which would see the discovery of wonders and the creation of nightmares to make society pause to consider whether it had chosen the right path.

the atom - physicists lend a hand

At the beginning of the 20th century, the concept that matter was composed of indivisible particles known as atoms was universally accepted. This approach had been building momentum since the beginning of the 19th century when English chemist John Dalton (1766-1844) proposed his 'atomic theory' to explain how compounds are formed. However, although the theory was accepted and widely used to explain chemical behaviour, there was no direct evidence that atoms and molecules existed and some prominent scientists still maintained that they were only convenient abstractions.

Then, in 1908, French physicist Jean Perrin (1870-1942) found the proof that molecules were real. It had been suspected since the middle of the 19th century that Brownian motion, the random movement of particles suspended in water, was caused by the particles colliding with water molecules. German-born US physicist Albert Einstein (1879-1955) assumed this to be the case and published his theoretical analysis of the phenomenon in 1905. In this study, he derived a formula which could be used to calculate the size of the water molecule. Perrin added a dye of known particle size to a cylinder of water and then studied the manner in which it settled. He noticed that the downward passage of the particles was being opposed by Brownian movement. Since the only force acting on the dye was gravity, Perrin could calculate the force being applied by the water to oppose the downward motion. This allowed him to use Einstein's formula to calculate the size of a water molecule. The results of his calculations convinced the sceptics that molecules did exist.

The discovery of the negatively charged electron, by English physicist J J Thomson (1856-1940) in 1897, had proved that the atom was divisible, but little else was known about atomic structure. Thomson proposed a 'plum pudding' model of the atom, where the majority of the mass was the positive sphere of the pudding, which had the negatively charged electrons imbedded like fruit inside it. This idea was generally accepted until New Zealand-born British physicist Ernest Rutherford (1871-1937) announced his concept of the nuclear atom in 1911. The research group he lead had been studying the effects of firing alpha particles at thin foils of gold and platinum using a photographic plate placed behind them as a target. Although most of the particles had passed straight through, he observed an unexpected scattering around the central spot. By positioning the photographic plate it was discovered that some particles had been deflected by large angles and some had even been bounced back along the path of the incoming alpha particle. Rutherford commented that this was the equivalent of shooting a 15-inch shell at a piece of tissue paper and then being hit by a rebound. Rutherford formed the correct conclusion that the alpha particles had struck something very dense in the foil and, since so few collisions had occurred, whatever this was must be very small. He concluded that he had found the nucleus. Rutherford's model of the atom had almost all of its mass located in a small, positively charged core called the nucleus surrounded by a mist of electrons that occupied most of the atom's space.

Why negatively charged electrons were not drawn into the positive nucleus was explained in 1913 by Danish physicist Niels Bohr (1885-1962). He suggested that electrons were fixed into circular orbits (shells) around the nucleus. Drawing on the 1900 theory of German physicist Max Planck (1858-1947) that radiation was emitted in fixed amounts or 'little packets' called quanta, Bohr argued that no electrons were present in the gaps between the shells of an atom and that the energy difference between each shell was exactly a quantum specific to that element. As only a limited number of electrons were allowed to occupy each shell, this theory resulted in all elements having a unique electronic configuration. Bohr's theory was crucial in explaining certain chemical properties of the elements.

Rutherford continued to study the bombardment of metals by alpha particles. He noticed that in every case, positively charged hydrogen ions were being given off as a by-product of the process. Hydrogen is the simplest element and Rutherford correctly concluded that the hydrogen ion was the positive counterpart of the electron in the atom. In 1920 he published his results and called this fundamental positive particle the proton from the Greek word meaning 'first'.

In 1932, English physicist James Chadwick (1891-1974) discovered neutrons. These electrically neutral particles act as the 'glue' which binds the positively charged protons together to form the nucleus. With their discovery, the structure of the most basic building block in chemistry, the atom, had been found.

the periodic table - the last pieces of the puzzle come together

In 1869, Russian chemist Dmitri Mendeleyev (1834-1907) had arranged the known elements into the periodic table - so called because it showed the periodic recurrence of elements with similar chemical properties and was based on the atomic weight of the element. However, Mendeleyev reasoned that the chemical properties of an element were more important than weight and he showed no hesitation in swapping elements if their properties did not match the rest of the series. More radically, if he could not get the order of the table to work with the known elements, he left gaps for future discoveries.

The search to find the missing elements led to the discovery of new radioactive members of the periodic table. Although radium had been discovered in 1898, the isolation of the element in the form of a pure compound had to wait until 1902. This achievement was a triumph of chemistry for Polish-born French nuclear chemist Marie Curie (1867-1934) and her husband, French physicist Pierre Curie (1859-1906). They had taken four years of painstaking effort to extract 1 g/0.04 oz of pure radium chloride from 8 tonnes of the uranium-rich mineral pitchblende. In 1900 German physicist Friedrich Dorn (1848-1916) had a considerably easier task when he discovered that radium decayed to produce the radioactive gas radon. He simply collected the gas in a glass tube.

It soon became clear that something unusual was happening in pitchblende. Studies of this mineral had led to the discovery of polonium and radium in 1898, actinium in 1899, and protactinium in 1913. It was correctly deduced by Rutherford and his English assistant physical chemist Frederick Soddy (1877-1956), that in the act of producing radiation, the elements were changing into other radioactive elements. The transmutation of elements, long searched for by the alchemists, had been found!

Chemists began looking eagerly for new transformations, but their efforts were rewarded by a bewildering assortment of compounds. It became clear that the reliance on characterizing the elements by their atomic weight led to ambiguous and misleading 'discoveries'. During this period many more 'elements' were claimed to have been found than there was space for in the periodic table and one by one each was identified as being chemically indistinguishable with a known element, but possessing a different atomic weight.

So what was going on? The evidence suggested that radioactive elements could exist in more than one form. Soddy expressed this idea fully in 1913 when he described the various forms of each element as being isotopes, from the Greek for 'the same position'. However, it was still not known if the concept of isotopes was confined to the radioactive elements. The issue was decided with the help of English physicist Francis William Aston (1877-1945) with his invention of the mass spectrograph. This machine separated out isotopes by the virtue of deflections of their ions by a magnetic field. In 1919 J J Thomson used it to show that neon existed in at least two forms. Aston carried on the work to show that several more stable elements were composed of isotopes, notably chlorine, for which feat he was awarded the Nobel Prize for Chemistry in 1922. It is now known that very few elements exist in nature as a single isotope. Following a suggestion by US chemist Truman Kohman in 1947, the nucleus of the atom is now called a nuclide. Isotopes are identified by their atomic mass number, for example neon exists as three isotopes, neon-20, neon-21, and neon-22.

A property for distinguishing between elements other than atomic weight had to be found. It took a physicist, the English physicist Henry Moseley (1887-1915), to find it. In 1913 Moseley discovered that the X-ray spectra of the elements had a deviation that changed regularly through the periodic table. A graph of the square root of the frequency of each radiation against a quantity he called the atomic number of the element, gave a straight line. Atomic number was shown later to correspond to the number of protons in the nucleus of the atom. This quantity is the characteristic feature of an element because all of its isotopes, whatever their mass, have the same atomic number. This fact fixes an element to its place in the periodic table. Moseley published his findings in 1914 and scientists used his discovery to draw up a new periodic table where the elements were arranged in order of their atomic numbers. This is the form in which the periodic table is used today, although atomic number is now called proton number.

Before Moseley, only two elements had been conclusively identified since the turn of the 20th century, radon and lutetium. Lutetium was isolated by French chemist Georges Urbain (1872-1938). and German chemist Carl Auer von Welsbach (1858-1929) independently of each other in 1907. There had been many false alarms because of confusion with discoveries of isotopes of the known elements. Now that elements could be unambiguously identified, it was only a matter of time before the table was completed.

Rhenium, named after the river Rhine, was discovered in platinum ores and columbite by German chemists Walter Noddack (1893-1960), Ida Tacke (1896-1979), and Otto Berg in 1925. Improved separation techniques allowed French chemist Marguérite Perey (1909-1975) in 1939 to isolate element 87 from the decay products of uranium in pitchblende where it had previously been missed by researchers. She named it francium after the country of her birth.

The last three elements, 43, 61, and 85 were not only missing from the table but were absent from nature as well. Where nature could not provide, science found a way. US physicist Ernest O Lawrence (1901-1958) now came into the picture. He had invented the cyclotron, a device capable of accelerating charged particles to incredible speeds and energies. In 1937 he used his invention to bombard a molybdenum target with protons and found that the material had become radioactive. He enlisted the help of Italian chemists Emilio Gino Segrè (1905-1989) and Carlo Perrier (1886-1948) who separated the radioactive section and proved that it was another element. Molybdenum, atomic number 42, had been transmuted by the addition of a proton to the missing element 43. This was the first element to have been created in a laboratory and was called technetium after the Greek word meaning 'artificial'. In 1940, Segrè and the cyclotron were again involved, this time in the synthesis of element 85, which was created by bombarding element 83, bismuth, with alpha particles. In this enterprise he worked with US physicists Dale Raymond Corson and Kenneth Ross Mackenzie. They called the element astatine after the Greek word for unstable. In 1945, the final element, 61, was separated from residues recovered from a nuclear reactor by three US chemists: Jacob A Marinsky, Lawrence E Glendenin, and Charles Dubois Coryell at Clinton Laboratories, Oak Ridge, Tennessee. They named it promethium after the mythological stealer of fire from the gods, to symbolize their discovery of the element from the nuclear fire of the reactor.

The periodic table was now complete. However, when it had first been drawn up, uranium had been thought the heaviest element in nature. The possibility of being able to transmute elements beyond this point had not been considered. Elements with atomic numbers higher than uranium are called the transuranic elements and these can now be created using devices such as the cyclotron. A leading figure in this enterprise was the US nuclear chemist Glenn Seaborg (1912-1999) who was involved in the identification of a host of transuranic elements. Between 1940 and 1957 he helped in the discovery of plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, and nobelium.

Over the course of the rest of the 20th century, progressively heavier elements have been created in laboratories around the world. The last one to be created in this fashion is element 118 (ununoctium), produced by US physicists bombarding lead with krypton in 1999. It then decayed into element 116, another new element. The new elements existed only for milliseconds.

synthesis - the rise of organic chemistry

The primary role of chemistry has always been to provide society with the compounds that it requires. In the early days of the chemical industry this usually involved the processing of natural materials from plants and minerals. However, 19th-century chemists had begun to understand the chemistry involved in making compounds containing carbon. This science is called organic chemistry, from the time that it was thought that only living, or organic, organisms could synthesize compounds of this element. The importance of this field cannot be stressed enough when we consider that every synthetic drug, dye, perfume, plastic, vitamin, rubber, and a whole host of other materials, contain this element. Understandably, a great deal of effort on the part of chemists has gone into investigating carbon chemistry and the various ways in which compounds can be synthesized. The scope of this field is truly enormous and so only a brief overview of the range of developments can be addressed here.

By the beginning of the 20th century, progress in organic synthesis had largely been restricted to the production of substitutes for natural dyes and perfumes. Then several significant advances took place.

In 1897, the Sabatier-Senderens reduction reaction was developed by French chemists Paul Sabatier (1854-1941) and Jean Baptiste Senderens (1856-1936) as a means of adding hydrogen to unsaturated hydrocarbons. Hydrocarbons contain only hydrogen and carbon and are the most important class of compounds as starting materials for organic synthesis. When a hydrocarbon possesses carbon-carbon double and triple bonds it is called unsaturated and reactions with these compounds form the basis of many synthetic routes.

In 1900, French chemist Victor Grignard (1871-1935) succeeded in creating a compound where a metal was linked directly to a carbon atom (an example of an organometallic compound) by dissolving magnesium in a number of organic halide solutions. Organomagnesium compounds, now known as Grignard reagents, became some of the most versatile compounds in organic synthesis, allowing the easy preparation of a range of materials using existing products, such as the conversion of aldehydes and ketones to alcohols and the synthesis of alkyl derivatives of halogen compounds.

In 1928, German chemists Kurt Alder (1902-1958) and Otto Diels (1876-1954) discovered a fundamental reaction which allowed the synthesis of cyclic carbon compounds. As many natural vitamins and drugs contain carbon rings in their atomic structure, this reaction allowed their synthesis for the first time. The process is now called the Diels-Alder reaction.

Further advances in finding multipurpose organometallic reagents owe much to the work of US chemist Henry Gilman (1893-1986). He systematically studied the organic chemistry of a number of metals as diverse as aluminium and uranium and discovered several new types of compounds. In 1936, he was the first to study organocuprates, organic compounds in which copper is linked directly to a carbon atom. These compounds proved to be just as versatile as Grignard reagents and were to become known as Gilman reagents. They are particularly useful in catalyzing addition reactions involving carbon double and triple bonds and in substitution reactions involving organic halide and alcohol derivatives, notably in the synthesis of drugs and perfumes.

In 1954, German chemist Georg Wittig (1897-1987) developed a method of synthesizing olefins, a class of unsaturated hydrocarbons, using a reaction now called the Wittig synthesis. The process involved the reaction of an organic carbonyl, such as an aldehyde or ketone, with an organic phosphorus compound to form a compound with a carbon-carbon double bond in its atomic structure. The reaction is particularly useful in the synthesis of vitamin D and precursors of sterols such as cholesterol.

In 1967, US organic chemist Charles Pedersen (1904-1990) discovered a new class of organic reagents, the crown ethers. These are planar cyclic polyethers, which are composed of molecules with twelve carbon atoms and six oxygen atoms arranged in a crown-like structure. Pedersen had been working on synthetic rubber at US company DuPont when he noticed that one of his preparations contained an unknown impurity. This turned out to be the first crown ether.

In 1969 French chemist Jean-Marie Lehn (1939-) demonstrated that the central cavity of a crown ether would accept a metal ion. He developed the procedure further by replacing oxygen atoms in the structure with nitrogen. Two crowns could then be linked together to form a three-dimensional structure which he called a 'cryptand'. This in turn led to the development of the host-guest branch of organic chemistry, the crown ether being the host and the species placed in the central cavity being the guest.

Soon afterward, US chemist Donald Cram (1919-2001) designed and produced a range of complex host molecules based on cryptands called 'cryptates', which selectively recognized and bound specific guest molecules and atoms. The host-guest mechanism worked because he succeeded in matching the shape of the host cavity with that of the guest species molecule. Cram demonstrated the usefulness of the technique by dissolving an inorganic salt in an organic solvent for the first time by encasing it in a cryptate. The compounds have since been used in broad applications in organic synthesis and biochemistry to catalyse chemical reactions and transport ions through biological barriers such as cell membranes.

Important developments were also occurring in the field of structural analysis. German physicist Max von Laue (1879-1960) had shown in 1912 that passing a narrow beam of X-rays through a crystal produced a precise pattern. Later that year, English physicist Lawrence Bragg (1890-1971) showed these patterns to be caused by diffraction of the X-rays by the atoms of the crystal. This led to the conclusion that a crystal was a substance made up of an orderly arrangement of atoms repeated infinitely throughout its structure. By 1914, Bragg had been able to work out the crystal structures of a number of inorganic compounds, including salt.

This was the beginning of X-ray crystallography as an invaluable tool to the synthetic chemist. In order to manufacture a compound it is very useful to know how its molecules are made up. This technique could provide valuable insights into the molecular structure of a substance as long as the substance could be made into a crystalline form. Advancements in the preparation of organic compounds made this possible.

US biochemist James Sumner (1887-1955) crystallized the enzyme urease in 1926. He was the first to propose that enzymes were proteins, a notion rejected at first by the scientific community. However, in 1930 US chemist John Northrop (1891-1987) crystallized a number of enzymes, including pepsin, and proved all of these to be proteins, confirming Sumner's earlier work. This was followed in 1935, when US biochemist Wendell Meredith Stanley (1904-1971) isolated the tobacco-mosaic virus in crystalline form from a pulp of infected leaves.

X-ray crystallography was soon applied to the study of vitamins, antibiotics, and progressively more complex natural molecules. Two of the greatest pioneers of this field were English biophysicist Rosalind Franklin (1920-1958) and English biochemist Dorothy Hodgkin (1910-1994).

Franklin is best known for her studies into the determination of the molecular structure of DNA. In 1952, she succeeded in the extremely difficult task of obtaining an X-ray photograph from a tiny crystal of DNA. She correctly deduced that the sugar-phosphate backbone of DNA was on the outside of the molecule. Her X-ray photographs were crucial to the elucidation of the structure of DNA the following year by English physicist Francis Crick (1916-) and US biochemist James Watson (1928-).

Hodgkin was by far the most prolific user of X-ray crystallography in structural analysis of the 20th century. She developed the technique to a stage which allowed her to determine the complete molecular structure of a compound without needing to confirm her results using organic chemical techniques, a common practice before her developments in the field. Her notable triumphs were the determination of the structures of penicillin, vitamin B_{12}, and insulin, each task more difficult than the last. To highlight the enormity of the effort involved, Hodgkin had managed to obtain the first diffraction pattern of insulin in 1935, but it took her until 1969 to complete the structural determination for the three-dimensional shape of the molecule.

The combination of an ever increasing ability to synthesize organic chemicals and an invaluable technique for the determination of molecular structures of compounds had given chemists the basic tools they required to push forward organic synthesis to limits undreamed of in the history of chemistry. A pioneer in this field was US chemist Robert Burns Woodward (1917-1979) who synthesized a number of complex natural molecules during his career, including quinine in 1944, cholesterol in 1951, and chlorophyll in 1960. He was awarded the Nobel Prize for Chemistry in 1965 for his contributions to organic synthesis. This tradition is carried on today by chemists such as US chemist Elias James Corey (1928-) who developed retrosynthetic analysis. Corey used this approach to synthesize more than a hundred complex natural compounds, such as terpenes, found in plant oils, and ginkgolide B, an extract from the ginkgo tree used to treat asthma. For this development he received the Nobel Prize for Chemistry in 1990.

biochemistry - the chemistry of life

The effectiveness of the techniques of the organic chemist are ably demonstrated by the development of vitamin and drug synthesis. By 1900, it was known that foods contained substances in trace amounts that were essential for life but it was not known what these substances were. For example, it was known that fresh fruit and vegetables would cure a patient suffering from scurvy but it was not known why. The challenge was to isolate the agent responsible for the cure. In 1912, Polish-born US biochemist Casimir Funk (1884-1967) isolated an amine compound from yeast that cured the disease beriberi. He called the compound a 'vitamine' from the Latin meaning 'life amine'. A year later, US biochemists Marguerite Davis and Elmer McCollum (1879-1967) discovered another vital substance in the fats of butter and egg yolk. McCollum named this substance fat-soluble A to distinguish it from Funk's compound which he designated as water-soluble B. In 1920, British biochemist Jack Drummond proposed that the antiscurvy substance was a third factor. In his description of the previously discovered substances, he changed Funk's designation from 'vitamine' to simply vitamin as he correctly deduced that not all the substances were amines. He called his factor vitamin C.

Progress occurred rapidly, vitamin D was isolated by McCollum in 1920 from cod-liver oil. By 1930 it had been discovered that vitamin B was in fact a group of compounds, which we call now the B vitamin complex. From this early research vitamins E and K were further identified. In 1921 the McCollum group showed that rats fed on a diet absent in vitamin D did not develop the deficiency related disease rickets when exposed to sunlight. Biochemists guessed that sunlight converted a chemical in the body of the rats into vitamin D. In 1926 British biochemists Otto Rosenheim and T A Webster and German chemist Adolf Windaus (1876-1959) independently discovered that exposing the sterol ergosterol to sunlight produced vitamin D. Ergosterol was the first example of a provitamin, a substance converted in living organisms to produce a vitamin. Vitamin C was first isolated from cabbages in 1928 by Hungarian biochemist Albert Szent-Györgi (1893-1986) although he had not known what the substance was. Around the same time US chemist Charles Glen King (1896-1988) compared crystals of a substance isolated from lemon juice with that isolated from cabbage. He found that they both protected against scurvy. In 1929, British biochemist Thomas Moore isolated the yellow coloured carotene from egg yolks. He showed that carotene was converted in living organisms to produce vitamin A. US chemists Herbert McClean Evans (1882-1971) and Gladys Anderson Emerson (1903-1984), and Oliver Emerson succeeded in isolating vitamin E in 1936, the absence of which in the diet, they had previously shown to cause sterility in animals when. US chemists Harry Nicholls Holmes (1879-1958) and Ruth Corbet isolated pure vitamin A in crystalline form in 1937 from the oil of fish livers.

It took until 1926 before work on the chemical structures of vitamins could begin. Vitamins occur in nature only in very small amounts and it took a great deal of patient separation chemistry just to isolate enough of the pure material for analysis. After several false starts, Japanese biochemist S Ohdake came closest to the structure of vitamin B1 when he correctly showed in 1932 that sulphur was an integral part of the vitamin. US chemist Robert Runnels Williams (1886-1965) succeeded in determining the whole structure for vitamin B_1 in 1934. The vitamin was called thiamine after the Greek words for sulphur amine. In 1933 Charles Glen King determined the structure of vitamin C, which he called ascorbic acid from the Greek meaning 'no scurvy'.

From the 1930s onwards increasing numbers of vitamins have been discovered and isolated by chemists, including vitamin K and the B group vitamins, biotin and folic acid. Synthesis followed soon afterwards. Polish-born Swiss biochemist Tadeus Reichstein (1897-1996) and English chemist Norman Haworth (1883-1950) independently synthesized ascorbic acid in 1933, Robert Runnels Williams and his group synthesized thiamine in 1937. Vitamin A had been synthesized by 1936. Soon, all vitamins could be produced synthetically and they are now routinely used as food additives and easily available as dietary supplements.

Impressive as the discovery of vitamins was, probably the greatest contribution of synthetic chemistry, the 20th century is the part it played in the development of antibiotics.

In 1932, German chemist Gerhard Domagk (1895-1964) discovered the first antibacterial drug, a coal tar dye called Prontosil red. In 1935, his daughter was dying from streptococcal blood poisoning. Domagk used Prontosil red to kill this bacterial infection, saving his daughter's life. The active ingredient of the dye was a sulphur-containing compound called sulphanilamide. Chemists found that a range of drugs could be synthesized from sulphanilamide by substituting different chemical groups next to the sulphur atom in the molecule, producing sulphapyridine in 1937, sulphathiazole in 1939, and sulphadiazine in 1941. The 'sulfa-drugs' became the most widely used drugs until the discovery of penicillin. Each had slightly different antibacterial properties.

Once this breakthrough had been accomplished, the search was on for more potent drugs, a path which led to the discovery of antibiotics. The first true antibiotics were developed by French-US microbiologist René Jules Dubos (1901-1982) in 1939. He had been searching for antibacterial agents in soil and had found two, gramicidin and tyrocidin. But they were overshadowed by the discovery of penicillin by Scottish bacteriologist Alexander Fleming (1881-1955). In 1929, Fleming published his results on his studies of the common bread mould, *Penicillium notatum*, which contained a substance which was lethal to germs. The discovery was ignored until years later, when Australian pathologist Howard Florey (1898-1968) and German-born British biochemist Ernst Chain (1906-1979) took an interest in the paper. In 1939, they had succeeded in isolating the active agent in the bread mould, which they called penicillin. By 1941, they had managed to isolate enough of the antibacterial agent to carry out a successful clinical trial on rats. However, Florey did not have the resources in war-torn Britain to develop the full-scale purification and production of the drug, so he went to the USA, where the necessary resources were available. The first clinical trials on humans proved a complete success and by 1943 the drug was in full commercial production.

The search for antibiotics continued and streptomycin, a powerful drug in the fight against tuberculosis, was discovered in 1943 by US bacteriologist Selman Waksman (1888-1973). Aureomycin, the first of the tetracycline broad-spectrum antibiotics, was found by US botanist Benjamin Duggar (1872-1956) and colleagues in 1944. Many more discoveries followed. Antibiotics are now the most commonly used drugs in chemotherapy.

the petrochemical industry - the next revolution

The lead that Germany had gained on the rest of the world in the 19th century, had granted its chemical industry the position of being a virtual monopoly. German chemists maintained this position into the 20th century by continually developing novel industrial processes.

Two substances very much in demand in the early 20th century were artificial fertilizers and explosives.

Both these substances contain nitrogen, the chief source of which was Chile saltpetre, a mineral mainly composed of sodium nitrate found in the northern desert of Chile. As this had been exported since 1830, supplies were becoming scarce and expensive, and so alternatives had to be found. However, nitrogen is a very stable element and does not form compounds readily. By 1900 there were several processes for converting nitrogen from the air into soluble compounds useful for chemical production, but they required too much energy to be cost effective. It was still cheaper to dig nitrates out of the ground. Then in 1908, German chemist Fritz Haber (1868–1934) developed a new process which combined atmospheric nitrogen with hydrogen to produce ammonia. From this chemical the whole range of nitrogen-based materials could be produced. He went so far as to design a pilot plant in 1909 to prove that his method was viable. Not surprisingly he called the method the Haber process. That same year, the rights to his process were bought by the German chemical firm Badische Anilin-und-Soda-Fabrik (BASF) and the task of developing the process into a full-scale industrial operation was given to German chemical engineer Carl Bosch (1874–1940). Haber had advocated the use of high pressures and an expensive osmium catalyst, both of which posed problems for Bosch. The first problem was overcome by developing a strong enough plant to withstand the high pressures. Bosch's team then found that finely divided iron, which contained proportions of oxides of potassium, calcium, and aluminium, was just as efficient as osmium as a catalyst. Another development they pioneered was passing steam over red hot coke to produce a cheap source of hydrogen. Bosch had a fully operational plant in production by 1913. The Haber process has stood the test of time and is still used to this day.

A colleague of Haber, German chemist Friedrich Bergius (1884–1949), continued improving high-pressure industrial methods. By 1912 he had developed a pilot scheme in which a combination of high temperature, high pressure, and a catalyst was used to convert coal dust and heavy oils into kerosene and petrol. Haber, Bosch, and Bergius all received Nobel prizes for their contributions to chemistry.

However, developments in the USA were about to change the direction of the chemical industry for the first time in over a century. The US chemical industry had access to a cheap source of potential chemical feedstocks in the form of petroleum, a mixture of heavy hydrocarbon oils, and natural gas. These hydrocarbon sources are much more suitable for the production of chemicals since the liquefaction phase necessary in the processing of coal is not required.

The main obstacle in the development of chemicals from petroleum sources, or petrochemicals, was that the technology did not exist to process the heavy oils and natural gas into a form that could be used. Rudimentary processes had been developed capable of breaking down or 'cracking' some of the heavy hydrocarbons in petroleum to produce petrol and the lamp oil, kerosene, but natural gas was still burnt off at oil well sites.

US chemist William Burton (1865–1954) was about to change everything. He invented the Burton thermal cracker in 1912. Thermal cracking is a process which uses heat and pressure to break down heavy petroleum oils into smaller and lighter hydrocarbon fractions. Burton's process incorporated a distillation phase which converted a higher proportion of the 'cracked' petroleum into a form that could be chemically converted into petrol. He effectively doubled the amount of fuel that could be obtained from oil overnight. As a bonus, the process also produced a proportion of unsaturated hydrocarbon gases, called 'olefins' by the industry, as a by-product. In 1915, a more efficient process using thermal cracking was developed by US chemist Jesse Dubbs.

Cracking technology developed further in 1930, when French inventor Eugène Houdry (1892–1962) developed fixed-bed catalytic cracking. His process used a series of heat exchanger reactors which incorporated a bed containing a clay catalyst. This process was able to break petroleum down into a range of much lighter hydrocarbon fractions than was possible with the thermal cracking technology and soon replaced it. By 1937 commercial 'cat crackers' were in full production.

The introduction of a catalyst by Houdry was the key to the development of the most important process used in oil refining, fluidized bed catalytic cracking. This was developed in 1939 at the Massachusetts Institute of Technology headed by US chemical engineers Warren K Lewis (1882–1975) and Edwin R Gilliand. In this process petroleum is forced through a bed of catalyst at a high enough velocity to cause the particles of the bed to be separated and suspended in the liquid. This maximizes the contact with the catalyst and produces the highest yields of petroleum fractions. It became the standard process used in oil refining.

With each advance in the refining technology, a greater variety of hydrocarbon feedstocks became available for the US chemical industry to use. From the 1930s onwards, it became recognized that the olefin gases were another useful source of chemicals, especially for the growing plastics industry. This prompted the development of the commercial recovery of olefin gases from oil refineries and natural gas sources. Refrigeration and high-pressure vessels were soon routinely used to store important gases such as ethylene, propylene, and the butylenes.

The development of the technology was paralleled by the better understanding of the chemistry of petroleum. The Bureau of Standards and the US Petroleum Institute had undertaken extensive investigations into the physical and thermal properties of pure hydrocarbons. By 1931, over 190 different substances had been identified and isolated for study.

By the 1940s virtually every chemical produced by coal-based technology could be produced cheaper and in much greater quantities by the US petrochemical industry. The rest of the world had little option but to adopt the new technology. Now petrochemicals are the dominant source of raw materials for the world's chemical industry.

plastics – the new materials

A plastic is an artificial non-metallic material that can be shaped in almost any form. The word originates from the Greek word *plastikos* meaning 'able to be moulded'. Prior to 1900, several plastic materials had been developed but they relied on being produced, at least in part, from natural materials, such as cellulose and natural rubber, and so fall short of what we now call plastics. Plastics are in the class of compounds known as polymers, which are materials built up from a series of smaller units called monomers. Other natural polymers include proteins.

The development of polymers owes a great deal to the persistence of German chemist Hermann Staudinger (1881–1965) who flew in the face of scientific opinion to push forward his theories. Staudinger was interested in the mechanism by which monomers are connected to form a polymer, a process called polymerization. He began by studying how the natural polymer, rubber, could be formed. In 1910 he developed a method of synthesizing isoprene, the monomer from which natural rubber was made. By 1920, Staudinger had learned enough to publish his book *On Polymerization*, where he discussed various mechanisms involved in polymerization. In 1922, he coined the word 'macromolecule' to describe the long chain of isoprene units which form a molecule of natural rubber. His suggestion that the molecule was composed of tens of thousands of atoms held together with ordinary chemical bonds was not well received by the scientific community. The prevailing opinion at the time was that polymers were composed of disorderly conglomerates of small molecules. However, in 1923, Staudinger's claims were verified by Swedish chemist Theodore Svedberg (1884-1971). He had developed the ultracentrifuge, a machine capable of very efficient separation of individual molecules according to their weight. Svedberg used his ultracentrifuge to separate individual molecules of proteins and plastics, which conclusively proved the existence of macromolecules. Staudinger continued his research and in 1930 he devised a relationship between the viscosity of a polymer solution and its molecular weight, Staudinger's law. This allowed the molecular weight of a polymer to be calculated without the need for complex separation techniques. For his contributions to polymer chemistry Staudinger was awarded the Nobel prize in 1956.

The first truly synthetic plastic materials were developed in New York by Belgian-born US chemist Leo Baekeland (1863-1944) in 1909. He developed the first synthetic thermoplastic Novolak and the thermosetting plastic Bakelite based on phenol-formaldehyde resins. Bakelite could be moulded into any shape, was chemically inert and non-conducting and was used widely to make electrical appliances. In 1912 German chemist Fritz Klatte patented the manufacture of vinyl chloride and proposed a method to polymerize the molecule to produce polyvinylchloride (PVC).

However, plastic development became established only when chemists gained access to olefins, a class of compounds being produced by the growing petrochemical industry in the 1930s. These unsaturated compounds could be joined together using existing synthetic techniques to form plastics. Modification of olefins using simple chemical reactions was adopted to form new monomer units such as vinyl chloride, which could be synthesized more cheaply and in greater amounts than ever before.

The Naugatuck Chemical company in Canada was the first to enter commercial production of polystyrene in 1925 using the brand name Victron. The material was expensive to produce and its yellow colour limited its applications. It was used mainly in the manufacture of false teeth. By the 1930s, chemists at the Dow Chemical Company in USA had developed a hydrogenation process for the production of styrene. This was a cheaper route and produced a white material, which was much more commercially acceptable. Full production of polystyrene under the brand name Styron took place in 1937.

Chemists at the US company Union Carbide advanced plastic synthesis in 1933 by developing a process to add two different types of monomer unit onto a polymer chain, a technique called copolymerization. They used this method to copolymerize vinyl chloride with vinyl acetate to produce Vinylite, the first commercial vinyl-based plastic.

It was known that the addition of certain chemicals in the manufacture of plastics could modify the nature of the final product. US chemist Waldo Semon (1898-1999) enhanced the flexibility of PVC in 1926 to produce the rubberlike plastic Koroseal, which was commercially available from 1932. This sort of additive is called a plasticizer and its use overcomes earlier production problems with the material. Further additive developments to improve its heat stability allowed PVC to be used in a range of applications as diverse as wire insulation and drainage piping.

The simplest of all plastics, polyethylene, was first proposed in 1898 by German chemist Hans von Pechmann (1850-1902) but ethylene proved very difficult to polymerize. Then in 1935, English chemist Michael Perrin working at ICI in Winington, England, succeeded in polymerizing ethylene using a high-pressure vessel. The first patent was issued in 1936 under the band name Alkathene and commercial production of low-density polyethylene (LDPE) started in 1939. The process required the reaction vessel to be under an immense pressure of 30,000 lb per square inch. In 1953 German organic chemist Karl Ziegler (1898-1973) developed a chemical catalyst that permits polyethylene to be produced at atmospheric pressure. This form of the plastic, high density polyethylene (HDPE), was much cheaper to manufacture.

In 1938 US chemist Roy J Plunkett (1910-1994) working at DuPont's Jackson laboratory in New Jersey, while studying gases related to freon, discovered that a sample of tetrafluoroethylene had spontaneously polymerized upon being frozen and compressed. This was the start of polytetrafluoroethylene (PTFE) synthesis. The plastic was more widely known by its brand name Teflon. It became commercially available in 1946 and still has wide applications as a coating agent in household goods and in the aerospace industry. This research led to the development of a family of fluoropolymers, the latest one being developed in 1972.

Progress was also being made in the production of synthetic fibres from plastics. The technology to create yarn from plastic materials had been established around the turn of the century with the development of the cellulose-based rayon fibres. Soon, these techniques were being applied to plastics.

In 1938, DuPont commercially produced the synthetic fibre nylon in Seaford, Delaware, USA. This was the culmination of years of work by US chemist and polymer pioneer Wallace Hume Carothers (1896-1937). He had achieved his breakthrough in 1935 when he had polymerized adipic acid with hexamethylenediamine using a condensation reaction at low pressure to produce a perfect synthetic fibre. Nylon was a strong lightweight material and soon replaced silk in the manufacture of parachutes and ladies' stockings.

The first polyester-based synthetic fibre was developed in England in 1941 by English chemists Rex Whinfield and James T Dickson but the material was not developed because of the advent of World War II and the move towards nylon production. In 1944, US chemist E F Izard working for DuPont independently developed an alternative route for polyester fibre production, only to discover after the war that the patent for the material had been filed in England by ICI. The two companies agreed to share their technology and started commercial production of polyester fibres in 1950, ICI with Terylene, DuPont with Dacron.

The acrylic fibre story began in 1939 when German chemists Otto Bayer (1902-1982). and P Kurtz patented a process for the manufacture of acrylonitrile, the first step in the production of acrylic synthetic fibres. By 1941, the German company Bayer had found a solvent for acrylic polymers that allowed them to be dissolved and then extruded into fibres. However, chemists working for DuPont in the USA independently discovered the same solvent, allowing them to develop the technology. DuPont started commercial production of acrylic fibres in Orlon, South Carolina, in 1950. Unfortunately the material could not be dyed and had an unpleasant texture which was unpopular with consumers. This particular problem was solved by rival US company Union Carbide. In 1953 they used copolymerization technology to develop Dynel, a fibre containing 40% acrylonitrile and 60% vinyl chloride. This could be dyed and had the texture of wool. From the 1950s onwards, it became common practice to mix different synthetic fibres with each other, and even with cotton, to improve the texture of the materials.

An indicator of the adaptability of the plastics industry to changing consumer trends was the development of Lycra in 1958 by DuPont. This was an example of an elastomer or elastic polymer and stretched to accommodate movement. Lycra is now one of the most common synthetic fibres used in the manufacture of modern sportswear.

Plastics are one of the most common materials that are in use today. They have applications in clothing, construction, packaging, coatings, manufactured goods, glass substitutes, and insulating materials to name just a few of their uses. Research is continuing to develop plastics with useful properties. In 1977 Japanese researcher Hideki Shirakawa (1936-) and US researchers Alan McDiarmid (1929-) and Alan Heeger (1936-), while researching into a new class of electrically conductive plastics, made the discovery that the addition of iodine vastly improved the electrical properties of the polymer. By 1981, scientists at the University of Pennsylvania were able to construct the first plastic battery. In 1988 the Dutch firm CCA Biochem developed the polymer polyactide, a biodegradable plastic which can be broken down by human metabolism. It found an immediate application as a suture thread used in surgery. Developments such as these highlight that there is still a lot of research to be carried out before we find the limits to the usefulness of this class of materials.

the chemistry of death - the chemist at war

It would be wrong to highlight the development of chemistry in the 20th century without paying some attention to the darker aspect of the science, and there can be none darker than the use of the chemist during times of war.

Every discovery can often be used to do as much harm as it does good. For example, the breakthrough of the Haber process came at just the right time to be used to supply the German army with high explosives during World War I. Likewise, Bergius's development of petrol from coal helped to fuel Hitler's war machine in World War II.

In both these conflicts, increased mechanization made rubber a vital strategic material. The only place where natural rubber could be obtained was the Malaysian peninsula, but this could not be relied upon during wartime, and so synthetic alternatives were sought. The first practical synthetic rubber polymer was produced in Germany during World War I. It was made from dimethyl butadiene and was called methyl rubber. Two grades were produced, a soft grade for tyres and a hard one for battery casings used in submarines. It was not perfect and did not hold up well to stress, but was better than nothing. In 1930 both Germany and the Soviet Union developed a synthetic rubber, called Buna rubber, from butadiene using a sodium catalyst. This had superior properties to methyl rubber but was still inferior to the natural product. German chemists researched through the 1930s and eventually produced Buna-S by copolymerizing styrene with butadiene. Copolymerization proved to be the solution to their problems and by the outbreak of World War II they had developed an effective rubber substitute in the form of Buna-N, a butadiene acrylonitrile copolymer.

The USA also required a substitute to natural rubber. In 1918 US chemist J C Patrick accidentally discovered a rubbery polymer by the condensation of dichloroethane with sodium polysulphide. This was patented and sold under the name Thiokol in 1927. It was the first synthetic rubber manufactured in the USA.

In 1931, US chemists Wallace Hume Carothers and Arnold Collins of DuPont developed a synthetic rubber by polymerizing chlorobutadiene. The material was called Duprene, but the name was changed to the more familiar Neoprene in 1937. This material was superior to natural rubber in several ways as it was more resistant to organic solvents such as petrol. It became a major source of synthetic rubber used by the USA during World War II.

Arguably, the worst misuse of chemistry in the 20th century was the development of chemical weapons. Developments in industrial production during the 19th century had meant that, for the first time in history, poisonous gases could be produced in the massive quantities required to make them a viable weapon in warfare. Phosgene had been discovered in 1812, and was intensively used in synthetic dye manufacture, and liquid chlorine had been available in industrial quantities since 1880. The danger these chemicals posed caused enough concern in the international community for leading industrial nations to sign the Hague Conventions of 1899 and 1907 that strictly prohibited the use in war of asphyxiation gases. Unfortunately, this did not stop these countries from researching and producing chemical agents, just in case.

During World War I, Germany was the first to break the spirit of the agreement by using tear gas at Neuve Chapelle on October 1914 against French troops, and on January 1915 at Bolimov against the Russians. The French retaliated at Argonne in March 1915 by using a tear gas attack of their own against German troops. Escalation was inevitable. The advanced German chemical industry had given them a lead in the chemical warfare race which was demonstrated at Ypres on 22 April 1915. German troops discharged a huge chlorine gas cloud that blew over French and Canadian positions. The Allied soldiers fled, leaving a gap in their lines of 7 km/4.5 mi. Even the German high command was surprised by the success of the weapon. However, it did not follow up on the initial attack because it did not have sufficient reserves or ammunition to hold such a huge area of land. However, after the initial shock of the gas, the psychological impact of gas attacks diminished. When chlorine was deployed again two days later, Canadian forces had improvised rudimentary protection from the gas and easily beat off the German assault. A valuable lesson was there to be learned. Chemical warfare against a prepared enemy is invariably ineffective. The wonder weapon designed to break the deadlock in World War I was not going to be gas.

Instead of abandoning chemical weapons as ineffective, both sides tried even harder to develop even more sophisticated chemical agents. The misery and suffering reached new heights with the introduction by the German army of dichlorethyl sulphide, commonly known as mustard gas due to its brown colour and distinctive smell. This chemical was a vesicant, or blistering agent, and gas masks were no protection against this development. Contact with the gas caused severe blistering of the skin and blindness if it reached the eyes. If inhaled the gas would blister the lungs, a virtual death sentence considering the medical treatment available. On the 12 and 13 July 1917 at Ypres, the weapon was used to great effect on British troops. But it was not long before both sides had this terrible weapon and the countermeasures to it. By September 1918, Allied chemists had developed mustard gas in a form that could be used as a weapon. New strategies were also tried including the use of chloropicrin, a respiratory and vomiting agent, which was able to penetrate gas masks. An affected soldier was forced to remove his gas mask in order to breathe and was therefore totally vulnerable to the lethal agent that was always put in the same shell charge.

After the war there was an immediate reaction to abolish future use of chemical agents. The treaty of Versailles in 1919 imposed a total ban on Germany to manufacture, research in, or use chemical weapons in the future. On a darker note, an article of the treaty required that the knowledge acquired by German chemists in the development of chemical weapons was to be disclosed to the Allies. In June 1925, a better step towards disarmament was taken. A protocol was signed in Geneva prohibiting the use of chemical and biological warfare. It did not ban the production, purchase, or even possession of such agents, but did prevent their use.

The fear of large-scale gas warfare increased with the approach of World War II. Between 1935 and 1936 the Italian army used mustard gas in their invasion of Abyssinia. But the expected wide-scale use of chemicals just did not happen despite the fact that German chemists had developed the next generation of weapons. In 1936 German chemist Gerhard Schrader had found the nerve agent tabun while investigating a new insecticide. He discovered the even more deadly sarin two years later. By 1942, a full-scale plant manufacturing tabun began production. But the nerve agent was never used. Advances in weapons technology, such as the development of aircraft, made the threat of retaliation against civilian populations a powerful deterrent. World War I had proved that chemical weapons were ineffective against a force that was prepared for them and so the risks involved in using these horrific weapons were just too great.

Fortunately there have been few incidents involving the use of chemical weapons since 1918. The one notable exception was the Iran-Iraq war of 1980-88. Iraqi forces used a variety of chemical weapons including phosgene and mustard gas on a large scale against largely unprotected Iranian soldiers. International condemnation against Iraq had little effect on this policy. The Iraqi army used poisonous agents against civilian targets in Iran in 1987 and in 1988 against Kurdish civilians in the town of Hallabyah in northern Iraq. Incidents such as these, show us that the dark legacy of 1914-18 is still with us.

Silent Spring - the price of success

After nearly two centuries of worldwide chemical production it was inevitable that there would be some consequences of an ever increasing dependence and demand for the products that the chemical industry provides. US chemist Thomas Midgely (1889-1944) and Swiss chemist Paul Müller (1899-1965) provide good examples of how a discovery seen as a breakthrough by one generation can become a curse to their descendants.

Midgely developed tetraethyl lead, an organometallic additive that prevents knocking in car engines, in 1921. He went on to discover freon-12 in 1930. This is an odourless, non-flammable gas that replaced the more dangerous ammonia as a refrigerant and was also used as a propellant in aerosols. At the time these were very useful developments, but unfortunately with the increased amount of motor vehicles on the roads, the lead additives in petrol now cause a serious pollution problem. They are toxic and cumulative in the human body and can result in a number of conditions including, in extreme cases, brain damage. Freon-12 is an example of a chloroflurocarbon (CFC) and all of this class of compounds are very efficient in breaking down ozone in the upper atmosphere. This accelerates ozone hole formation and increases the danger of exposure to harmful ultraviolet radiation from the Sun. By 2000 the ozone hole over Antarctica was more than three times the size of the USA.

Müller developed the insecticide dichlorodiphenyltrichloroethane, better known as DDT, in 1939. It was cheap and easy to manufacture and while non-toxic to humans was lethal to all forms of insect. It was soon used all over the world. The World Health Organization (WHO) used it as a basis to attempt to eradicate malaria by killing every mosquito, the insect which carries the disease. For a time there were dramatic drops in deaths caused by malaria, and the virtual elimination of the disease in some parts of the world. Unfortunately, this overuse of DDT highlighted the flaw in this global strategy: some mosquitoes were resistant to the chemical and over time an immune mosquito population returned. In 1962, US science writer Rachel Carson (1907-1964) wrote the influential book *Silent Spring*, in which she outlined the dangers of indiscriminate use of insecticides. She pointed out that harmless and potentially useful species were being eradicated at the same time as the undesirable insects and that in many cases, insecticides can make a problem worse by removing the natural predators, but failing to eradicate the original pest. Her book fostered a growing public interest in ecology.

The sheer scale of the chemical industry causes some unique problems. The supplanting of coal-based chemicals by petrochemicals has resulted in the transport of huge quantities of crude oil around the world and it was only a matter of time before a serious accident occurred. In December 1976, the Liberian tanker *Argo Merchant* ran aground off Nantucket island and broke in two spilling 180,000 barrels of crude oil into the Atlantic ocean devastating sealife for miles in every direction. In March 1989, the tanker *Exxon Valdez* spilled oil in Alaska's Prince William Sound, the oil eventually covered an area of 12,400 sq km/4,800 sq mi, and devastated the wildlife and environment of one of the world's most unspoilt regions. But by far the largest oil spill in history was the deliberate release of millions of gallons of crude oil into the Persian Gulf in 1991 by the Iraqi forces occupying Kuwait. The heavy oils, which sank to the bottom of the Gulf and destroyed the fragile ecosystem there, will persist well into the 21st century.

Many chemical companies have plants in heavily populated areas that have no protection from leakages and the consequences can be devastating. In July 1976, a pesticides plant near Seveso, Italy, released a massive cloud of dioxin gas, one of the world's most toxic poisons. It killed thousands of domestic and farm animals in the area and led to birth defects in the nearby population. In August 1978, the USA's worst chemical waste disaster occurred in the Love canal neighbourhood of Niagara Falls, New York. The houses were built on an abandoned canal which the Hooker Chemicals and Plastics Corporation had used to dump waste chemicals into between 1947 and 1953. Dioxins, pesticides, and PCBs were included in the poisonous cocktail that leaked into the basements of the houses. The leak was discovered too late for some, as a higher incident of birth defects was found to occur for the former residents. In December 1984, the world's worst chemical accident took place in Bhopal, India. The Union Carbide pesticides plant there suffered a huge leak of toxic waste which poured out into the surrounding town, killing over 6,000 people and injuring many thousands more.

The chemical industry produces large quantities of waste materials, which in many cases are discharged straight into rivers and the sea. The dilution of the effluent by water increases the difficulty in tracing the source of the pollution. However, the effects become obvious over time. A common chemical used in the manufacture of detergents, herbicides, and paints is alkylphenolethoxylate (APEO). This breaks down in contact with water to form nonylphenol, a substance which mimics a female hormone in fish. This causes male fish to partially change into females and drastically reduces fish stocks as a consequence.

The overuse of chemicals has also produced unwanted side effects. Misuse of antibiotics has led to the development of drug-resistant strains of common bacteria. The increased use of artificial fertilizers in farming has resulted in higher levels of nitrates being present in the soil than can be removed by natural processes, with excess nitrates being washed into the local water supply. The nitrate-enriched water this produces, becomes an ideal medium for the rapid growth of algae, which reduces the oxygen content of the water, killing plants and fish.

The amount of chemicals being manufactured today is greater than at any time in history. In 1983 the US Chemical Society reported that it has 6 million chemicals on record, most of which can be produced by the chemical industry. Many have been found to have had a severe environmental impact.

DNA - the chemical of identity

The application of chemistry to biology - biochemistry - made major contributions to science from the 1930s onwards with the analysis and then synthesis of vitamins, hormones, and other biologically active chemicals. By the mid-20th century biochemistry had spawned its own subdivisions. One of these is molecular biology, which is concerned with the chemistry of living molecules as they exist within cells. And of all these substances, the most significant is DNA.

German cytologist Walther Flemming (1853-1905) discovered the threadlike structures in the nuclei of cells now known as chromosomes, in the 1880s. With the rediscovery of the work of Austrian monk Gregor Mendel (1822-1884) in 1900, the US geneticist Thomas Hunt Morgan (1866-1945) began studying the chromosomes of the fruit fly *Drosophila*, destined to be come the mostly widely used experimental animal in biology. In 1908 he finally made the link between chromosomes and heredity (and earned for himself the 1933 Nobel Prize for Physiology or Medicine).

Morgan showed that chromosomes consist of strings of genes. At first, scientists thought that genes were proteins. Then in 1944 that US bacteriologist Oswald Avery (1877-1955) and his colleagues demonstrated that genes are composed of deoxyribonucleic acid, (DNA). Through the genes, DNA controls all the activities of cells - metabolism, growth, division, and the formation of eggs and sperm, the progenitors of new life and the actual stuff of heredity. DNA is truly the key chemical of life.

To gain a better understanding of the role of DNA, several scientists started work to determine its structure. In the USA, chemist Linus Pauling (1901-1994) found a protein molecule that was shaped like a helix (a long spiral resembling a screw thread). In Britain, four scientists tackled the problem. Using hydrated DNA, Rosalind Franklin obtained X-ray diffraction photographs, as did Maurice Wilkins (1916-), working independently. These seemed to indicate a spiral structure. In 1952 the photographs were studied (in England) by US biochemist James Watson (1928-), who was working on the structure of DNA with English molecular biologist Francis Crick,(1916-). By 1953 they had built a model of the DNA molecule, revealing its structure to be a pair of strands in the form of a double helix linked by pairs of bases, the whole thing resembling a twisted ladder. For determining the chemistry and structure of DNA, Crick, Wilkins and Watson shared the 1962 Nobel Prize for Physiology or Medicine. Franklin had died in 1958, before her contribution could be rewarded.

DNA turned out to be a remarkable chemical. For example, during cell division it replicates itself. It does this by 'unzipping' down the centre of the helical ladder and each half then acts as a template for the creation of a new molecule. US molecular biologists Matthew Meselson (1930-) and Franklin Stahl (1929-) demonstrated this mechanism experimentally in 1958. The molecule also acts as the carrier of hereditary information. The sequence of bases in one DNA strand determines the sequence of amino acids in proteins manufactured in cells, with a combination three bases unique for each amino acid. These sequences are the genetic codes, which were first cracked by Spanish-born US biochemist Severo Ochoa (1905-1993) and, independently, US biochemist Marshall Nirenberg (1927-) who shared the 1968 Nobel Prize for Physiology or Medicine for this work.

Every cell of every organism contains DNA and the DNA of any plant or animal, including humans, is unique to that organism. Every organism has its own individual DNA profile. So in theory a sample of DNA can be used to identify the organism from which it came. One application has been in establishing the parentage (or not) of a particular individual, because his or her DNA profile reveals some characteristics of the mother and some of the father. Forensic scientists also use these DNA fingerprints to identify a body or to prove a link between a suspect and a victim in cases of rape or murder.

the future - 'a brave new world'

A primary role of the chemist of the future will be to provide alternatives to today's problem chemicals. In 1995, US chemist F Sherwood Roland (1927-), Mexican chemist Mario Molina (1943-), and Dutch chemist Paul Crutzen (1933-) were awarded the Nobel Prize for Chemistry for explaining the mechanism by which ozone reacts with pollutants such as CFCs in the upper atmosphere. This was the first chemistry award for environmental research, but it will not be the last. The rapid development of the chemistry industry has left a legacy of problems and finding their solution is the challenge chemistry faces now. Roland and his colleagues showed that understanding the problem is the first step to solving it. Their research has led to an international effort to replace CFCs with more 'ozone friendly' materials. These measures are already having an impact. Between 1988 and 1994 the amount of CFCs released into the atmosphere by the USA decreased by over 50% and in 1996 the National Oceanic and Atmospheric Administration in Washington, DC, announced the first decline in the levels of all ozone-depleting chemicals in the air. The majority of alternatives to CFCs still had a reduced ozone-depleting action. Research in this field, published in 2003, showed that the amount of ozone in the upper stratosphere was declining at a rate of 4% per decade, a drop from 8% pre-1997. The CFC ban had not had an immediate effect on ozone levels because it takes five years for CFCs on the ground to reach the stratosphere. Ironically, scientists are concerned that the CFC ban and global warming could lead ozone levels to increase 'beyond natural levels'. This, in turn, could lead to a rise in pollution.

Strategies for reducing existing levels of greenhouse gases have been under development since the early 1990s. Various ways to remove the major pollutant, carbon dioxide, from the atmosphere for storage in a frozen solid form exist, but these are too expensive to implement in the scale needed to have a beneficial effect. A cheaper alternative, such as reacting the gas to form a stable, solid compound, is one approach which is being studied. This route has the advantage that the resulting compound could be dumped safely in the oceans without harming the environment.

Alternatives to oil as the primary source of fuel are being developed, such as using 'biomass' from waste vegetation. The chemical industry already has the means to process a wide range of carbon-based materials into chemicals. Further development of the techniques involved in processing biomass could make this route competitive with petroleum, with the added advantage that it is free from the pollution risks inherent in petrochemicals.

The lessons of the 20th century have shown that the chemist of the future cannot ignore the wider implications of new chemical developments. The introduction of any new chemical must now be carefully monitored to determine its impact on the environment. Pesticides, insecticides, and fertilizers will still have to be developed to help maintain the food supply for an ever increasing population. However, better care can be shown in future developments, such as a species-specific reagent which will leave insects useful to agriculture unscathed while removing the pests. The plastics industry has already responded to the need to reduce pollution by developing the first biodegradable plastics.

The disasters and accidents associated with the chemical industry that occurred during the 20th century had at least one good effect: they raised public awareness of the risks. Now, even the most trivial chemical accident receives global news coverage. The glare of publicity had the effect of producing new legislation that limits industrial pollution such as effluent discharge. Detection of illegal waste disposal is possible due to the development of techniques which detect minute quantities of pollutants in rivers, and companies can now be heavily fined for breaching environmental legislation.

Antibiotics have proved that chemicals can be effective in treating disease. New antibiotics are continually being developed to combat the ever-increasing strains of drug-resistant bacteria which are also developing. It will be the job of the chemist to ensure that science stays ahead of nature in this race. Many potential breakthroughs in chemotherapy are possible, such as an antiviral drug or an all-purpose anticancer agent. The chemist in the future will be expected to find the solutions to these challenges.

The 20th century taught us that we pay a price for every discovery and breakthrough that science makes. But we have more understanding than ever before of what that price is and so have the choice of whether we pay it or not. There now exists the will and the ability to decrease the effects of pollution and contamination that are our legacy from two centuries of industrial growth. We have the capability to make a difference, and if we do, then the 21st century can become 'a brave new world'.

Chemistry Today

introduction

Chemistry is all around us; everything, including ourselves, is made of chemicals. Chemistry's effects underlie change throughout the universe and in the new millennium. Our understanding of chemistry is increasing faster than ever.

chemical synthesis

Chemists have hundreds of techniques for manipulating chemicals, from the simplest gases to complex anticancer drugs and supermolecules. In the 1960s, Elias J Corey made a breakthrough in organic (carbon-based) chemistry when he developed retrosynthesis, a powerful tool for building complex molecules from smaller, cheaper, and more readily available ones. Retrosynthesis can be used to picture a molecule like a jigsaw, working backwards to find reactive components to complete the puzzle. Modern chemists use retrosynthesis to design everything from insect antifeedants for 'greener' farming to better drugs with fewer side effects.

One such chemical puzzle, Taxol, received worldwide attention. Extracted from Pacific yew tree bark, it is an effective treatment for advanced forms of ovarian, breast, and other cancers, which resist traditional drugs. Retrosynthesis will help chemists design a laboratory production method for Taxol. Such a 'total' synthesis might need 25 individual chemical steps, making industrial scale-up difficult, but the payback could easily make such a process commercially viable.

enzymes in chemistry

Traditional synthesis is powerful, but often requires numerous steps, and many reactions need high temperatures and pressures to work at a useful rate. Artificial catalysts help speed up some reactions, such as the conversion of methane (natural gas) into useful products. But some are expensive, and can pose disposal problems.

Chemists are turning to nature to solve such problems. Enzymes - nature's catalysts - have many advantages. They work at low temperatures, using less energy. Each type only catalyses certain reactions, so by-products are reduced. This does not limit their use because over 10,000 enzymes are known, and protein engineering could lead to even more.

Enzymes can distinguish between the right- and left-hand forms of a molecule. Some chemicals exist in two forms - enantiomers - with the chemical groups arranged as mirror images, like a pair of hands. The two enantiomers often interact very differently with other molecules. For example, one form of the morning sickness drug thalidomide is an effective tranquillizer; the other severely disturbs fetal development. Enzymes allow the chemist to determine the handedness of such reaction products.

molecular recognition

Some researchers are working towards building 'molecular machines': tiny switches and transistors that respond to light; molecular wires and diodes that carry signals; and self-replicating systems and artificial enzymes.

To do this they are exploiting 'molecular recognition'. Certain large molecules can 'recognize' and trap smaller molecules or ions in their cavities. A simple example is the crown ethers - simple rings of alternating carbon and oxygen atoms. The number of atoms in the ring determines its size, and this determines which chemicals the molecule will recognize. The smallest crown ether can recognize and trap lithium metal ions, but nothing larger, and could be incorporated in a sensor to detect lithium in the presence of other metal ions.

self-assembly

A second important property is 'self-assembly'. If the component parts of the crown ether ring are mixed in a solution containing lithium ions the parts will spontaneously assemble around the ion to complete the ring. The lithium acts as a 'template' for the self-assembly of the ring.

research

Fraser Stoddart's research team at Birmingham University, UK, built some long-chain compounds with cyclic molecules threaded on ring-shaped molecules, like beads on a string. They made the 'beads' shuttle backwards and forwards between chemical groups incorporated along the chain.

Once they could control this movement using an external input such as light, they had a switch for use in molecular-scale optoelectronic computers.

Jean-Marie Lehn and colleagues at the University Louis Pasteur, France, used cyclic rings related to crown ethers to mimic biochemical processes and to develop chemical sensors and other devices.

Julius Rebek's group at MIT, USA found a molecule that could help explain the early replication processes at life's origins. It acts as a template, bringing molecules together and speeding up their self-assembly. The first template catalyses the formation of a second; the two templates then separate and each catalyses the next round of assembly. Rebek's self-replicating system is analogous to DNA replication in dividing cells. A single helical strand acts as a template for the self-assembly of the DNA base units forming a double helix. These two entwined templates then uncoil, resulting in two single-stranded templates, and so on.

the round chemistry of fullerenes

Fullerenes, or buckyballs, are a fascinating chemical discovery. These all-carbon compounds were first produced in the laboratory in the early 1990s. Fullerene-60 (buckminsterfullerene) is the archetypal 60-carbon spherical molecule. Chemists and other scientists invest vast amounts of time and money researching buckyballs, which have huge potential as everything from high-temperature superconductors to superlubricants.

Chemistry: key dates of industrial processes

c. AD 1100	Alcohol is first distilled.
1746	John Roebuck invents the lead-chamber process for the manufacture of sulphuric acid.
1790	Nicolas Leblanc develops a process for making sodium carbonate from sodium chloride (common salt).
1827	John Walker invents phosphorus matches.
1831	Peregrine Phillips develops the contact process for the production of sulphuric acid; it is first used on an industrial scale in 1875.
1834	Justus von Liebig develops melamine.
1835	Tetrachloroethene (vinyl chloride) is first prepared.
1850	Ammonia is first produced from coal gas.
1855	A technique is patented for the production of cellulose nitrate (nitrocellulose) fibres, the first artificial fibres.
1856	Henry Bessemer develops the Bessemer converter for the production of steel.
1857	William Henry Perkin sets up the first synthetic-dye factory, for the production of mauveine.
1861	Ernest Solvay patents a method for the production of sodium carbonate from sodium chloride and ammonia; the first production plant is established in 1863.
1862	Alexander Parkes produces the first known synthetic plastic (Parkesine, or xylonite) from cellulose nitrate, vegetable oils, and camphor; it is the forerunner of celluloid.
1864	William Siemens and Pierre Emile Martin develop the Siemens-Martin process (open-hearth method) for the production of steel.
1868	Henry Deacon invents the Deacon process for the production of chlorine by the catalytic oxidation of hydrogen chloride.
1869	Celluloid is first produced from cellulose nitrate and camphor.
1880	The first laboratory preparation of polyacrylic substances is undertaken.
1886	Charles M Hall and Paul-Louis-Toussaint Héroult develop, independently of each other, a method for producing aluminium by the electrolysis of aluminium oxide.
1891	Rayon is invented. Herman Frasch patents the Frasch process for the recovery of sulphur from underground deposits. Lindemann produces the first epoxy resins.
1894	Carl Kellner and Hamilton Castner develop, independently of each other, a method for the production of sodium hydroxide by the electrolysis of brine; collaboration gives rise to the Castner-Kellner process.
1895	The Thermit reaction for the reduction of metallic oxides to their molten metals is developed by Johann Goldschmidt.
1902	Friedrich Ostwald patents a process for the production of nitric acid by the catalytic oxidation of ammonia.

1908	Fritz Haber invents the Haber process for the production of ammonia from nitrogen and hydrogen. Heike Kamerlingh-Onnes prepares liquid helium.
1909	The first totally synthetic plastic (Bakelite) is produced by Leo Baekeland.
1912	I Ostromislensky patents the use of plasticizers, which render plastics mouldable.
1913	The thermal cracking of petroleum is established.
1919	Elwood Haynes patents non-rusting stainless steel.
1927	The commercial production of polyacrylic polymers begins.
1930	Freons are first prepared and used in refrigeration plants. William Chalmers produces the polymer of methyl methacrylate (later marketed as Perspex).
1933	E W Fawcett and R O Gibson first produce polyethylene (polyethene) by the high-pressure polymerization of ethene.
1935	The catalytic cracking of petroleum is introduced. Triacetate film (used as base for photographic film) is developed.
1937	Wallace Carothers invents nylon. Polyurethanes are first produced.
1938	Roy Plunkett first produces polytetrafluoroethene (PTFE, marketed as Teflon).
1943	The industrial production of silicones is initiated. J R Whinfield invents Terylene.
1953	The German chemist Karl Zeigler produces high-density polyethylene.
1955	Artificial diamonds are first produced.
1959	The Du Pont company develops Lycra.
1963	Leslie Phillips and co-workers at the Royal Aircraft Establishment, Farnborough, England, invent carbon fibre.
1980	Nippon Oil patents the use of methyl-tert-butyl ether (MTBE) as a lead-free antiknock additive to petrol.
1984	About 2,500 people die in Bhopal, central India, when poisonous methyl isocyanate gas escapes from a chemical plant owned by US company Union Carbide.
1991	ICI begins production of the hydrofluorocarbon HFA-134a, a substitute for CFCs in refrigerators and air-conditioning systems. Superconducting salts of buckminsterfullerene are discovered by researchers at AT&T Bell Laboratories, New Jersey, USA.
1993	Scientists at BP Chemicals build a pilot plant to convert plastic waste into an oil like naphtha, the crude oil fraction from which most plastics are derived. Chemists at the University of Cambridge, England, develop light-emitting diodes (LEDs) from the polymer poly(*p*-phenylenevinyl) that emit as much light as conventional, semiconductor-based LEDs and in a variety of colours.
1996	US scientists announce the invention of the all-plastic battery.

Chemistry: key events

c. 3000 BC	Egyptians begin producing bronze - an alloy of copper and tin.
c. 450 BC	Empedocles proposes that all substances are made up of a combination of four elements - earth, air, fire, and water - an idea that is developed by Plato and Aristotle and persists for over 2,000 years.
c. 400 BC	Democritus theorizes that matter consists ultimately of tiny, indivisible particles, *atomoi*. The Greek word *atomos* means uncuttable.
AD 1	Gold, silver, copper, lead, iron, tin, and mercury are known.
200	The techniques of solution, filtration, and distillation are known.
7th-17th centuries	Chemistry is dominated by alchemy, the attempt to transform nonprecious metals such as lead and copper into gold. Though misguided, it leads to the discovery of many new chemicals and techniques.
12th century	Alcohol is first distilled in Europe.
1242	Gunpowder is introduced to Europe from the Far East.
1620	The scientific method of reasoning is expounded by Francis Bacon in his *Novum Organum*.
1650	Leyden University in the Netherlands sets up the first chemistry laboratory.
1661	Robert Boyle defines an element as any substance that cannot be broken down into still simpler substances and asserts that matter is composed of 'corpuscles' (atoms) of various sorts and sizes, capable of arranging themselves into groups, each of which constitutes a chemical substance.
1662	Boyle describes the inverse relationship between the volume and pressure of a fixed mass of gas (Boyle's law).
1697	Georg Stahl proposes the erroneous theory that combustible materials are rich in a substance called phlogiston, which is released when they burn.
1755	Joseph Black discovers carbon dioxide.
1774	Joseph Priestley discovers oxygen, which he calls 'dephlogisticated air'. Antoine Lavoisier demonstrates his law of conservation of mass.
1777	Lavoisier shows air to be made up of a mixture of gases, and shows that one of these - oxygen - is the substance necessary for combustion (burning) and rusting to take place.
1781	Henry Cavendish shows water to be a compound.
1792	Alessandro Volta demonstrates the electrochemical series.
1807	Humphry Davy passes an electric current through molten compounds (the process of electrolysis) in order to isolate elements, such as potassium, that have never been separated by chemical means. Jöns Berzelius proposes that chemicals produced by living creatures should be termed 'organic'.
1808	John Dalton publishes his atomic theory. It states that every element consists of similar indivisible particles - called atoms - which differ from the atoms of other elements in their mass. Dalton also draws up a list of relative atomic masses. Joseph Gay-Lussac announces that the volumes of gases that combine chemically with one another are in simple ratios.
1811	Amedeo Avogadro's hypothesis on the relation between the volume and number of molecules of a gas, and its temperature and pressure, is published.
1813-14	Berzelius devises the chemical symbols and formulae still used to represent elements and compounds.
1828	Franz Wöhler converts ammonium cyanate into urea - the first synthesis of an organic compound from an inorganic substance.

1832-33	Michael Faraday expounds the laws of electrolysis, and adopts the term 'ion' for the particles believed to be responsible for carrying current.
1846	Thomas Graham expounds his law of diffusion.
1853	Robert Bunsen invents the Bunsen burner.
1858	Stanislao Cannizzaro differentiates between atomic and molecular weights (masses).
1861	Organic chemistry is defined by German chemist Friedrich Kekulé as the chemistry of carbon compounds.
1864	John Newlands devises the first periodic table of the elements.
1869	Dmitri Mendeleyev expounds his periodic table of the elements (based on atomic mass), leaving gaps for elements that are predicted but have not yet been discovered.
1874	Jacobus van't Hoff suggests that the four bonds of carbon are arranged tetrahedrally, and that carbon compounds can therefore be three-dimensional and asymmetric.
1884	Svante Arrhenius suggests that electrolytes (solutions or molten compounds that conduct electricity) dissociate into ions, atoms, or groups of atoms that carry a positive or negative charge.
1894	William Ramsey and Lord Rayleigh discover the first inert gas, argon.
1897	The electron is discovered by J J Thomson.
1901	Mikhail Tsvet invents paper chromatography as a means of separating pigments.
1909	Sören Sörensen devises the pH scale of acidity-alkalinity.
1912	Max von Laue shows crystals to be composed of regular, repeating arrays of atoms by studying the patterns in which they diffract X-rays.
1913-14	Henry Moseley equates the atomic number of an element with the positive charge on its nuclei, and draws up the periodic table, based on atomic number, that is used today.
1916	Gilbert Newton Lewis explains covalent bonding between atoms as a sharing of electrons.
1927	Nevil Sidgwick publishes his theory of valency, based on the numbers of electrons in the outer shells of the reacting atoms.
1930	Electrophoresis, which separates particles in suspension in an electric field, is invented by Arne Tiselius.
1932	Deuterium (heavy hydrogen), an isotope of hydrogen, is discovered by Harold Urey.
1940	Edwin McMillan and Philip Abelson show that new elements with a higher atomic number than uranium can be formed by bombarding uranium with neutrons, and synthesize the first transuranic element, neptunium.
1942	Plutonium is first synthesized by Glenn T Seaborg and Edwin McMillan.
1950	Derek Barton deduces that some properties of organic compounds are affected by the orientation of their functional groups (the study of which becomes known as conformational analysis).
1954	Einsteinium and fermium are synthesized.
1955	Ilya Prigogine describes the thermodynamics of irreversible processes (the transformations of energy that take place in, for example, many reactions within living cells).
1962	Neil Bartlett prepares the first compound of an inert gas, xenon hexafluoroplatinate; it was previously believed that inert gases could not take part in a chemical reaction.
1965	Robert B Woodward synthesizes complex organic compounds.
1981	Quantum mechanics is applied to predict the course of chemical reactions by US chemist Roald Hoffmann and Kenichi Fukui of Japan.
1985	Fullerenes, a new class of carbon solids made up of closed cages of carbon atoms, are discovered by Harold Kroto and David Walton at the University of Sussex, England.
1987	Donald Cram, Charles Pederson, and Jean-Marie Lehn create artificial molecules that mimic the vital chemical reactions of life processes.
1990	Jean-Marie Lehn, Ulrich Koert, and Margaret Harding report the synthesis of a new class of compounds, called nucleohelicates, that mimic the double helical structure of DNA, turned inside out.
1993	Chemists at the University of California and the Scripps Institute synthesize rapamycin, one of a group of complex, naturally occurring antibiotics and immunosuppressants that are being tested as anticancer agents.
1995	German chemists build the largest ever wheel molecule, made up of 154 molybdenum atoms surrounded by oxygen atoms. It has a relative molecular mass of 24,000 and is soluble in water.
1997	The International Union of Pure and Applied Chemistry (IUPAC) officially names elements 104-109. Element 104 (discovered in Russia in 1964 and the USA in 1969) is named rutherfordium, element 105 (discovered in Russia in 1967 and the USA in 1970) is named dubnium, element 106 (discovered in 1973) is named seaborgium, element 107 (discovered in 1976) is named bohrium, element 108 (discovered in 1984) is named hassium, and element 109 (discovered in 1982) is named meitnerium.
1999	Russian scientists at the Institute of Nuclear Research at Dubna create element 114 by colliding isotopes calcium 48 and plutonium 44.

Chem101

Go to site

Student-created site for those studying chemistry. Aimed at keeping the whole experience fun, this site includes an interactive textbook that covers the basics of the science.

Chemistry Exam Exchange Centre

Go to site

Approximately 40 chemistry exams and quizzes are freely available to download in PDF format from this site.

Chemistry for Children

Go to site

Fun introduction to chemistry. You can take a quiz to test your knowledge of the basics, take a tour around the site, or search for specific information.

ChemTutor

Go to site

Beginning with the fundamentals, and graduating to 'the parts of primary chemistry that have been... the hardest for students to grasp', this site is a useful resource for any chemistry student.

CHEMystery

Go to site

Detailed interactive textbook that includes subjects such as 'Atomic structure and bonding', 'Equilibrium', and 'Thermodynamics'. Use the left-hand menu to navigate to a relevant chapter.

Creative Chemistry GCSE Stuff

Go to site

Good general resource on chemistry, split into six modules. Each module is split further into downloadable information sheets, which require Adobe Acrobat to read them (a link is provided), and these are arranged in a table for quick selection. The sheets are in three styles: a practical guide, a question sheet, and a structured worksheet.

Eric Weisstein's World of Chemistry

Go to site

Searchable database of facts relating to chemistry. The author has included an A-Z glossary of terms, history, biographies, and concepts of chemistry and chemical engineering.

GCSE Chemistry: The Complete GCSE Chemistry Guide

Go to site

Colourful and quick-loading page which covers all of the main topics of chemistry. Clicking on the main topics brings up a comprehensive overview of sub-topics. Each sub-topic contains a detailed explanation, and all of the relevant chemical equations. Alternatively the site can be browsed via an A to Z index, making it easy to dip into.

General Chemistry Glossary

Go to site

List of common chemistry terms, with clear definitions. It is possible to browse by letter or by subject, or to carry out a keyword search of the whole glossary. An added feature is the provision of audio clips giving the pronunciation of many of the terms defined.

General Chemistry Online

Go to site

This sophisticated Web site is run by the chemistry department of a US university, but its clear text and comprehensive coverage of general chemistry topics make it worth a visit for keen GCSE-level chemists. Searchable databases of common compounds and important chemical terms are two of the most powerful features of a very comprehensive resource.

Journal of Chemical Education

Go to site

Online version of a CD-ROM designed to accompany the general study of chemistry, including text, videos, and pictures to support the text.

Natural Science Pages

Go to site

Designed for general as well as academic use by John Jay College, City University of New York, this interactive site allows the user to explore concepts in basic science including the scientific method, the nature of matter, and atomic structure.

Science is Fun in the Lab of Shakhashiri

Go to site

University of Wisconsin-Madison chemistry professor Shakhashiri shares the fun of science through home experiments such as 'Exploring acids and bases with red cabbage'.

Virtual Experiments

Go to site

Series of interactive chemistry experiments for A-level and university-level students hosted by this site from Oxford University, UK. As well as clear instructions and safety information, the site contains photos of key stages of each experiment. Please note that most of the experiments require specialist equipment and are not suitable for the home. However, the site does contain introductions to various subject areas, such as superconductors and simple inorganic solids.

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chemosynthesis

method of making protoplasm (contents of a cell) using the energy from chemical reactions, in contrast to the use of light energy employed for the same purpose in photosynthesis. The process is used by certain bacteria, which can synthesize organic compounds from carbon dioxide and water using the energy from special methods of respiration.

Nitrifying bacteria are a group of chemosynthetic organisms that change free nitrogen into a form that can be taken up by plants; nitrobacteria, for example, oxidize nitrites to nitrates. This is a vital part of the nitrogen cycle. As chemosynthetic bacteria can survive without light energy, they can live in dark and inhospitable regions, including the hydrothermal vents of the Pacific Ocean. Around these vents, where temperatures reach up to 350°C/662°F, the chemosynthetic bacteria that can use the oxidation of sulphides as an energy source are the basis of a food web supporting fishes and other marine life.

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chemotaxis

in biology, the property that certain cells have of attracting or repelling other cells. For example, white blood cells are attracted to the site of infection by the release of substances during certain types of immune response.

---

chemotherapy

any medical treatment with chemicals. It usually refers to treatment of cancer with cytotoxic and other drugs. The term was coined by the German bacteriologist Paul Ehrlich for the use of synthetic chemicals against infectious diseases.

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chemotropism

movement by part of a plant in response to a chemical stimulus. The response by the plant is termed 'positive' if the growth is towards the stimulus or 'negative' if the growth is away from the stimulus.

Fertilization of flowers by pollen is achieved because the ovary releases chemicals that produce a positive chemotropic response from the developing pollen tube.

Cherenkov, Pavel Alexeevich (1904-1990)

Soviet physicist. He was awarded the Nobel Prize for Physics in 1958 for his discovery in 1934 of Cherenkov radiation; this occurs as a bluish light when charged atomic particles pass through water or other media at a speed in excess of that of light. He shared the award with his colleagues Ilya Frank and Igor Tamm for work resulting in a cosmic-ray counter.

Chernobyl

town in northern Ukraine, 100 km/62 mi north of Kiev; site of a former nuclear power station. The town is now abandoned. On 26 April 1986, two huge explosions occurred at the plant, destroying a central reactor and breaching its 1,000-tonne roof. In the immediate vicinity of Chernobyl, 31 people died (all firemen or workers at the plant) and 135,000 were permanently evacuated. It has been estimated that there will be an additional 20,000-40,000 deaths from cancer over 60 years; 600,000 people are officially classified as at risk. According to World Health Organization (WHO) figures from 1995, the incidence of thyroid cancer in children increased 200-fold in Belarus as a result of fallout from the disaster. The last remaining nuclear reactor at Chernobyl was shut down in December 2000.

The Chernobyl disaster occurred as the result of an unauthorized test being conducted, in which the reactor was run while its cooling system was inoperative. The resulting clouds of radioactive isotopes spread all over Europe, from Ireland to Greece. A total of 9 tonnes/8.9 tons of radioactive material were released into the atmosphere, 90 times the amount produced by the Hiroshima A-bomb. In all, 5 million people are thought to have been exposed to radioactivity following the blast. In Ukraine, Belarus, and Russia more than 500,000 people were displaced from affected towns and villages and thousands of square miles of land were contaminated.

Chernobyl: Ten Years On

Go to site

This site examines the disaster at the Chernobyl nuclear reactor in August 1986 and what has happened in the decade since the accident. In addition to learning about the events leading up to the accident, you can find out about the health impacts of the radiation leak, and learn how the nuclear reactors at Chernobyl were meant to work. This official document, produced by the OECD (Organization of Economic Cooperation and Development), contains the most recent news regarding the accident and its after-effects.

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cherry

any of a group of fruit-bearing trees distinguished from plums and apricots by their fruits, which are round and smooth and not covered with a bloom. They are cultivated in temperate regions with warm summers and grow best in deep fertile soil. (Genus *Prunus*, family Rosaceae.)

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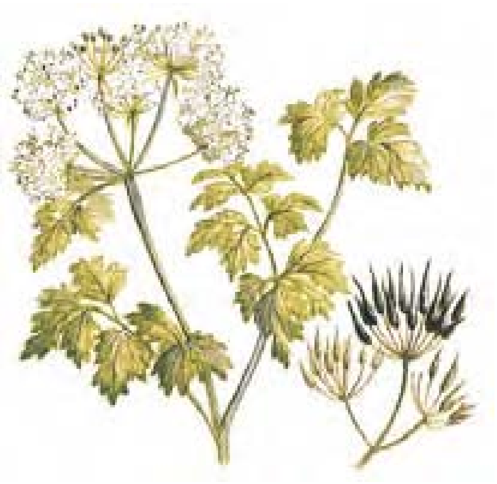
chervil

any of several plants belonging to the carrot family. The garden chervil (*Anthriscus cerefolium*) has leaves with a sweetish smell, similar to parsley. It is used as a garnish and in soups. Chervil originated on the borders of Europe and Asia and was introduced to Western Europe by the Romans. (Genus *Anthriscus*, family Umbelliferae.)

chervil



(Image © Research Machines plc)

Chervil is a small annual with a delicate parsleylike appearance, growing to a height of 30-45 cm/12-18 in. It has a hollow stem and its leaves are often used in cooking as a flavouring.

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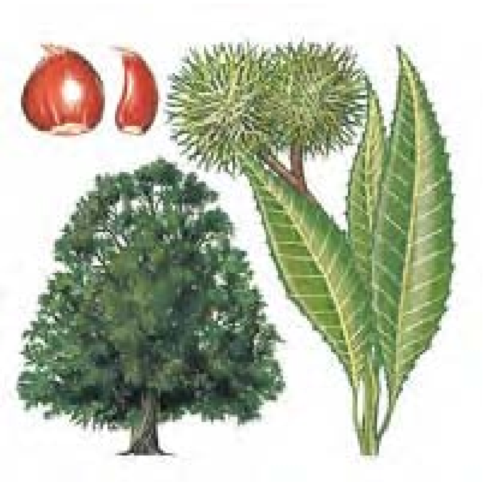
chestnut

any of a group of trees belonging to the beech family. The Spanish or sweet chestnut (*Castanea sativa*) produces edible nuts inside husks; its timber is also valuable. Horse chestnuts are quite distinct, belonging to the genus *Aesculus*, family Hippocastanaceae. (True chestnut genus *Castanea*, family Fagaceae.)

chestnut



(Image © Research Machines plc)

There are two types of chestnut tree: the sweet or Spanish chestnut (illustrated) and the horse chestnut.

The sweet chestnut, native to Southern Europe, Asia, and North America, has toothed leaves and edible seeds, and can grow to a height of 21 m/70 ft.

Chestnut, Sweet

Go to site

This site contains information relating to the sweet chestnut. It contains a detailed description of the tree, its propagation methods, and its habitat. There are also notes on the many uses of the sweet chestnut, which include making stuffing for turkeys and whitening linen. The possible medicinal uses of the tree are also featured.

chevrotain

or mouse deer

small forest-dwelling mammals resembling deer. Horns are absent and they reach a maximum height at the shoulder of about 35 cm/14 in. They are active at night and feed mainly on plants and fruit.

There are four species in two genera, *Tragulus* and *Hyemoschus*. *Tragulus* contains three species of small animals, which have more or less the characteristics and habits of some rodents. They inhabit Asia, Malaysia, Sri Lanka, and India. *Hyemoschus* contains only one species, the African **water chevrotain**.

classification

Chevrotains are members of the family Tragulidae in the mammalian order Artiodactyla.

chicken

domestic fowl; see under poultry.

chickenpox

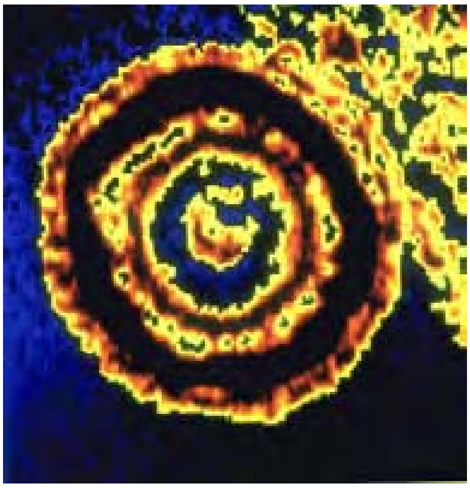
or varicella

common, usually mild disease, caused by a virus of the herpes group and transmitted by airborne droplets. Chickenpox chiefly attacks children under the age of ten. The incubation period is two to three weeks. One attack normally gives immunity for life.

The temperature rises and spots (later inflamed blisters) develop on the torso, then on the face and limbs. The sufferer recovers within a week, but remains infectious until the last scab disappears.

The US Food and Drug Administration approved a chickenpox vaccine in March 1995. Based on a weakened form of the live virus, the vaccine is 70–90% effective. A vaccine is available in Europe, but is only used in children with an impaired immune system.

chickenpox



(Image © SmithKline Beecham Plc)

A false-colour electron micrograph of the chickenpox virus *Varicella zoster*. Viruses are minute infectious particles that can only multiply if they invade a living cell and use its genetic machinery. It is therefore difficult to find a treatment that attacks the virus itself but leaves the host cell unharmed. A healthy body produces antiviral proteins to prevent the infection from spreading to adjacent cells. Though highly contagious, chickenpox usually creates a lifelong immunity. The chickenpox virus is part of the herpes family of viruses.

chickpea

annual leguminous plant (see legume), grown for food in India and the Middle East. Its short hairy pods contain edible seeds similar to peas. (*Cicer arietinum*, family Leguminosae.)

---

chickweed

any of several low-growing plants belonging to the pink family, with small white starlike flowers. (Genera *Stellaria* and *Cerastium*, family Caryophyllaceae.)

Chickweed

Go to site

This Web site contains a detailed description of the plant and its habitat. There are also notes on the possible medicinal uses of chickweed, which include treating ulcers and external abscesses. Hydrophobia and scurvy are two other conditions the plant is said to treat.

---

chicory

plant native to Europe and West Asia, with large, usually blue, flowers. Its long taproot is used dried and roasted as a coffee substitute. As a garden vegetable, grown under cover, its blanched leaves are used in salads. It is related to endive. (*Cichorium intybus*, family Compositae.)

Chicory

Go to site

In addition to a detailed description of the plant, its history, and its habitat, this site also includes extensive notes on the cultivation of chicory, as well as on its constituents and possible medicinal uses, which include acting as a laxative and diuretic.

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chiffchaff

small songbird *Phylloscopus collybita* of the warbler family, Muscicapidae, order Passeriformes. It is found in woodlands and thickets in Europe and northern Asia during the summer, migrating south for winter. About 11 cm/4.3 in long, olive above, greyish below, with yellow-white nether parts, an eyestripe, and usually dark legs, it looks similar to a willow warbler but has a distinctive song.

---

chigger

or harvest mite

scarlet or rusty brown mite genus *Trombicula*, family Trombiculidae, in the order Acarina, common in summer and autumn. Chiggers are parasitic, and their tiny red larvae cause intensely irritating bites in places where the skin is thin, such as behind the knees or between the toes. After a time they leave their host and drop to the ground where they feed upon minute insects.

Chiggers are medically important and can be harmful to humans in two ways: either by the feeding activities of the larval mite, on folds of skin or the edges of hair follicles resulting in painful lesions 0.4-2 cm/0.16-0.8 in long, or by acting as carriers of disease, for example scrub typhus or haemorrhagic fever.

---

chihuahua

smallest breed of dog, 15 cm/10 in high, developed in the USA from Mexican origins. It may weigh only 1 kg/2.2 lb. The domed head and wide-set ears are characteristic, and the skull is large compared to the body. It can be almost any colour, and occurs in both smooth (or even hairless) and long-coated varieties.

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chilblain

painful inflammation of the skin of the feet, hands, or ears, due to cold. The parts turn red, swell, itch violently, and are very tender. In bad cases, the skin cracks, blisters, or ulcerates.

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childbirth

the expulsion of a baby from its mother's body following pregnancy. In a broader sense, it is the period of time involving labour and delivery of the baby.

Childe, V(ere) Gordon (1892-1957)

Australian archaeologist. He was an authority on early European and Middle Eastern societies, and pioneered current methods of analytical archaeology. Following his travels in central and eastern Europe, he published *The Dawn of European Civilization* (1925), which set out a chronological framework for central Europe.

Childe was professor of prehistoric archaeology at Edinburgh University 1927-46 and director of the London Institute of Archaeology 1946-57. His earlier emphasis on economic factors as a cause of social change was revised to take into account Marxist principles and cultural evolution, and his work became the basis for attempts at reconstruction of the social contexts of prehistoric societies. *Man Makes Himself* (1936) and *What Happened in History* (1942) were written for the general public as well as professional archaeologists.

---

chilli

pod, or powder made from the pod, of a variety of capsicum (*Capsicum frutescens*), a small, hot, red pepper. It is widely used in cooking. The hot ingredient of chilli is capsaicin. It causes a burning sensation in the mouth by triggering nerve branches in the eyes, nose, tongue, and mouth.

Capsaicin does not activate the taste buds and therefore has no flavour. It is claimed that people can become physically addicted to it.

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chimaera

fish of the group Holocephali. Chimaeras have thick bodies that taper to a long thin tail, large fins, smooth skin, and a cartilaginous skeleton. They can grow to 1.5 m/4.5 ft. Most chimaeras are deep-water fish, and even *Chimaera monstrosa*, a relatively shallow-living form caught around European coasts, lives at a depth of 300-500 m/1,000-1,600 ft.

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chimera

or chimaera

in biology, an organism composed of tissues that are genetically different. Chimeras can develop naturally if a mutation occurs in a cell of a developing embryo, but are more commonly produced artificially by implanting cells from one organism into the embryo of another.

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chimpanzee

highly intelligent African ape *Pan troglodytes* that lives mainly in rainforests but sometimes in wooded savannah. Chimpanzees are covered in thin but long black body hair, except for the face, hands, and feet, which may have pink or black skin. They normally walk on all fours, supporting the front of the body on the knuckles of the fingers, but can stand or walk upright for a short distance. They can grow to 1.4 m/4.5 ft tall, and weigh up to 50 kg/110 lb. They are strong and climb well, but spend time on the ground, living in loose social groups. The bulk of the diet is fruit, with some leaves, insects, and occasional meat. Females reach sexual maturity at 8-12 years of age, males at 17-18. Chimpanzees give birth to a single infant approximately every five years. Chimpanzees can use 'tools', fashioning twigs to extract termites from their nests. According to a 1998 estimate by the Worldwide Fund for Nature, the world population of chimpanzees stands at 200,000.

Chimpanzees are found in an area from West Africa to western Uganda and Tanzania in the east. There are four subspecies of common chimpanzee. The **bonobo** or pygmy chimpanzee, *Pan paniscus* is found only in a small area of rainforest in the Democratic Republic of Congo (formerly Zaire). Bonobos are a distinct species about the same height as 'common' chimpanzees, but they are of a slighter build, with less hair, and stand upright more frequently. In 1999 there were believed to be fewer than 15,000 bonobos left and these were threatened by the civil war in the Democratic Republic of Congo.

Studies of chromosomes suggest that chimpanzees are the closest apes to humans, perhaps sharing 99% of the same genes. Trained chimpanzees can learn to communicate with humans with the aid of machines or sign language, but are probably precluded from human speech by the position of the voicebox.

In 1999 British researchers revealed that chimpanzees exhibit diverse cultural behaviour in different study populations, showing that behaviour is learned and passed on in chimpanzee societies. The researchers identified 39 separate behaviours, including differences in feeding techniques, courtship rituals, and domination displays.

chimpanzee

Sick chimpanzees use natural remedies to heal themselves. Internal parasites are purged by eating certain leaves, and stomach upsets are treated with mouthfuls of earth rich in clay minerals, sodium, iron, and aluminium.

Chimpanzee

Go to site

Illustrated guide to the chimpanzee including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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china clay

commercial name for kaolin.

china clay

(Image © Research Machines plc)

China clay, or kaolin, is used in the manufacture of fine porcelain. The modern production method is a three-part process. First, the earth overlying the clay is removed, and a high-pressure water jet is fired at the quarry face, liberating the clay. The clay must then be sifted and refined to remove impurities before finally being dried to reduce its moisture content.

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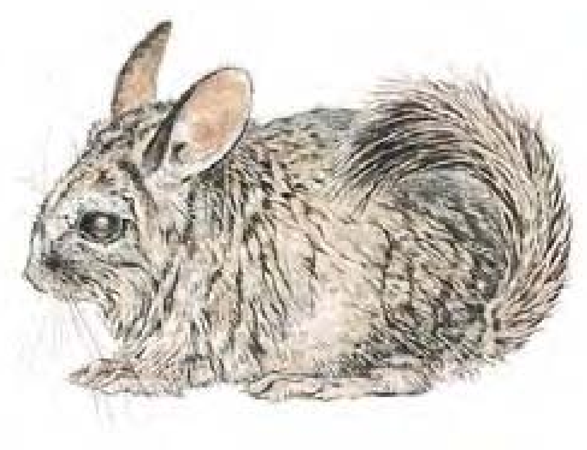
chinchilla

South American rodent *Chinchilla laniger* found in high, rather barren areas of the Andes in Bolivia and Chile. About the size of a small rabbit, it has long ears and a long bushy tail, and shelters in rock crevices. These gregarious animals have thick, soft, silver-grey fur, and were hunted almost to extinction for it. They are now farmed and protected in the wild.

chinchilla



(Image © Research Machines plc)

The chinchilla's dense, soft fur enables it to survive at altitudes of around 3,000 m/10,000 ft in the Andes. It is this fur, however, that has caused the chinchilla to be hunted to such an extent that it is now rare and is protected in the wild.

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chinook

(American Indian 'snow-eater')

warm dry wind that blows downhill on the east side of the Rocky Mountains of North America. It often occurs in winter and spring when it produces a rapid thaw, and so is important to the agriculture of the area.

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chip

or silicon chip

another name for an integrated circuit, a complete electronic circuit on a slice of silicon (or other semiconductor) crystal only a few millimetres square.

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chipmunk

any of several species of small ground squirrel with characteristic stripes along its side. Chipmunks live in North America and East Asia, in a variety of habitats, usually wooded, and take shelter in burrows. They have pouches in their cheeks for carrying food. They climb well but spend most of their time on or near the ground.

The **Siberian chipmunk** *Eutamias sibiricus*, about 13 cm/5 in long, is found in northern Russia, northern China, and Japan.

Chipmunk Place

Go to site

Extensive guide to the species of ground squirrel. Information available includes facts about chipmunks, their diet and control, and there is also a section on 'Famous chipmunks'.

Chiron

unusual object orbiting between Saturn and Uranus, discovered in 1977 by US astronomer Charles Kowal. Initially classified as an asteroid, it has now been given both an asteroid designation (2060 Chiron) and a comet designation (95P/Chiron). It is 130,140 km/8,087 mi across, composed of ice with a dark crust of carbon dust. It has a 51-year orbit and a coma (cloud of gas and dust) caused by evaporation from its surface, resembling that of a comet. It is classified as a centaur.

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chiropody

the specialized care and treatment of feet. Originally, it referred to the treatment of hands as well as feet, but it is now synonymous with podiatry.

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chiropractic

in alternative medicine, technique of manipulation of the spine and other parts of the body, based on the principle that physical disorders are attributable to aberrations in the functioning of the nervous system, which manipulation can correct.

Developed in the 1890s by US practitioner Daniel David Palmer, chiropractic is widely practised today by accredited therapists, although orthodox medicine remains sceptical of its efficacy except for the treatment of back problems.

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chiru

Tibetan species of antelope. It is pale fawn in colour with coarse hair; the male alone has horns, and these are long, straight, ringed and gazellelike. It is nearly 1 m/3.3 ft in height.

classification

The chiru *Pantholops hodgsoni* is in the family Bovidae (cattle and antelopes) of order Artiodactyla.

The fine underfleece of the chiru antelope is used to weave shatoosh (very fine shawls). One shawl takes three to four chiru to produce, so despite being protected (listed on Convention on International Trade in Endangered Species (CITES) Appendix I, which bans all trade in the species) they are under threat from poachers, who kill an estimated 15,000 animals a year. In 2000 there were 50,000 chiru remaining.

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chitin

complex long-chain compound, or polymer; a nitrogenous derivative of glucose. Chitin is widely found in invertebrates. It forms the exoskeleton of insects and other arthropods. It combines with protein to form a covering that can be hard and tough, as in beetles, or soft and flexible, as in caterpillars and other insect larvae. It is insoluble in water and resistant to acids, alkalis, and many organic solvents. In crustaceans such as crabs, it is impregnated with calcium carbonate for extra strength.

Chitin also occurs in some protozoans and coelenterates (such as certain jellyfishes), in the jaws of annelid worms, and as the cell-wall polymer of fungi. Its uses include coating apples (still fresh after six months), coating seeds, and dressing wounds. In 1993 chemists at North Carolina State University found that it can be used to filter pollutants from industrial waste water.

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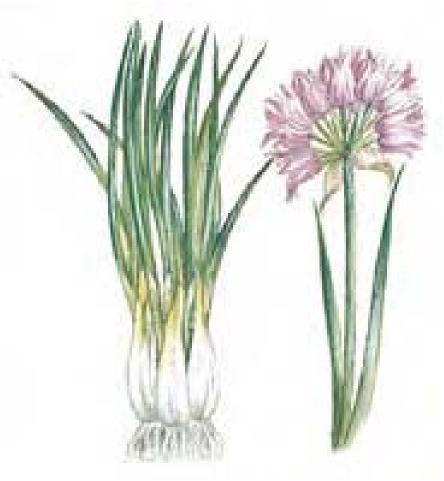
chive

or chives

perennial European plant belonging to the lily family, related to onions and leeks. It has an underground bulb, long hollow tubular leaves, and globe-shaped purple flower heads. The leaves are used as a garnish for salads. (*Allium schoenoprasum*, family Liliaceae.)

chive



(Image © Research Machines plc)

Chives grow wild throughout most of the northern hemisphere, forming perennial clumps about 12 cm/5 in high. They are the mildest member of the onion family, without the bitterness of raw onions or the pungency of garlic.

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chlamydia

viruslike bacteria which live parasitically in animal cells, and cause disease in humans and birds. Chlamydiae are thought to be descendants of bacteria that have lost certain metabolic processes. In humans, a strain of chlamydia causes trachoma, a disease found mainly in the tropics (a leading cause of blindness); venereally transmitted chlamydiae cause genital and urinary infections.

Possible links were found between infection with chlamydia and further disorders, including Alzheimer's disease and cervical cancer.

Childhood Infections - Chlamydia

Go to site

Useful information about chlamydia. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

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chloral

or trichloroethanal; CCl_3CHO

oily, colourless liquid with a characteristic pungent smell, produced by the action of chlorine on ethanol. It is soluble in water and its compound chloral hydrate is a powerful sleep-inducing agent.

---

chloramphenicol

the first broad-spectrum antibiotic to be used commercially. It was discovered in 1947 in a Venezuelan soil sample containing the bacillus *Streptomyces venezuelae*, which produces the antibiotic substance $C_{11}H_{12}Cl_2N_2O_5$, now synthesized. Because of its toxicity, its use is mainly limited to the treatment of life-threatening infections, such as meningitis, legionnaire's disease, and typhoid fever.

---

chlorate

the anion of chloric acid ($HClO_4$), or any salt containing this anion. Common chlorates are those of sodium, potassium, and magnesium.

In these compounds, chlorine has the the oxidation level +5. Chlorine compounds with different oxidation levels include the perchlorates (+7), chlorites (+3), hypochlorites (+1), and chlorides (-1).

---

chloride

Cl^-

negative ion formed when hydrogen chloride dissolves in water, and any salt containing this ion, commonly formed by the action of hydrochloric acid (HCl) on various metals or by direct combination of a metal and chlorine. Sodium chloride (NaCl) is common table salt.

---

chlorinated solvent

any liquid organic compound that contains chlorine atoms, often two or more. These compounds are very effective solvents for fats and greases, but many have toxic properties.

They include trichloromethane (chloroform, $CHCl_3$), tetrachloromethane (carbon tetrachloride, CCl_4), and trichloroethene ($CH_2ClCHCl_2$).

Breath of Fresh Chlorine

Go to site

Part of a larger site maintained by *Scientific American*, this page reports on a strain of bacteria that may reduce the level of hazardous waste in the world by removing the chlorine molecules found in noxious chlorinated solvents that degrade our environment. Find out how this bacterium powers itself and whether it has a future in the waste management industry. The text includes hypertext links to further information, and there is also a list of related links at the bottom of the page.

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chlorination

treatment of water with chlorine in order to disinfect it; also, any chemical reaction in which a chlorine atom is introduced into a chemical compound.

---

chlorine

chemical symbol Cl

(Greek chloros 'green')

greenish-yellow, gaseous, non-metallic element with a pungent odour, atomic number 17, relative atomic mass 35.453. It is a member of the halogen group and is widely distributed, in combination with the alkali metals, as chlorides.

Chlorine was discovered in 1774 by the German chemist Karl Scheele, but English chemist Humphry Davy first proved it to be an element in 1810 and named it after its colour. In nature it is always found in the combined form, as in hydrochloric acid, produced in the mammalian stomach for digestion. Chlorine is obtained commercially by the electrolysis of concentrated brine and is an important bleaching agent and germicide, used for sterilizing both drinking water and swimming pools. As an oxidizing agent it finds many applications in organic chemistry. The pure gas (Cl_2) is a poison and was used in gas warfare in World War I, where its release seared the membranes of the nose, throat, and lungs, causing pneumonia. Chlorine is a component of chlorofluorocarbons (CFCs) and is partially responsible for the depletion of the ozone layer; it is released from the CFC molecule by the action of ultraviolet radiation in the upper atmosphere, making it available to react with and destroy the ozone. The concentration of chlorine in the atmosphere in 1997 reached just over 3 parts per billion. It was expected to reach its peak in 1999 and then start falling rapidly due to international action to curb ozone-destroying chemicals.

Chlorine

Go to site

Designed to promote better understanding of the science of chlorine chemistry, examining how it contributes to an enhancement of our standard of living and quality of life.

---

chlorofluorocarbon

CFC

a class of **synthetic chemicals** that are odourless, non-toxic, non-flammable, and chemically inert. The first CFC was synthesized in 1892, but no use was found for it until the 1920s. Their stability and apparently harmless properties made CFCs popular as propellants in aerosol cans, as refrigerants in refrigerators and air conditioners, as degreasing agents, and in the manufacture of foam packaging. They are now known to be partly responsible for the destruction of the ozone layer. In 1987, an international agreement called the Montréal Protocol was established; it was one of the first global environmental treaties and it banned the use of chemicals responsible for ozone damage, such as CFCs in aerosols and refrigerants.

When CFCs are released into the atmosphere, they drift up slowly into the stratosphere, where, under the influence of ultraviolet radiation from the Sun, they react with ozone (O_3) to form free chlorine (Cl) atoms and molecular oxygen (O_2), thereby destroying the ozone layer which protects the Earth's surface from the Sun's harmful ultraviolet rays. The chlorine liberated during ozone breakdown can react with still more ozone, making the CFCs particularly dangerous to the environment. CFCs can remain in the atmosphere for more than a hundred years. Replacements for CFCs are being developed, and research into safe methods for destroying existing CFCs is being carried out.

---

chloroform

or trichloromethane; $CHCl_3$

clear, colourless, toxic, carcinogenic liquid with a characteristic pungent, sickly sweet smell and taste, formerly used as an anaesthetic (now superseded by less harmful substances). It is used as a solvent and in the synthesis of organic chemical compounds.

---

chlorophyll

group of pigments including chlorophyll a and chlorophyll b, the green pigments present in chloroplasts in most plants; it is responsible for the absorption of light energy during photosynthesis. The pigment absorbs the red and blue-violet parts of sunlight but reflects the green, thus giving plants their characteristic colour. Other chlorophylls include chlorophyll c (in brown algae) and chlorophyll d (found in red algae).

Chlorophyll is found within chloroplasts, present in large numbers in leaves. Cyanobacteria and other photosynthetic bacteria also have chlorophyll, though of a slightly different type. Chlorophyll is similar in structure to haemoglobin, but with magnesium instead of iron as the reactive part of the molecule. Because magnesium is contained in chlorophyll it is considered an essential plant mineral salt. Magnesium can often be a part of a mixture of minerals used as a fertilizer.

chlorophyll

The deep-sea fish *Malecosteus niger* has chlorophyll in the retina of its eye. This is the only known instance of chlorophyll being found in an organism that is not plant or bacteria.

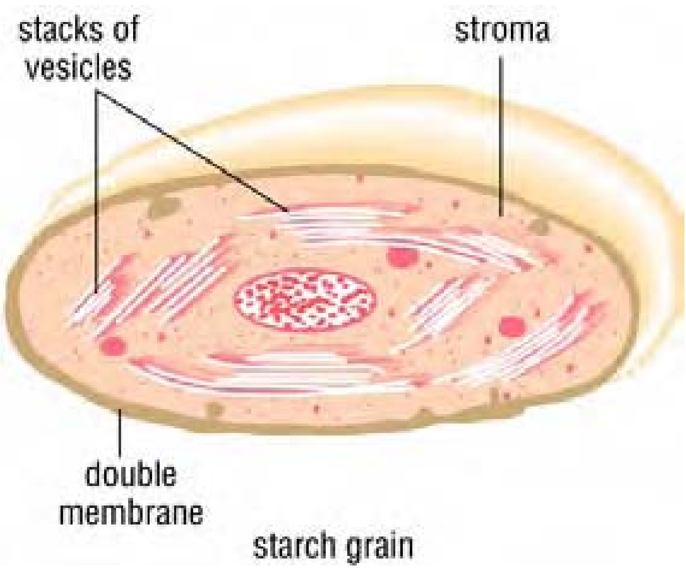
---

chloroplast

structure (organelle) within a plant cell containing the green pigment chlorophyll. Chloroplasts occur in most cells of green plants that are exposed to light, often in large numbers. Typically, they are shaped like a flattened disc, with a double membrane enclosing the stroma, a gel-like matrix. Within the stroma are stacks of fluid-containing cavities, or vesicles, where photosynthesis occurs, creating glucose from carbon dioxide and water to be used in the plant's life processes. Sunlight is absorbed by chlorophyll, providing energy which is transferred to the glucose. The glucose may be converted to starch and stored. Starch can then be converted back to glucose to provide energy for the plant at a later stage.

It is thought that the chloroplasts were originally free-living cyanobacteria which invaded larger, non-photosynthetic cells and developed a symbiotic relationship with them. Like mitochondria, they contain a small amount of DNA and divide by fission. Chloroplasts are a type of plastid.

chloroplast



(Image © Research Machines plc)

A chloroplast is shaped like a flattened disc, with a double membrane enclosing the gel-like stroma. The stroma contains cavities, or vesicles, where photosynthesis occurs.

chlorosis

abnormal condition of green plants in which the stems and leaves turn pale green or yellow. The yellowing is due to a reduction in the levels of the green chlorophyll pigments. It may be caused by a deficiency in essential elements (such as magnesium, iron, or manganese), a lack of light, genetic factors, or viral infection.

choke coil

in physics, a coil employed to limit or suppress alternating current without stopping direct current, particularly the type used as a 'starter' in the circuit of fluorescent lighting.

choking

in medicine, a process that results from an obstruction in the larynx that inhibits breathing. It is usually due to irritation produced by a piece of food or other substance that has been introduced via the mouth. The irritation of the sensitive mucus membrane lining the larynx provokes coughing as an attempt to expel the irritant. If the foreign body is large, the face may appear livid because of partial suffocation.

The choking individual should be encouraged to take slow, deep breaths that do not force the foreign body further into the respiratory tract. If the individual attempts to catch breath suddenly between coughs, the foreign body may penetrate further into the respiratory tract and stimulate further coughing. Blows with the palm of the hand over the shoulder blades, timed to coincide with the coughs, may assist the effect of the coughing. Medical attention is necessary if these methods do not result in the foreign body being expelled.

cholecalciferol

or vitamin D

fat-soluble chemical important in the uptake of calcium and phosphorous for bones. It is found in liver, fish oils, and margarine. It can be produced in the skin, provided that the skin is adequately exposed to sunlight. Lack of vitamin D leads to rickets and other bone diseases.

cholecystectomy

surgical removal of the gall bladder. It is carried out when gallstones or infection lead to inflammation of the gall bladder, which may then be removed either by conventional surgery or by a 'keyhole' procedure (see endoscopy).

cholera

disease caused by infection with various strains of the bacillus *Vibrio cholerae*, transmitted in contaminated water and characterized by violent diarrhoea and vomiting. It is prevalent in many tropical areas.

The formerly high death rate during epidemics has been much reduced by treatments to prevent dehydration and loss of body salts, together with the use of antibiotics. There is an effective vaccine that must be repeated at frequent intervals for people exposed to continuous risk of infection. The worst epidemic in the Western hemisphere for 70 years occurred in Peru in 1991, with 55,000 confirmed cases and 258 deaths. It was believed to have been spread by the consumption of seafood contaminated by untreated sewage. 1991 was also the worst year on record for cholera in Africa with 13,000 deaths.

The sequencing of the complete cholera genome was completed in August 2000, revealing that many of the genes that enable cholera to attack humans are found on a single chromosome. The discovery should aid the development of a more effective vaccine and other drugs to combat the disease.

---

cholesterol

white, crystalline sterol found throughout the body, especially in fats, blood, nerve tissue, and bile; it is also provided in the diet by foods such as eggs, meat, and butter. A high level of cholesterol in the blood is thought to contribute to atherosclerosis (hardening of the arteries).

Cholesterol is an integral part of all cell membranes and the starting point for steroid hormones, including the sex hormones. It is broken down by the liver into bile salts, which are involved in fat absorption in the digestive system, and it is an essential component of **lipoproteins**, which transport fats and fatty acids in the blood.
Low-density lipoprotein cholesterol (LDL-cholesterol), when present in excess, can enter the tissues and become deposited on the surface of the arteries, causing atherosclerosis.
High-density lipoprotein cholesterol (HDL-cholesterol) acts as a scavenger, transporting fat and cholesterol from the tissues to the liver to be broken down. The composition of HDL-cholesterol can vary and some forms may not be as effective as others. Blood cholesterol levels can be altered by reducing the amount of alcohol and fat in the diet and by substituting some of the saturated fat for polyunsaturated fat, which gives a reduction in LDL-cholesterol. A 1999 US study of children with high levels of cholesterol found no evidence that controlling cholesterol levels through diet is harmful. Another 1999 US study suggested that cholesterol-lowering drugs are as beneficial for older men and women as they are for the middle-aged. HDL-cholesterol can be increased by exercise.

cholesterol

The Inuit people rarely suffer from heart disease. One explanation for this may be the high amount of fish, notably salmon, in their diet, which reduces the level of blood cholesterol.

---

choline

in medicine, one of the members of the vitamin B complex. The daily requirement in adults, approximately 500 mg, is present in egg yolk, liver, and meat and sufficient choline can be obtained from a normal diet. Choline can be synthesized by the body and deficiency results in a fatty liver.

---

cholinergic

in biology, activity of nerve fibres to release the neurotransmitter acetylcholine that mediates the transmission of nerve impulses between nerves or between nerves and muscles. Anticholinergic agents, such as pilocarpine, prolong the action of acetylcholine and have a role in the treatment of glaucoma.

---

chondrule

in astronomy, small, round mass of the silicate minerals olivine and orthopyroxene. Chondrites (stony meteorites) are characterized by the presence of chondrules.

Chondrules are thought to be mineral grains that condensed from hot gas in the early Solar System, most of which were later incorporated into larger bodies from which the planets formed.

---

chord

in geometry, a straight line joining any two points on a curve. The chord that passes through the centre of a circle (its longest chord) is the diameter. The longest and shortest chords of an ellipse (a regular oval) are called the major and minor axes, respectively.

---

chordate

animal belonging to the phylum Chordata, which includes vertebrates, sea squirts, amphioxi, and others. All these animals, at some stage of their lives, have a supporting rod of tissue (notochord or backbone) running down their bodies.

Chordates are divided into three major groups: tunicates, cephalochordates (see lancelet), and craniates (including all vertebrates).

Classification of chordates

Animals belonging to the phylum Chordata have, at least at some stage in their lives, a rod of tissue (notochord or backbone) running down their bodies.

Common name	Taxonomic name	Level	Number of species
sea squirts, etc.	Tunicata	subphylum	2,000
lancelets	Cephalochordata	subphylum	14
hags, etc.	Myxini	class	67
lampreys, etc.	Cephalaspidomorphi	class	31
sharks, rays, etc.	Elasmobranchiomorphi	class	630
bony fishes	Osteichthyes	class	18,000
amphibians	Amphibia	class	2,900
reptiles	Reptilia	class	6,300
birds	Aves	class	8,600
mammals	Mammalia	class	4,000
of which:	Prototherians	subclass	6
	Marsupials	subclass	240
	Placentals	subclass	3,800

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chorea

condition featuring involuntary movements of the face muscles and limbs. It is seen in a number of neurological diseases, including Huntington's chorea. See also St Vitus' dance.

---

chorion

outermost of the three membranes enclosing the embryo of reptiles, birds, and mammals; the amnion is the innermost membrane.

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chorionic villus sampling

CVS

biopsy of a small sample of placental tissue, carried out in early pregnancy at 10-12 weeks' gestation. Since the placenta forms from embryonic cells, the tissue obtained can be tested to reveal genetic abnormality in the fetus. The advantage of CVS over amniocentesis is that it provides an earlier diagnosis, so that if any abnormality is discovered, and the parents opt for an abortion, it can be carried out more safely.

Chorionic Villus Sampling

Go to site

Comprehensive plain-English guide to chorionic villus sampling (CVS). For a pregnant woman wanting to know more about the procedure, this is an invaluable source of information. The advantages and the risks associated with CVS are frankly and clearly presented.

---

choroid

layer found at the rear of the eye beyond the retina. By absorbing light that has already passed through the retina, it stops back-reflection and so prevents blurred vision.

---

chough

bird *Pyrrhocorax pyrrhocorax* of the crow family, Corvidae, order Passeriformes, about 38 cm/15 in long, black-feathered, with red bill and legs, and long hooked claws. Choughs are frugivorous and insectivorous. They make mud-walled nests and live on sea cliffs and mountains from Europe to East Asia, but are now rare.

The **alpine chough** *Pyrrhocorax graculus* is similar, but has a shorter yellow bill and is found up to the snowline in mountains from the Pyrenees to Central Asia.

---

chow chow

breed of dog originating in China in ancient times. About 45 cm/1.5 ft tall, it has a broad neck and head, round catlike feet, a soft woolly undercoat with a coarse outer coat, and a mane. Its coat should be of one colour, and it has an unusual blue-black tongue.

Chow Chow Club

Go to site

All there is to know about chow chows. The site is filled with information about the history of the breed, the breed standard, US chow shows, veterinary advice, and many tips for owners. There is a useful bibliography and information on subscribing to *Chow Life*.

Christmas rose

decorative species of hellebore.

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chromatography

(Greek chromos 'colour')

technique for separating or analysing a mixture of gases, liquids, or dissolved substances. This is brought about by means of two immiscible substances, one of which (**the mobile phase**) transports the sample mixture through the other (**the stationary phase**). The mobile phase may be a gas or a liquid; the stationary phase may be a liquid or a solid, and may be in a column, on paper, or in a thin layer on a glass or plastic support. The components of the mixture are adsorbed or impeded by the stationary phase to different extents and therefore become separated. The technique is used for both qualitative and quantitive analyses in biology and chemistry.

In **paper chromatography**, the mixture separates because the components have differing solubilities in the solvent flowing through the paper and in the chemically bound water of the paper.

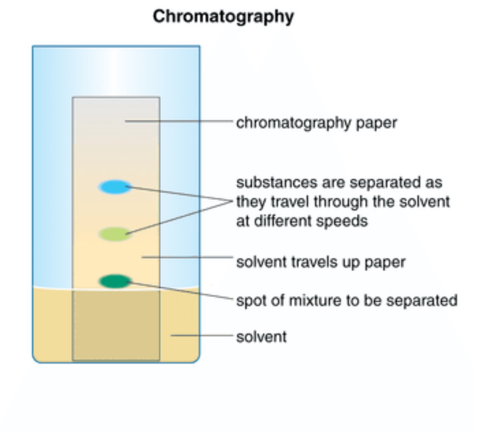
In **thin-layer chromatography**, a wafer-thin layer of adsorbent medium on a glass plate replaces the filter paper. The mixture separates because of the differing solubilities of the components in the solvent flowing up the solid layer, and their differing tendencies to stick to the solid (adsorption). The same principles apply in **column chromatography**.

In **gas-liquid chromatography**, a gaseous mixture is passed into a long, coiled tube (enclosed in an oven) filled with an inert powder coated in a liquid. A carrier gas flows through the tube. As the mixture proceeds along the tube it separates as the components dissolve in the liquid to differing extents or stay as a gas. A detector locates the different components as they emerge from the tube. The technique is very powerful, allowing tiny quantities of substances (fractions of parts per million) to be separated and analysed.

Preparative chromatography is carried out on a large scale for the purification and collection of one or more of a mixture's constituents; for example, in the recovery of protein from abattoir wastes.

Analytical chromatography is carried out on far smaller quantities, often as little as one microgram (one-millionth of a gram), in order to identify and quantify the component parts of a mixture. It is used to determine the identities and amounts of amino acids in a protein, and the alcohol content of blood and urine samples. The technique was first used in the separation of coloured mixtures into their component pigments.

chromatography


Chromatography
chromatography paper
substances are separated as they travel through the solvent at different speeds
solvent travels up paper
spot of mixture to be separated
solvent

(Image © Research Machines plc)

Paper chromatography utilizes the fact that different substances dissolve at different rates. As the solvent travels up the paper it dissolves the mixture, the components of which travel at different speeds and so become separated.

---

chromite

$FeCr_2O_4$

iron chromium oxide, the main chromium ore. It is one of the spinel group of minerals, and crystallizes in dark-coloured octahedra of the cubic system. Chromite is usually found in association with ultrabasic and basic rocks; in Cyprus, for example, it occurs with serpentine, and in South Africa it forms continuous layers in a layered intrusion.

---

chromium

chemical symbol Cr

(Greek chromos 'colour')

hard, brittle, grey-white, metallic element, atomic number 24, relative atomic mass 51.996. It takes a high polish, has a high melting point, and is very resistant to corrosion. It is used in chromium electroplating, in the manufacture of stainless steel and other alloys, and as a catalyst. Its compounds are used for tanning leather and for alums. In human nutrition it is a vital trace element. In nature, it occurs chiefly as chrome iron ore or chromite ($FeCr_2O_4$). Kazakhstan, Zimbabwe, and Brazil are sources.

The element was named in 1797 by the French chemist Louis Vauquelin after its brightly coloured compounds.

---

chromium ore

essentially the mineral chromite, $FeCr_2O_4$, from which chromium is extracted. South Africa and Zimbabwe are major producers.

---

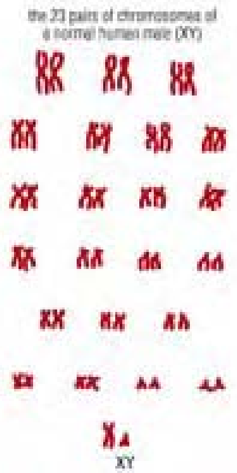
chromosome

structures in a cell nucleus that carry the many thousands of genes, in sequence, that determine the characteristics of an organism. There are 46 chromosomes in a normal human cell. Each chromosome normally consists of one very long strand (or molecule) of DNA, coiled and folded to produce a compact structure. The exception is just before cell division when each chromosome contains two strands of DNA, a result of the copying of each molecule of DNA. The point on a chromosome where a particular gene occurs is known as its locus. Most higher organisms have two copies of each chromosome, together known as a **homologous pair** (they are diploid) but some have only one (they are haploid). See also mitosis and meiosis.

In a working cell chromosomes exist in a less dense form called chromatin and cannot be seen using a laboratory light microscope. However, during cell division they get shorter and fatter and so become visible. When pictures are seen of chromosomes, they have usually been taken in this state during mitosis. In such pictures of human chromosomes it can be seen that most chromosomes in a cell have a matching chromosome of exactly the same size. These are known as homologous pairs. However, one pair is not matched. These are the sex chromosomes - a short, male determining one called the Y chromosome and the X chromosome. Males have an X and a Y chromosome and females have two Xs.

In a sex cell (gamete) that has been produced by meiosis, the number of chromosomes is halved. Only one chromosome from each pair of homologous chromosomes is found in a gamete.

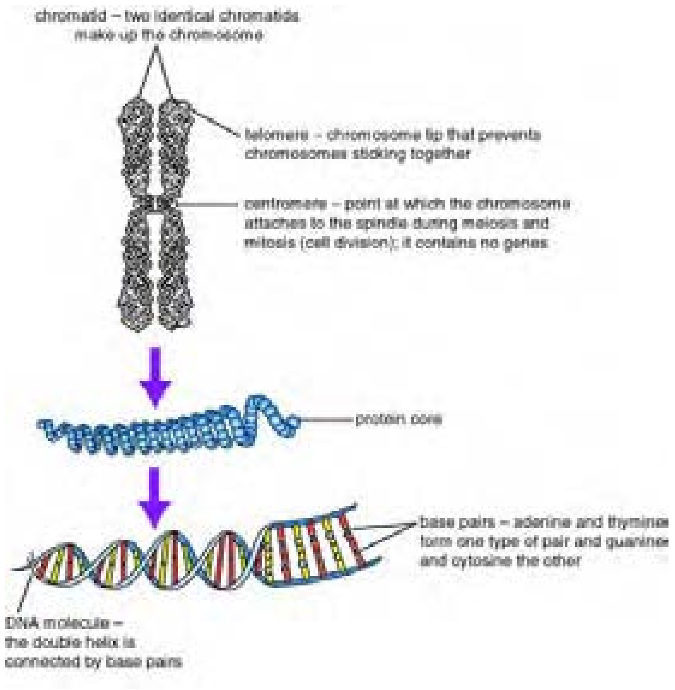
chromosome



(Image © Research Machines plc)

The 23 pairs of chromosomes of a normal human male.

chromosome


chromatid – two identical chromatids make up the chromosome
telomere – chromosome tip that prevents chromosomes sticking together
centromere – point at which the chromosome attaches to the spindle during meiosis and mitosis (cell division); it contains no genes
protein core
base pairs – adenine and thymine form one type of pair and guanine and cytosine the other
DNA molecule – the double helix is connected by base pairs

(Image © Research Machines plc)

The structure of a chromosome. The chromosome is made up of two identical chromatids joined by a centromere. Each chromatid is made up of coiled DNA.

Cytogenetics Gallery

Go to site

Online gallery of chromosomes from the Pathology Department of the University of Washington, Seattle. This in-depth look at the chromosome contains a concise definition of the subject as well as a collection of images used to show how scientists pin-point chromosomal abnormalities.

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chromosphere

(Greek chromos 'colour', sphaira 'sphere')

layer of mostly hydrogen gas about 10,000 km/6,000 mi deep above the visible surface of the Sun (the photosphere). It appears pinkish red during eclipses of the Sun.

---

chronic

in medicine, term used to describe a condition that is of slow onset and then runs a prolonged course, such as rheumatoid arthritis or chronic bronchitis. In contrast, an **acute** condition develops quickly and may be of relatively short duration.

---

chronic fatigue syndrome

CFS; or myalgic encephalomyelitis (ME) or postviral fatigue syndrome

common debilitating condition characterized by a diffuse range of symptoms present for at least six months including extreme fatigue, muscular pain, weakness, depression, poor balance and coordination, joint pains, and gastric upset. It is usually diagnosed after exclusion of other diseases and frequently follows a flulike illness.

The cause of CFS remains unknown, but it is believed to have its origin in a combination of viral, social, and psychological factors. Theories based on one specific cause (such as Epstein-Barr virus) have been largely discredited. There is no definitive treatment, but with time the symptoms become less severe. Depression is treated if present, and recent research has demonstrated the effectiveness of cognitive therapy.

Chronic Fatigue Syndrome FAQ

Go to site

Extensive answer sheet shedding light on the hottest questions regarding chronic fatigue syndrome. The site deals with issues such as the relation to stress and depression, the possible causes and duration of the illness, and the onset and clinical symptoms of the disease. It also discuss a series of common misunderstandings related to the syndrome.

'Putting the Rest Cure to Rest - Again'

Go to site

Part of a collection of articles maintained by the British Medical Journal, this page features the full text of a 14 March 1998 editorial concerning flawed advice that doctors are giving patients suffering from chronic fatigue syndrome. In addition to the editorial, you will find a list of related articles from the extensive PubMed collection. You can also search the collections under which this article appears, search other articles written by the authors of this article, and submit or read responses to this article. There is a list of references at the bottom of the article.

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chronometer

instrument for measuring time precisely, originally used at sea. It is designed to remain accurate through all conditions of temperature and pressure. The first accurate marine chronometer, capable of an accuracy of half a minute a year, was made in 1761 by John Harrison in England.

---

chrysalis

pupa of an insect, but especially that of a butterfly or moth. It is essentially a static stage of the creature's life, when the adult insect, benefiting from the large amounts of food laid down by the actively feeding larva, is built up from the disintegrating larval tissues. The chrysalis may be exposed or within a cocoon.

---

chrysanthemum

any of a large group of plants with colourful, showy flowers, containing about 200 species. There are hundreds of cultivated varieties, whose exact wild ancestry is uncertain. In the Far East the common chrysanthemum has been cultivated for more than 2,000 years and is the imperial emblem of Japan. Chrysanthemums can be grown from seed, but new plants are more commonly produced from cuttings or by dividing up established plants. (Genus *Chrysanthemum*, family Compositae.)

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chrysotile

mineral in the serpentine group, $Mg_3Si_2O_5(OH)_4$. A soft, fibrous, silky mineral, the primary source of asbestos.

---

chub

any of several large minnows of the carp family. Creek chub *Semotelus atromaculatus*, up to 12 in/30 cm, is found widely in North American streams. Also, any of a number of small-mouthed marine fishes of the family Kyphosidae.

---

chyme

general term for the stomach contents. Chyme resembles a thick creamy fluid and is made up of partly digested food, hydrochloric acid, and a range of enzymes.

The muscular activity of the stomach churns this fluid constantly, continuing the mechanical processes initiated by the mouth. By the time the chyme leaves the stomach for the duodenum, it is a smooth liquid ready for further digestion and absorption by the small intestine.

Cibachrome

in photography, a process of printing directly from transparencies. It can be home-processed and the rich, saturated colours are highly resistant to fading. It was introduced in 1963.

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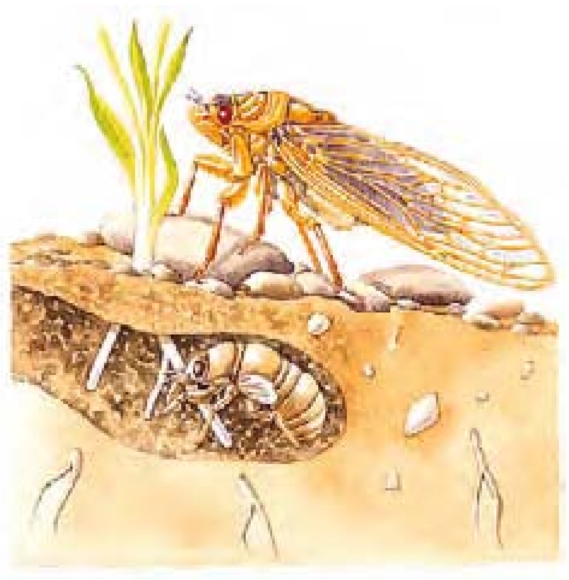
cicada

any of several insects of the family Cicadidae. Most species are tropical, but a few occur in Europe and North America. The adults live on trees, whose juices they suck. The males produce a loud, almost continuous, chirping by vibrating membranes in resonating cavities in the abdomen.

Cicadas with a periodic life cycle, such as the 13-year cicada and the 17-year cicada, are found only in the USA. These species spend most of their lives as larvae underground, synchronizing their emergence every 13 or 17 years depending on species.

cicada



(Image © Research Machines plc)

As in other cicada species, the nymph, or larva, of the Australian double drummer *Thopha saccata* is a strong digger, burrowing down from the surface to feed on the roots of shrubs and trees. After several moults, the adult emerges and climbs the plant to feed on the smaller branches. Eggs are laid on the twigs, and after hatching, the nymphs drop to the ground to begin the cycle again.

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cichlid

any freshwater fish of the family Cichlidae. Cichlids are somewhat perchlike, but have a single nostril on each side instead of two. They are mostly predatory, and have deep, colourful bodies, flattened from side to side so that some are almost disc-shaped. Many are territorial in the breeding season and may show care of the young. There are more than 1,000 species found in South and Central America, Africa, and India.

The **discus fish** *Symphysodon* produces a skin secretion on which the young feed. Other cichlids, such as those of the genus *Tilapia*, brood their young in the mouth.

More than 50% of the world's cichlids are found in Africa's great lakes, and within each of these lakes 99% of the species are found nowhere else. Many species remain unclassified and Lake Malawi alone may contain up to 1,000 species.

Cichlid Home Page

Go to site

Comprehensive source of information on cichlidae, their habitats, and how to keep them in an aquarium. There are a large number of photographs. Fish can be searched for by scientific or common names.

Ciechanover, Aaron (1947-)

Israeli scientist. With Hungarian-born Israeli scientist Avram Hershko and US scientist Irwin Rose he shared the Nobel Prize for Chemistry in 2004 for his contributions to the discovery of how cells can regulate protein levels by controlled selection and degradation processes.

Ciechanover won his share of the Nobel Prize for his work in explaining how the human cell selects and removes unwanted or damaged proteins. The human cell contains around 100,000 proteins, each of which carries out a specific task in various forms, such as enzymes. Although much work had been carried out on how the proteins were made, little was known about how they were removed once their usefulness to the cell was complete. Ciechever and the other laureates discovered that a protein known as ubitquitin formed a stable covalent bond with unwanted proteins in the cells, effectively labelling them for a disposal process called protein degradation. Later work showed that several ubiquitin molecules attached to the same protein and delivered it to a structure in the cell called a proteasome, where it was degraded. It subsequently was discovered that errors in the cell degradation process can cause diseases such as cystic fibrosis, cancer, and Alzheimer's disease to occur.

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cigarette beetle

small beetle that feeds preferentially on tobacco products, such as cigarettes and cigars. It may, however, feed on a wide range of other products for example, raisins, ginger, cocoa, drugs, and even straw.

classification

The cigarette beetle *Lasioderma serricorne* is a member of the family Anobiidae (furniture beetles) in order Coleoptera, class Insecta, phylum Arthropoda.

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cilia

singular cilium

small hairlike organs on the surface of some cells, particularly the cells lining the upper respiratory tract. Their wavelike movements waft particles of dust and debris towards the exterior. Some single-celled organisms move by means of cilia. In multicellular animals, they keep lubricated surfaces clear of debris. They also move food in the digestive tracts of some invertebrates.

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ciliary body

in biology, the part of the eye that connects the iris and the choroid. The ciliary muscles contract and relax to change the shape of the lens during accommodation. The ciliary body is lined with cells that secrete aqueous humour into the anterior chamber of the eye.

---

ciliary muscle

ring of muscle surrounding and controlling the lens inside the vertebrate eye, used in accommodation (focusing). Suspensory ligaments, resembling spokes of a wheel, connect the lens to the ciliary muscle and pull the lens into a flatter shape when the muscle relaxes. When the muscle is relaxed the lens has its longest focal length and focuses rays from distant objects. On contraction, the lens returns to its normal spherical state and therefore has a shorter focal length and focuses images of near objects.

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cinchona

any of a group of tropical American shrubs or trees belonging to the madder family. The drug quinine is produced from the bark of some species, and these are now cultivated in India, Sri Lanka, the Philippines, and Indonesia. (Genus *Chinchona*, family Rubiaceae.)

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cinnabar

mercuric sulphide mineral, HgS, the only commercially useful ore of mercury. It is deposited in veins and impregnations near recent volcanic rocks and hot springs. The mineral itself is used as a red pigment, commonly known as **vermilion**. Cinnabar is found in the USA (California), Spain (Almadén), Peru, Italy, and Slovenia.

---

cinnamon

dried inner bark of a tree belonging to the laurel family, grown in India and Sri Lanka. The bark is ground to make the spice used in curries and confectionery. Oil of cinnamon is obtained from waste bark and is used as flavouring in food and medicine. (*Cinnamomum zeylanicum*, family Lauraceae.)

Cinnamon

Go to site

Informative resource relating to the cinnamon tree. It contains a detailed description of the tree, its constituents, and its habitat. There are also extensive notes on the possible medicinal uses of the cinnamon tree, which include relieving flatulence, treating diarrhoea, and acting as an antiseptic.

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cinquefoil

any of a group of plants that usually have five-lobed leaves and brightly coloured flowers. They are widespread in northern temperate regions. (Genus *Potentilla*, family Rosaceae.)

Five-Leaf Grass

Go to site

Informative resource relating to five-leafed grass, or cinquefoil. It contains a detailed description of the plant and its habitat. There are also extensive notes on the possible medicinal uses of cinquefoil, which include treating fevers and diarrhoea and acting as a styptic.

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circadian rhythm

metabolic rhythm found in most organisms, which roughly coincides with the 24-hour day and is re-adjusted to precise day-length by light-sensitive mechanisms. Its most obvious manifestation is the regular cycle of sleeping and waking, but body temperature and the concentration of hormones that influence mood and behaviour also vary over the day. In humans, alteration of habits (such as rapid air travel round the world) may result in the circadian rhythm being out of phase with actual activity patterns, causing malaise until it has had time to adjust.

At the cellular level, circadian rhythms can be observed as a negative feedback loop in the activity of two genes, known as 'period' and 'timeless' in the fruit fly Drosophila. Similar cellular circadian clocks have been found in cells from many different body parts of animals, implying that there must be a central clock that controls the local ones.

---

circle

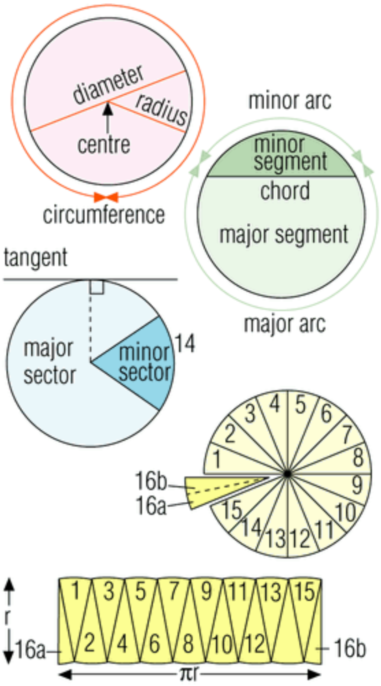
perfectly round shape, the path of a point that moves so as to keep a constant distance from a fixed point (the **centre**). A circle has a **radius** (the distance from any point on the circle to the centre), a **circumference** (the boundary of the circle, part of which is called an **arc**), **diameters** (straight lines crossing the circle through the centre), **chords** (lines joining two points on the circumference), **tangents** (lines that touch the circumference at one point only), **sectors** (regions inside the circle between two radii), and **segments** (regions between a chord and the circumference).

The ratio of the distance all around the circle (the circumference) to the diameter is an irrational number called π (**pi**), roughly equal to 3.1416.

A circle of radius r and diameter d has a circumference $C = \pi d$, or $C = 2\pi r$, and an area $A = \pi r^2$. The area of a circle can be shown by dividing it into very thin sectors and reassembling them to make an approximate rectangle. The proof of $A = \pi r^2$ can be done only by using integral calculus.

Angles within a circle can be calculated using the circle theorems.

circle



(Image © Research Machines plc)

Technical terms used in the geometry of the circle; the area of a circle can be seen to equal πr^2 by dividing the circle into segments that form a rectangle.

circle

To remember the circumference and area of a circle:

Fiddlededum, fiddlededee,
A ring round the moon is π times *d*.
If a hole in your sock you want repaired,
You use the formula πr squared

StudyWeb

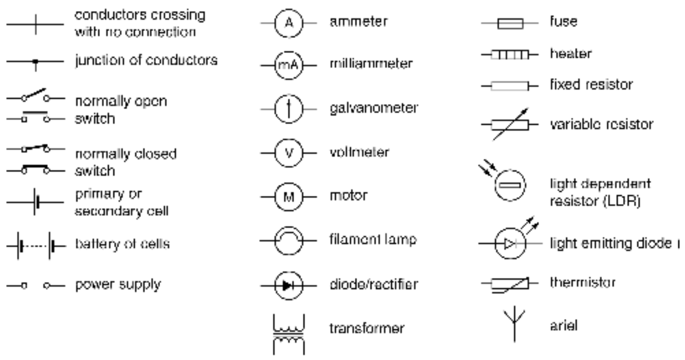
Go to site

Basic properties of circles. This site aims to cover issues such as the centre, radius, and the equation of the circle. There are exercises and examples included, along with a link to maths-related content on the rest of the site.

circuit

in physics or electrical engineering, an arrangement of electrical components connected by a conducting material through which a current can flow. There are two basic circuits, series and parallel. In a series circuit, the components are connected end to end so that the current flows through all components one after the other. In a parallel circuit, components are connected side by side so that part of the current passes through each component. A circuit diagram shows in graphical form how components are connected together, using standard symbols for the components. If the circuit is unbroken, it is a closed circuit and current flows. If the circuit is broken, it becomes an open circuit and no current flows.

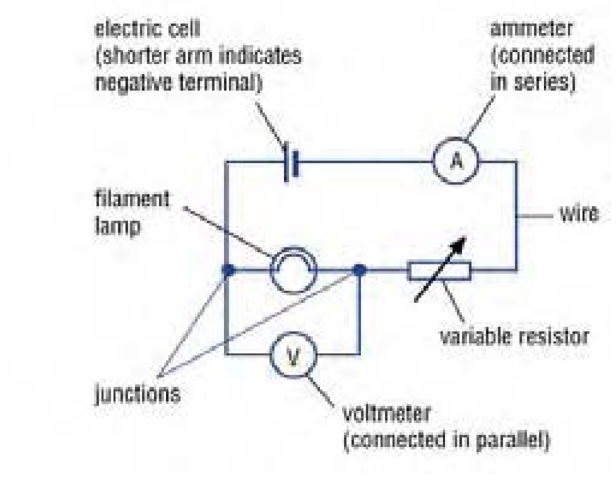
circuit


conductors crossing with no connection
junction of conductors
normally open switch
normally closed switch
primary or secondary cell
battery of cells
power supply
A
ammeter
mA
milliammeter
galvanometer
V
voltmeter
M
motor
filament lamp
diode/rectifier
transformer
fuse
heater
fixed resistor
variable resistor
light dependent resistor (LDR)
light emitting diode
thermistor
ariel

(Image © Research Machines plc)

Electrical symbols commonly used in circuit diagrams.

circuit diagram


electric cell (shorter arm indicates negative terminal)
ammeter (connected in series)
A
filament lamp
wire
variable resistor
V
junctions
voltmeter (connected in parallel)

(Image © Research Machines plc)

A circuit diagram shows in graphical form how the components of an electric circuit are connected together. Each component is represented by an internationally recognized symbol, and the connecting wires are shown by straight lines. A dot indicates where wires join.

circuit

To remember the order of items in an AC circuit:

The **voltage** (**V**) across a **capacitor** (**C**) lags the **current** (**I**) by 90 degrees. The voltage across the **inductor** (**L**) leads the current by 90 degrees. This is given by the word CIVIL, when split into CIV and VIL

---

circuit breaker

switching device designed to protect an electric circuit from overloads such as excessive current flows and voltage failures. It has the same action as a fuse, and many houses now have a circuit breaker between the incoming mains supply and the domestic circuits. Circuit breakers usually work by means of magnetic-type relays or solenoids. Those at electricity-generating stations have to be specially designed to prevent dangerous arcing (the release of luminous discharge) when the high-voltage supply is switched off. They may use an air blast or oil immersion to quench the arc.

When a current exceeds a fixed limit as it flows through the magnetic coil of a circuit breaker, a triggering mechanism is released, pulling the contacts apart and opening the circuit, thus preventing any more current flowing. Circuit breakers have many advantages; for example, they are fast acting, can be adjusted to operate at different current values, and can be easily reset.

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circulatory system

system of vessels in an animal's body that transports essential substances (blood or other circulatory fluid) to and from the different parts of the body. It was first discovered and described by English physician William Harvey. All animals except for the most simple – such as sponges, jellyfish, sea anemones, and corals – have some type of circulatory system. Some invertebrates (animals without a backbone), such as insects, spiders, and most shellfish, have an 'open' circulatory system which consists of a simple network of tubes and hollow spaces. Other invertebrates have pump-like structures that send blood through a system of blood vessels. All vertebrates (animals with a backbone), including humans, have a 'closed' circulatory system which principally consists of a pumping organ – the heart – and a network of blood vessels.

Fish have a single circulatory system in which blood passes once around the body before returning to a two-chambered heart. In birds and mammals, there is a double circulatory system – the lung or pulmonary circuit and the body or systemic circuit. Blood is first pumped from the heart to the lungs and back to the heart, before being pumped to the remainder of the body and back. The heart is therefore a double pump and is divided into two halves. In all vertebrates, blood flows in one direction. Valves in the heart, large arteries, and veins prevent backflow, and the muscular walls of the arteries assist in pushing the blood around the body. A network of tiny capillaries carries the blood from arteries to veins. It is through the walls of capillaries that materials are transported to and from the blood.

Although most animals have a heart or hearts to pump the blood, in some small invertebrates normal body movements circulate the fluid. In the **open system**, found in snails and other molluscs, the blood (more correctly called haemolymph) passes from the arteries into a body cavity (haemocoel), and from here is gradually returned by other blood vessels to the heart, via the gills. Insects and other arthropods have an open system with a heart. In the **closed system** of earthworms, blood flows directly from the main artery to the main vein, via smaller lateral vessels in each body segment.

The human circulatory system performs a number of functions: it supplies the cells of the body with the food and oxygen they need to survive (see nutrition); it carries carbon dioxide and other waste products away from the cells; it helps to regulate the temperature of the body; and protects the body from disease. In addition, the system transports hormones, which help to regulate the activities of various parts of the body.

Blood: The Discovery of Circulation

background

After completing a preliminary medical course at the University of Cambridge, where would an ambitious young man in the 17th century go to get a really good medical training? To the University of Padua in Italy, where the great Italian anatomist Hieronymous Fabricius (1537-1619) taught. So this is where English physician William Harvey (1578–1657) naturally went.

William Harvey had a consuming interest in the movement of the blood in the body. In 1579, Fabricius had publicly demonstrated the valves, which he termed 'sluice gates', in the veins: his principal anatomical work was an accurate and detailed description of them.

Galen's theory

Galen, a Greek physician (*c.* 130- *c.* 200), had 1,500 years previously written a monumental treatise covering every aspect of medicine. In this work, he asserted that food turned to blood in the liver, ebbed and flowed in vessels and, on reaching the heart, flowed through pores in the septum (the dividing wall) from the right to left side, and was sent on its way by heart spasms. The blood did not circulate. This doctrine was still accepted and taught well into the 16th century.

one-way flow

Harvey was unconvinced. He had done a simple calculation. He worked out that for each human heart beat, about 60 cm^3 of blood left the heart, which meant that the heart pumped out 259 litres every hour. This is more than three times the weight of the average man.

Harvey examined the heart and blood vessels of 128 mammals and found that the valve which separated the left side of the heart from the right ventricle is a one-way structure, as were the valves in the veins discovered by his tutor Fabricius. For this reason he decided that the blood in the veins must flow only towards the heart.

Harvey's experiment

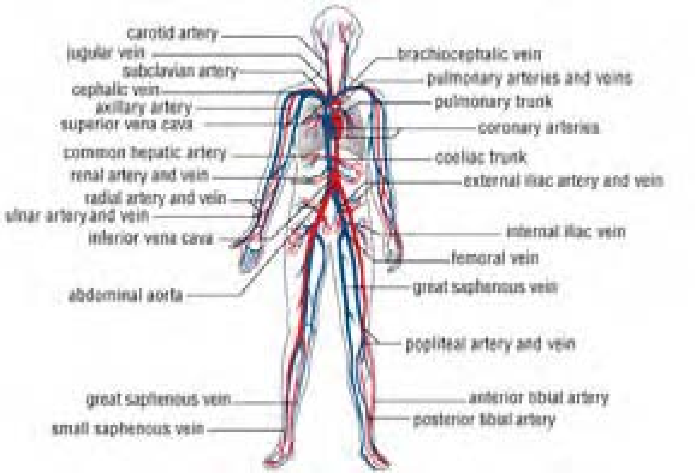
Harvey was now in a position to do his famous experiment. He tied a tourniquet round the upper part of his arm. It was just tight enough to prevent the blood from flowing through the veins back into his heart – but not so tight that arterial blood could not enter the arms. Below the tourniquet, the veins swelled up; above it, they remained empty. This showed that the blood could be entering the arm only through the arteries. Further, by carefully stroking the blood out of a short length of vein, Harvey showed that it could fill up only when blood was allowed to enter it from the end that was furthest away from the heart. He had proved that blood in the veins must flow only towards the heart.

a new theory of circulation

Galen's pores in the septum of the heart had never been found. Belgian physician Andreas Vesalius (1514-1564) was another alumnus of Padua University. Although brought up in the Galen tradition, he had carried out secret dissections to discover the pores, and had failed. He did, however, show that men and women had the same number of ribs!

Harvey clinched his researches into the movement of the blood when he demonstrated that no blood seeps through the septum of the heart. He reasoned that blood must pass from the right side of the heart to the left through the lungs. He had discovered the circulation of the blood, and thus, some 20 years after he left Padua, became the father of modern physiology. In 1628 Harvey published his proof of the circulation of the blood in his classic book *On the Motion of the Heart and Blood in Animals*. A new age in medicine and biology had begun.

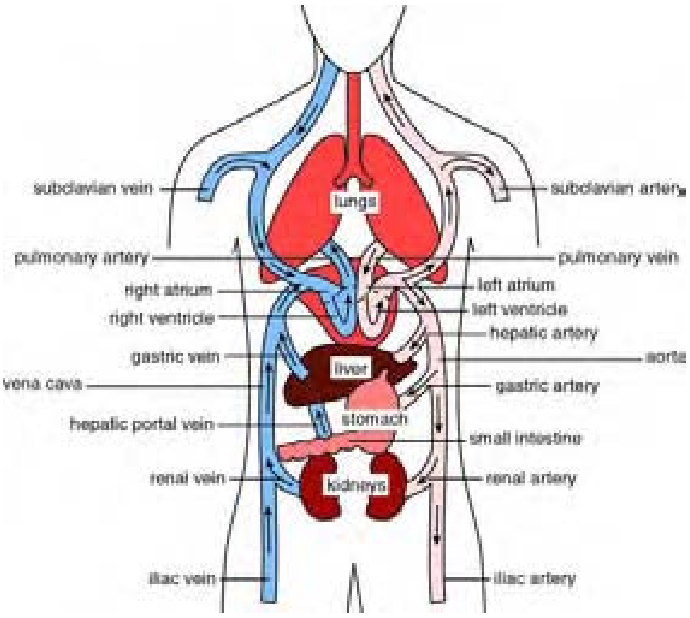
circulatory system


carotid artery
jugular vein
subclavian artery
cephalic vein
axillary artery
superior vena cava
common hepatic artery
renal artery and vein
radial artery and vein
ulnar artery and vein
inferior vena cava
abdominal aorta
great saphenous vein
small saphenous vein
brachiocephalic vein
pulmonary arteries and veins
pulmonary trunk
coronary arteries
coeliac trunk
external iliac artery and vein
internal iliac vein
femoral vein
great saphenous vein
popliteal artery and vein
anterior tibial artery
posterior tibial artery

(Image © Research Machines plc)

Blood flows through 96,500 km/60,000 mi of arteries and veins, supplying oxygen and nutrients to organs and limbs. Oxygen-poor blood (blue) circulates from the heart to the lungs where oxygen is absorbed. Oxygen-rich blood (red) flows back to the heart and is then pumped round the body through the aorta, the largest artery, to smaller arteries and capillaries. Here oxygen and nutrients are exchanged with carbon dioxide and waste products and the blood returns to the heart via the veins. Waste products are filtered by the liver, spleen, and kidneys, and nutrients are absorbed from the stomach and small intestine.

circulatory system


subclavian vein
lungs
subclavian artery
pulmonary artery
pulmonary vein
right atrium
left atrium
right ventricle
left ventricle
hepatic artery
gastric vein
aorta
vena cava
liver
gastric artery
hepatic portal vein
stomach
small intestine
renal vein
kidneys
renal artery
iliac vein
iliac artery

(Image © Research Machines plc)

The direction of blood flow in the human body, through the major blood vessels to the principal organs.

---

circumcision

surgical removal of all or part of the foreskin (prepuce) of the penis, usually performed on the newborn; it is practised among Jews (b'rit milah) and Muslims as a sign of God's covenant with the prophet Abraham. In some societies in Africa and the Middle East, female circumcision or clitoridectomy (removal of the labia minora and/or clitoris) is practised on adolescents as well as babies; it is illegal in the West.

Male circumcision is usually carried out for cultural reasons and not as a medical necessity, apart from cases where the opening of the prepuce is so small as to obstruct the flow of urine. Some evidence indicates that it protects against the development of cancer of the penis later in life and that women with circumcised partners are at less risk from cancer of the cervix.

---

circumference

in geometry, the curved line that encloses a curved plane figure, for example a circle or an ellipse. Its length varies according to the nature of the curve, and may be ascertained by the appropriate formula. The circumference of a circle is πd or $2\pi r$, where d is the diameter of the circle, r is its radius, and π is the constant pi, approximately equal to 3.1416.

---

circumpolar

in astronomy, term used to describe celestial objects that remain above the horizon at all times and do not set as seen from a given location. The amount of sky that is circumpolar depends on the observer's latitude on Earth. At the Earth's poles, all the visible sky is circumpolar, but at the Earth's Equator none of it is circumpolar.

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cirque

French name for a corrie, a steep-sided armchair-shaped hollow in a mountainside.

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cirrhosis

any degenerative disease in an organ of the body, especially the liver, characterized by excessive development of connective tissue, causing scarring and painful swelling. Cirrhosis of the liver may be caused by an infection such as viral hepatitis, chronic obstruction of the common bile duct, chronic alcoholism or drug use, blood disorder, heart failure, or malnutrition. However, often no cause is apparent. If cirrhosis is diagnosed early, it can be arrested by treating the cause; otherwise it will progress to coma and death.

CISC

acronym for Complex Instruction-Set Computer

in computing, a term referring to the design of the central processing unit (CPU) and its instruction set. CISC computers are characterized by having large numbers of instructions, varying a lot in size and complexity. Usually, the various stages of instruction execution are followed, and only when all the stages have been finished can a new instruction start to be executed. RISC CPUs, by comparison, usually have few instructions in the instruction set, and the instructions are smaller and simpler. Complex problems are solved by executing several of the smaller instructions.

RISC CPUs often outperform CISC designs because the instructions are executed in a pipeline, which is analogous to a factory assembly line. The pipeline enables the execution of instructions to be overlapped, with the first stages of instruction taking place before the final stages of the previous instruction have been completed.

---

cistron

in genetics, the segment of DNA that is required to synthesize a complete polypeptide chain. It is the molecular equivalent of a gene.

CITES

acronym for Convention on International Trade in Endangered Species

international agreement under the auspices of the World Conservation Union with the aim of regulating trade in endangered species of animals and plants. The text of the convention was agreed by members of 80 countries in Washington, DC, on 3 March 1973 and came into force on 1 July 1975. By 2004, 160 countries had signed up for the convention. It prohibits any trade in a category of 8,000 highly endangered species and controls trade in a further 30,000 species. The CITES secretariat is administered by the United Nations Environment Programme (UNEP).

Animals and plants listed in Appendix 1 of CITES are classified endangered, and all trade in these species is banned; those listed in Appendix 2 are classified vulnerable, and trade in these species is controlled without a complete ban; those listed in Appendix 3 are subject to domestic controls, while national governments request help in controlling international trade.

---

citizens' band

CB

short-range radio communication facility (frequency around 27 MHz) used by members of the public in the

USA and many European countries to talk to one another or call for emergency assistance.

citric acid

$HOOCCH_2C(OH)(COOH)CH_2COOH$

organic acid widely distributed in the plant kingdom; it is found in high concentrations in citrus fruits and has a sharp, sour taste. At one time it was commercially prepared from concentrated lemon juice, but now the main source is the fermentation of sugar with certain moulds.

In biochemistry, citric acic plays a key role in metabolism, as the defining compound of the Krebs cycle, also known as the citric acid cycle or tricarboxylic acid cycle.

citronella

lemon-scented oil used in cosmetics and insect repellents, obtained from a South Asian grass (*Cymbopogon nardus*).

citrus

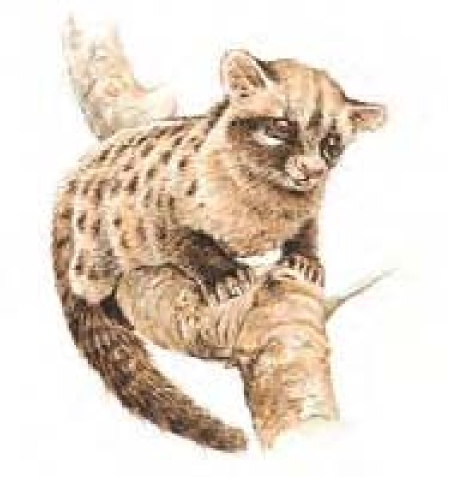
any of a group of evergreen and aromatic trees or shrubs, found in warm parts of the world. Several species - the orange, lemon, lime, citron, and grapefruit - are cultivated for their fruit. (Genus *Citrus*, family Rutaceae.)

civet

small to medium-sized carnivorous mammal found in Africa and Asia, belonging to the family Viverridae, which also includes mongooses and genets. Distant relations of cats, they generally have longer jaws and more teeth. All have a scent gland in the inguinal (groin) region. Extracts from this gland are taken from the **African civet** *Civettictis civetta* and used in perfumery.

As well as eating animal matter, many species, for example, the Southeast Asian **palm civet** *Arctogalidia trivirgata*, are fond of fruit.

civet



(Image © Research Machines plc)

The African palm civet *Nandinia binotata* spends most of its life in trees, resting among the branches during the day and searching for food at night.

civil aviation

operation of passenger and freight transport by air. With increasing traffic, control of air space is a major problem. In the USA, the Federal Aviation Agency (FAA) is responsible for regulating development of aircraft, air navigation, traffic control, and communications and the Civil Aeronautics Board prescribes safety regulations and investigates accidents. In Europe, Eurocontrol was established in 1963 by Belgium, France, West Germany, Luxembourg, the Netherlands, and the UK to supervise both military and civil movement in the air space over member countries. Close cooperation is maintained with authorities in other countries, and there is also a tendency to coordinate services and other facilities between national airlines; for example, the establishment of Air Union in 1963 by France (Air France), West Germany (Lufthansa), Italy (Alitalia), and Belgium (Sabena).

International Civil Aviation Organization

Go to site

Site of the specialized UN agency regulating civil aviation. The role and history of the ICAO are well presented. There is information on rules of the air, international conventions, and standardization of safety standards. The ICAO tries to reassure nervous flyers that air travel is getting safer. There are links to all the online airlines, airports, and pilot training centres in the world.

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civil engineering

branch of engineering that is concerned with the construction of roads, bridges, airports, aqueducts, waterworks, tunnels, canals, irrigation works, and harbours.

Civil engineering was first recognized as a separate profession from architecture and military engineering by the French. They established a department concerned with roads and bridges which, in 1763, became the Corps des Ingénieurs des Ponts.

The British engineer John Smeaton established his Society of Civil Engineers in 1771 to distinguish civilian from military engineering projects.

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cladistics

method of biological classification that uses a formal step-by-step procedure for objectively assessing the extent to which organisms share particular characteristics, and for assigning them to taxonomic groups called **clades**. Clades comprise all the species descended from a known or inferred common ancestor plus the ancestor itself, and may be large - consisting of a hierarchy of other clades.

The cladistic method of classification was proposed by German teacher and entomologist Willi Hennig (1913-1976) in 1950, though his ideas did not gain currency until his work was translated into English in 1966.

---

cladode

in botany, a flattened stem that is leaflike in appearance and function. It is an adaptation to dry conditions because a stem contains fewer stomata than a leaf, and water loss is thus minimized. The true leaves in such plants are usually reduced to spines or small scales. Examples of plants with cladodes are butcher's-broom *Ruscus aculeatus*, asparagus, and certain cacti. Cladodes may bear flowers or fruit on their surface, and this distinguishes them from leaves.

---

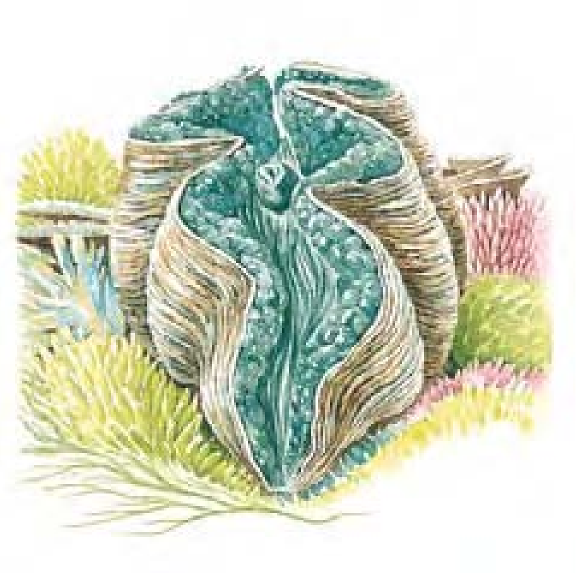
clam

common name for a bivalve mollusc. The giant clam *Tridacna gigas* of the Indopacific can grow to 1 m/3 ft across in 50 years and weigh, with the shell, 500 kg/1,000 lb.

A giant clam produces a billion eggs in a single spawning.

The term is usually applied to edible species, such as the North American hard clam *Venus mercenaria*, used in clam chowder, and whose shells were formerly used as money by North American Indians. A giant clam may produce a billion eggs in a single spawning.

clam



(Image © Research Machines plc)

The giant clam has a siphon with two tubes: one to take in water, the other to expel waste. The water supplies the animal with oxygen and food in the form of tiny plankton.

Clarke orbit

alternative name for geostationary orbit, an orbit 35,900 km/22,300 mi high, in which satellites circle at the same speed as the Earth turns. This orbit was first suggested by English writer Arthur C Clarke in 1945.

class

in biological classification, a subdivision of phylum and forms a group of related orders. For example, all mammals belong to the class Mammalia and all birds to the class Aves. Among plants, all class names end in 'idae' (such as Asteridae) and among fungi in 'mycetes'; there are no equivalent conventions among animals. Related classes are grouped together in a phylum.

classification

in biology, the arrangement of organisms into a hierarchy of groups on the basis of their similarities. The basic grouping is a species, several of which may constitute a genus, which in turn are grouped into families, and so on up through orders, classes, phyla (in plants, sometimes called divisions), and finally to kingdoms. The system that is used is one that reflects the evolutionary origin of the organisms. In other words, organisms belonging one group are thought to have evolved from a common ancestor at some time in the past.

All organisms are given a name formed from the species name and the genus name. This name is therefore called a binomial. The binomial name of humans is *Homo sapiens*. *Homo* is the genus name and *sapiens* the species name. Humans belong to the animal kingdom.

The oldest method of classification, called **phenetic classification**, aims to classify organisms on the basis of as many as possible of their observable characteristics: their morphology, anatomy, physiology, and so on. Greek philosopher Theophrastus adopted this method in the 4th century BC, when he classified plants into trees, shrubs, undershrubs, and herbs.

Awareness of evolutionary theory, however, led to the development of **phylogenetic classification**, which aims to classify organisms in a way that mirrors their evolutionary (see evolution) and genetic relationships (see genetics). Species are grouped according to shared characteristics believed to be derived from common ancestors (care being taken to exclude shared characteristics known to be due to convergent evolution - such as the wings of bats and birds). In practice, most present-day systems of classification compromise between the phenetic and the phylogenetic approaches.

Classification: The Influence of DNA Analysis

the influence of DNA analysis on classification

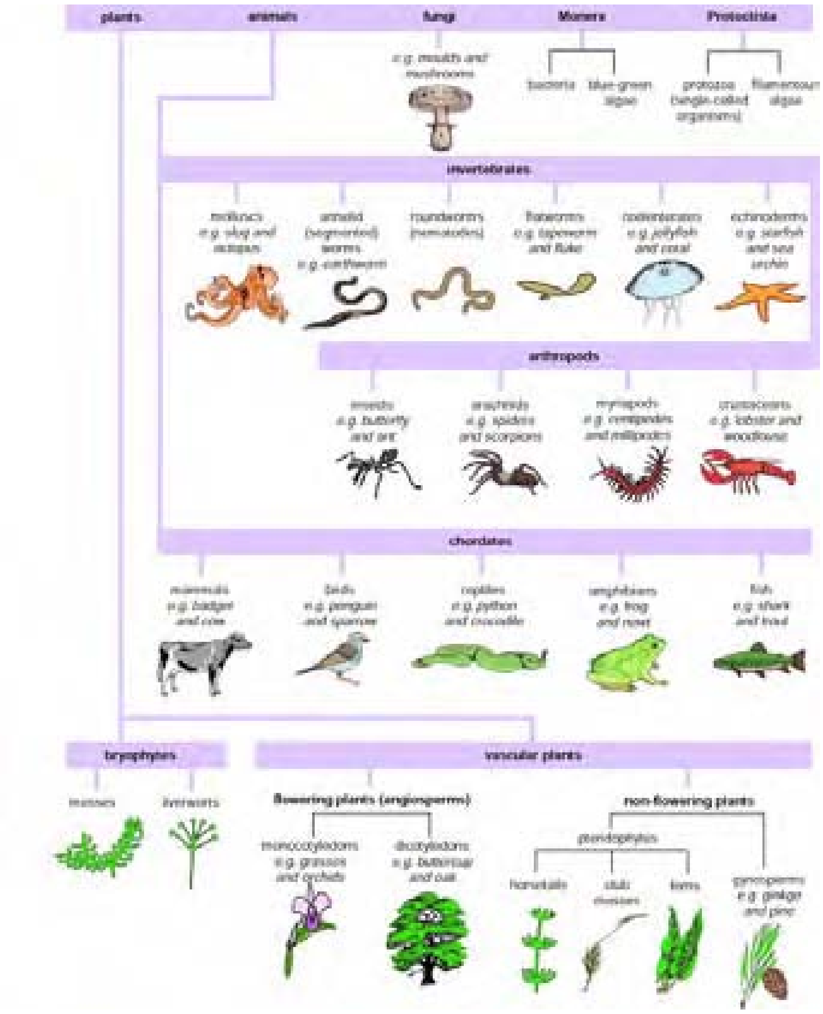
DNA analysis is changing the way we classify animals, and throwing new light on how they evolve. A good example is shown by findings concerning whale families. Researchers in Belgium and the USA made a detailed analysis of similar genes in 16 species of whales, and the results were at variance with the way these species had been traditionally classified.

Whales with teeth, such as the sperm whale and the dolphins, were thought to be closely related and had been classified as such. However, comparing the DNA that codes for **ribosomal RNA** in whales shows that the sperm whales are more closely related to the baleen whales, which do not have teeth but which filter food from the sea. The comparison also showed that the beaked whale, which has a few teeth, is only distantly related to the other whale families. The results were confirmed by comparison of the DNA sequence for **myoglobin** in different whale species.

the influence of DNA analysis on evolutionary theory

The research on whales expanded our understanding of how this important group evolved. One important point, for example, concerns echolocation, the ability of whales to navigate by listening to the echoes of sounds. According to traditional classification, baleen whales never had the ability to echolocate. The new classification implies that baleen whales have evolved from species that were able to echolocate, and have now lost the ability. The application of DNA analysis holds endless possibilities for taxonomy (the science of classification).

classification


plants
animals
fungi
Monera
Protoctista
e.g. moulds and mushrooms
bacteria
blue-green algae
protozoa (single-celled organisms)
filamentous algae
invertebrates
molluscs e.g. slug and octopus
annelid (segmented) worms e.g. earthworm
roundworms (nematodes)
flatworms e.g. tapeworm and fluke
coelenterates e.g. jellyfish and coral
echinoderms e.g. starfish and sea urchin
arthropods
insects e.g. butterfly and ant
arachnids e.g. spiders and scorpions
myriapods e.g. centipedes and millipedes
crustaceans e.g. lobster and woodlouse
chordates
mammals e.g. badger and cow
birds e.g. penguin and sparrow
reptiles e.g. python and crocodile
amphibians e.g. frog and newt
fish e.g. shark and trout
bryophytes
mosses
liverworts
vascular plants
flowering plants (angiosperms)
monocotyledons e.g. grasses and orchids
dicotyledons e.g. buttercup and oak
non-flowering plants
pteridophytes
horsetails
club mosses
ferns
gymnosperms e.g. ginkgo and pine

(Image © Research Machines plc)

The classification of the plant and animal kingdoms.

classification

To remember the order of taxonomic classification:

Krakatoa **p**ositively **c**asts **o**ff **f**umes **g**enerating **s**ulphurous **v**apours or **K**indly **p**lace **c**over **o**n **f**resh **g**reen **s**pring **v**egetables or **K**ing **P**hillip **c**ame **o**ver **f**or **g**inger **s**naps

Kingdom, **p**hylum, **c**lass, **o**rder, **f**amily, **g**enus, **s**pecies, **v**ariety

The five kingdoms of living things

Kingdom	Main features of organisms	Number of species
Monera[1]	all are bacteria; single-celled; prokaryotic (lack a membrane-bound nucleus); autotrophic (feed on simple substances by photosynthesis and chemosynthesis) and heterotrophic (feed on complex substances); all reproduce asexually, some also reproduce sexually	>10,000
Protista	single-celled or multicelled; eukaryotic (have a membrane-bound nucleus and membrane-bound organelles); autotrophic (photosynthesis in algae and Euglenoids) and heterotrophic; may reproduce asexually or sexually	>100,000
Fungi	single-celled and multicellular; eukaryotic; heterotrophic; form spores at all stages of their life cycle; usually reproduce asexually, many reproduce by conjugation (a simple form of sexual reproduction)	about 100,000
Plantae	all are multicellular; eukaryotic; most are autotrophic (via photosynthesis); reproduce sexually; in some the life cycle includes an alternation of generations (there is a haploid gametophyte stage when sex cells are created; these go on to produce spores in the diploid sporophyte stage: the spores then produce sex cells, and so on)	>250,000
Animalia	all are multicellular; eukaryotic; all are heterotrophic; reproduce sexually; develop from a blastula; most have tissues organized into organs	>1,000,000

[1] The Kingdom Monera is sometimes called the Kingdom Prokaryotae.

Classification of Living Things

Go to site

Well-written introduction to the principles of Linnaean classification. This Web site explains the general principles of taxonomy, with lavish use of photography, diagrams, and hypertext links. It follows this with a number of tables illustrating taxonomic relationships, such as the five kingdoms of life. A table of human classification shows how humans fit into the scheme.

Linnaeus, Carolus

Go to site

Profile of the life and legacy of the Swedish 'father of taxonomy', Carl Linnaeus. A biography traces how his childhood interest in plants led to him becoming the greatest observational biologist of his day. There is also a discussion as to whether he could be considered an evolutionist.

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class interval

in statistics, the range of each class of data, used when arranging large amounts of raw data into grouped data. To obtain an idea of the distribution, the data are broken down into convenient classes (commonly 6-16), which must be mutually exclusive and are usually equal in width to enable histograms to be drawn. The class boundaries should clearly define the range of each class. When dealing with discrete data, suitable intervals would be, for example, 0-2, 3-5, 6-8, and so on. When dealing with continuous data, suitable intervals might be $170 \leq X < 180$, $180 \leq X < 190$, $190 \leq X < 200$, and so on.

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clathrate

compound formed when the small molecules of one substance fill in the holes in the structural lattice of another, solid, substance - for example, sulphur dioxide molecules in ice crystals. Clathrates are therefore intermediate between mixtures and true compounds (which are held together by ionic or covalent chemical bonds).

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clathration

in chemistry, a method of removing water from an aqueous solution, and therefore increasing the solution's concentration, by trapping it in a matrix with rare gases such as freons.

Claudet, Antoine François Jean (1797-1867)

French-born pioneer of photography. Working in London, he made daguerreotype portraiture commercially viable when he discovered that chlorine and iodine vapour increased the sensitivity of the plate and greatly reduced exposure time. His other innovations include the earliest light meter and the introduction of painted backgrounds into studio portraits.

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clausius

in engineering, a unit of entropy (the loss of energy as heat in any physical process). It is defined as the ratio of energy to temperature above absolute zero.

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claustrophobia

phobia involving fear of enclosed spaces.

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clavicle

(Latin clavis 'key')

the collar bone of many vertebrates. In humans it is vulnerable to fracture, since falls involving a sudden force on the arm may result in very high stresses passing into the chest region by way of the clavicle and other bones. It is connected at one end with the sternum (breastbone), and at the other end with the shoulder-blade, together with which it forms the arm socket. The wishbone of a chicken is composed of its two fused clavicles.

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claw

hard, hooked, pointed outgrowth of the digits of mammals, birds, and most reptiles. Claws are composed of the protein keratin, and grow continuously from a bundle of cells in the lower skin layer. Hooves and nails are modified structures with the same origin as claws.

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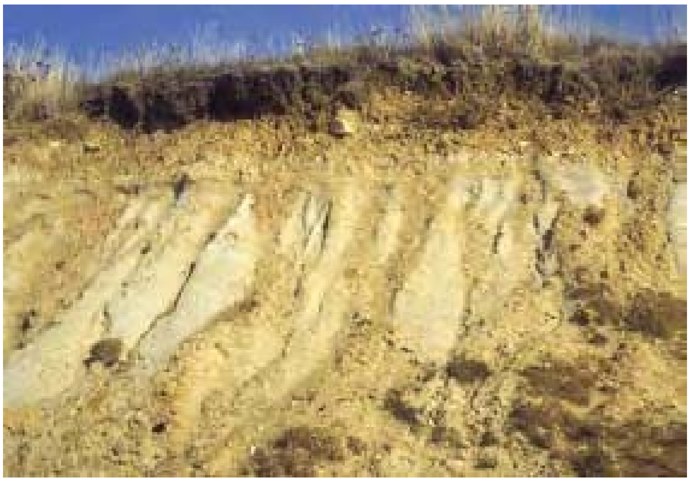
clay

very fine-grained sedimentary deposit that has undergone a greater or lesser degree of consolidation.

When moistened it is plastic, and it hardens on heating, which renders it impermeable. It may be white, grey, red, yellow, blue, or black, depending on its composition. Clay minerals consist largely of hydrous silicates of aluminium and magnesium together with iron, potassium, sodium, and organic substances. The crystals of clay minerals have a layered structure, capable of holding water, and are responsible for its plastic properties. According to international classification, in mechanical analysis of soil, clay has a grain size of less than 0.002 mm/0.00008 in.

clay



(Image © Garret Nagle)

Water runs off a clay surface. Clay is an impermeable rock. This means that water flows over it. (A little water can enter the clay, but this only causes the clay particles to expand and become even more impermeable.) The more water that falls, the greater the flow over the surface; this causes small gullies to form on the clay. In addition to the amount of rain, a steeper gradient will also increase the quantity of overland runoff.

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clay mineral

one of a group of hydrous silicate minerals that form most of the fine-grained particles in clays. Clay minerals are normally formed by weathering or alteration of other silicate minerals. Virtually all have sheet silicate structures similar to the micas. They exhibit the following useful properties: loss of water on heating; swelling and shrinking in different conditions; cation exchange with other media; and plasticity when wet. Examples are kaolinite, illite, and montmorillonite.

Kaolinite $Al_2Si_2O_5(OH)_4$ is a common white clay mineral derived from alteration of aluminium silicates, especially feldspars. Illite contains the same constituents as kaolinite, plus potassium, and is the main mineral of clay sediments, mudstones, and shales; it is a weathering product of feldspars and other silicates. Montmorillonite contains the constituents of kaolinite plus sodium and magnesium; along with related magnesium- and iron-bearing clay minerals, it is derived from alteration and weathering of mafic igneous rocks. Kaolinite (the mineral name for kaolin or china clay) is economically important in the ceramic and paper industries. Illite, along with other clay minerals, may also be used in ceramics. Montmorillonite is the chief constituent of fuller's earth, and is also used in drilling muds (muds used to cool and lubricate drilling equipment). Vermiculite (similar to montmorillonite) will expand on heating to produce a material used in insulation.

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cleavage

in geology and mineralogy, the tendency of a rock or mineral to split along defined, parallel planes related to its internal structure; the clean splitting of slate is an example. It is a useful distinguishing feature in rock and mineral identification. Cleavage occurs as a result of realignment of component minerals during deformation or metamorphism. It takes place where bonding between atoms is weakest, and cleavages may be perfect, good, or poor, depending on the bond strengths; a given rock or mineral may possess one, two, three, or more orientations along which it will cleave.

Some minerals have no cleavage, for example, quartz will fracture to give curved surfaces similar to those of broken glass. Some other minerals, such as apatite, have very poor cleavage that is sometimes known as a parting. Micas have one perfect cleavage and therefore split easily into very thin flakes. Pyroxenes have two good cleavages and break (less perfectly) into long prisms. Galena has three perfect cleavages parallel to the cube edges, and readily breaks into smaller and smaller cubes. Baryte has one perfect cleavage plus good cleavages in other orientations.

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cleft palate

fissure of the roof of the mouth, often accompanied by a harelip, the result of the two halves of the palate failing to join properly during embryonic development. It can be remedied by plastic surgery. Approximately 1 child in 2,000 is born with a cleft palate.

The chances of having a baby with a cleft palate are increased by smoking, taking Valium, or undergoing high stress levels.

cleistogamy

production of flowers that never fully open and that are automatically self-fertilized. Cleistogamous flowers are often formed late in the year, after the production of normal flowers, or during a period of cold weather, as seen in several species of violet *Viola*.

clematis

any of a group of temperate woody climbing plants with colourful showy flowers. They belong to the buttercup family. (Genus *Clematis*, family Ranunculaceae.)

clematis

(Image © Research Machines plc)

The *Clematis* genus of climbing plants includes more than two hundred members distributed across most of the world's temperate regions. They look very effective trained through trellising, entwined with other plants, or along walls like this one at Cotehele, a stately home beside the River Tamar in Cornwall.

Clematis

Go to site

In addition to a detailed description of the plant, its habitat, and other related species, there are also extensive notes on the possible medicinal uses of clematis, which include acting as a diuretic and diaphoretic. As the plant is poisonous, there are details of possible antidotes.

Cleve, Per Teodor (1840-1905)

Swedish chemist and geologist who discovered the elements holmium and thulium in 1879. He also demonstrated that the substance didymium, previously supposed to be an element, was in fact two elements, now known as neodymium and praseodymium.

Towards the end of his life he developed a method for identifying the age of glacial and postglacial deposits from the diatom fossils found in them.

click beetle

beetle that can regain its feet from lying on its back by jumping into the air and turning over, clicking as it does so.

client-server architecture

in computing, a system in which the mechanics of looking after data are separated from the programs that use the data. For example, the 'server' might be a central database, typically located on a large computer that is reserved for this purpose. The 'client' would be an ordinary program that requests data from the server as needed.

Most Internet services are examples of client-server applications, including the World Wide Web, FTP, and Telnet.

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climacteric

period during the lifespan when an important physiological change occurs, usually referring to menopause.

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climate

combination of weather conditions at a particular place over a period of time - usually a minimum of 30 years. A climate classification encompasses the averages, extremes, and frequencies of all meteorological elements such as temperature, atmospheric pressure, precipitation, wind, humidity, and sunshine, together with the factors that influence them.

The primary factors that influence the climate of an area are: latitude (as a result of the Earth's rotation and orbit); ocean currents; large-scale movements of wind belts and air masses over the Earth's surface; temperature differences between land and sea surfaces; topography; continent positions; and vegetation. In the long term, changes in the Earth's orbit and the angle of its axis inclination also affect climate. Climatologists are especially concerned with the influences of human activity on climate change, among the most important of which, at both local and global levels, are those currently linked with ozone depleters, the greenhouse effect, and global warming.

The World's Changing Climate

what is the greenhouse effect?

The surface of the Earth is warmed by energy from the Sun. The Earth then radiates energy through the atmosphere into space. Gases in the lower atmosphere such as carbon dioxide, methane, and water vapour are warmed by the radiation released by the Earth's surface. The atmosphere then radiates heat back towards the ground, adding to the heat the ground receives from the Sun. This process is called the **greenhouse effect**. Without the natural greenhouse effect, the surface of the planet would be about 34°C/61°F colder than it is now, and life as we know it would not be possible.

global warming

The rising concentration of **greenhouse gases** in the atmosphere is increasing the amount of radiation trapped near the Earth's surface. It is this *enhanced* greenhouse effect, also called **global warming**, that most scientists believe is changing the planet's climate. Everyone agrees that the world is getting warmer, but there is debate about whether the activity of human beings is responsible. Most scientists now believe it is; the enhanced greenhouse effect is due to the world's growing population burning more fossil fuels (such as coal, oil, and natural gas) for energy, as well as expanding agriculture and increasing deforestation.

after the Industrial Revolution

About 200 years ago, the Industrial Revolution ushered in an era in which humans rely on fossil fuels to run the many machines used in industry and everyday life. The burning of fossil fuels releases carbon dioxide into the atmosphere. Since the Industrial Revolution, there has been a steady increase in the production of carbon dioxide, and an increase in global population. Some of the carbon dioxide is absorbed by trees and plants or dissolved into the oceans; these are known as **carbon sinks**. But human activities have been producing carbon dioxide faster than it can be absorbed naturally, while widespread forest clearance has reduced the carbon sinks.

Scientists have been measuring the amount of carbon dioxide in the atmosphere for about 40 years, over which time the concentration has risen by about 15%. Older records of carbon dioxide levels, obtained from bubbles of air trapped in Antarctic ice, extend back hundreds of thousands of years. Carbon dioxide levels are now 31% higher than before the Industrial Revolution, higher than they have been for 420,000 years and probably higher than they have been for 20 million years. Other greenhouse gases have also increased: methane levels have more than doubled and nitrous oxide levels have increased by 17%. Humans have also introduced greenhouse gases to the atmosphere that did not exist until this century, such as chlorofluorocarbons (CFCs). We are changing the atmosphere faster than ever before.

rising temperatures

Additional greenhouse gases add to the natural greenhouse effect and are likely to make the planet warmer than it would otherwise be. Temperature changes vary from region to region, but records show that the Earth is about 0.6°C/1°F warmer than it was a century ago, with most of the warming occurring in the past 40 years. The 1990s were the Earth's warmest decade since measurements began in 1860, with eight of the ten warmest years occurring since 1990. The warmest year ever recorded was 1998.

Changes in **natural phenomena** can also indicate changes in temperature, and over a longer period of time. Evidence of warming includes melting glaciers, the temperature of the upper layers of the Earth's crust, coral growth, sea floor sediments, and the width of tree rings. These records show the 1900s to have been the warmest century in the past 1,000 years. They also confirm the 1990s to be the warmest decade and 1998 the warmest year of the millennium.

changes in the weather

As well as rises in temperature, many other aspects of the world's climate have changed. Some countries have experienced heavier rainfall, while other areas have suffered drought. There has been a reduction in the number of frosts and an increase in the number of heatwaves in many parts of the world. Mountain glaciers have shrunk, late summer Arctic sea-ice has thinned by 40%, and sea levels have risen by 10–20 cm/4–8 in. (Sea levels rise because water expands as it warms, and because the melting of glaciers adds to the amount of water.) Scientists expect to see more such changes in future.

But it is not possible to say for certain that all these changes have been due to the enhanced greenhouse effect. The temperature of the Earth may change naturally due to variations in the amount of energy emitted by the Sun, wobbles in the Earth's orbit around the Sun, and fluctuations in greenhouse gases, and, in the shorter term, because of variations in ocean currents and the cooling effect of dust emitted by volcanoes. Any warming due to human activities is superimposed on, and hidden by, these natural variations.

Over a longer time scale, there have been ice ages and warm periods fluctuating every 100,000 years or so over the past million years. The past 11,500 years have been relatively warm with short cool periods, such as the Little Ice Age that occurred in the Middle Ages. But although temperatures vary naturally between ice ages and warm periods, there is no record of the average global temperature ever having increased as rapidly as it has this century.

predicted changes

If greenhouse gases continue to be emitted as a result of human activities the way they do today, carbon dioxide levels will rise to at least double their pre-industrial levels by the end of the 21st century, even if we reduce global greenhouse gas emissions to the levels that they were in 1990. To guarantee no further increases in carbon dioxide in the atmosphere, we will need rapidly to reduce the levels of emissions by about 60 to 70% of current levels. Such major reductions are unlikely, so further changes in the climate will probably be felt over the next century.

Scientists use sophisticated computer programs running on powerful supercomputers to predict how the climate will change in the future. The programs create a global, three-dimensional model based on the physical laws that govern how the atmosphere, land, and oceans behave. Scientists first simulate the current climate, then increase the amount of greenhouse gases in the simulated atmosphere to see what effect this has. A doubling of carbon dioxide concentrations will increase the average global temperature by between 1.4 and 5.8°C/2.5 and 10.4°F. The warming over the next 100 years is predicted to be greater than any temperature change over the past 10,000 years.

It is not clear how global warming will change other aspects of the weather around the world. Some areas may receive more rain while others receive less. In general, global rainfall is likely to increase but evaporation will also increase, leaving soils drier. Scientists expect a greater number of extreme weather events, such as storms, floods, heatwaves, and droughts. By the end of the century, sea level is expected to rise by 9–88 cm/4–35 in above current levels.

These predictions are based on the assumption that changes will occur gradually. However, there are concerns that abrupt and massive changes in climate may take place, as have occurred in the distant past, due to unexpected changes in ocean currents.

impacts on our world

A few degrees of warming does not sound much, but the effects of such warming are serious. Increased temperature will cause a rise in the number of deaths related to heat stress. Infectious diseases such as malaria are expected to spread as disease-carrying insects are able to move to areas that are currently too cold. Drier soils will make food more difficult to grow and change the distribution of crops, with some areas facing increased risk of famine. Pests and weeds will flourish. Changing river flow patterns could reduce the amount of available fresh water. Small rises in sea levels increase the risk of storm surges that could flood low-lying coastal areas, and small islands and salt marsh habitats could be lost. Tropical forests and grasslands could die, and many plants and animals unable to adapt to such rapid changes in climate could become extinct.

Societies will need to adapt to these negative impacts, but there may also be positive changes in various regions. For example, forest production will increase due to the higher concentrations of carbon dioxide, and some areas may experience tourism and agricultural benefits from the warmer temperatures.

If the climate changes we have experienced at the end of the 20th century are a result of human activities, it is likely that changes in climate will continue to occur for the next century due to the long life of greenhouse gases.

political response

Advice from the Intergovernmental Panel on Climate Change (IPCC), an international group of more than 2,000 experts, has led to governments agreeing to stabilize greenhouse-gas concentrations to prevent dangerous interference with the world's climate. The first such legal agreement, the United Nations Framework Convention on Climate Change, took place in Rio de Janeiro, Brazil, in 1992, and in Kyoto, Japan, in 1997. A protocol was proposed that would require countries to cut their emissions. However, there is still disagreement about how this should be achieved, and a summit in The Hague, the Netherlands, in 2000 was inconclusive.

Continental Climate

Go to site

Clear guide to climate and climatic types. The hyperlinked, text-only introduction leads to fuller descriptions and images of the various climate zones including tropical, savannah, desert, temperate, and polar. The influences on climate are also explained with numerous links to other useful areas of information.

Department of Atmospheric Sciences

Go to site

Masses of data and other information on climate around the planet. Among the site's more attractive features is the use of multimedia instructional modules, customized weather maps, and real-time weather data.

El Niño

Go to site

Description and brief history of El Niño. This site provides examples of how El Niño can affect different parts of the world, and illustrates how it occurs with animated diagrams. La Niña, the presence of a cooler-than-normal body of water, is also explained.

Storm Chaser Home Page

Go to site

Set up by an devotee of the sport, this site has swiftly expanded through voluntary contributions of other fans. There are a vast number of stunning photos and a whole online Tornado Museum to tempt you into this hobby. On the other hand, an extended section of veterans' thoughts on safety may make you think twice. The site also offers severe weather reports for emergencies!

UK and Ireland Climate Index

Go to site

Highlights of this very comprehensive climate information site include an index of the main UK and Irish weather stations, with tables of monthly minimum and maximum temperatures, as well as rainfall figures.

Water Science for Schools: Earth's Water

Go to site

Information on the Earth's water. Part of a larger site run by the US Geological Survey, this section includes clear and well-illustrated information on topics such as the water cycle, water on the Earth's surface, and glaciers and icecaps. The main site is regularly updated with information on any natural disasters as and when they happen.

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climate change

change in the climate of an area or of the whole world over an appreciable period of time. That is, a single winter that is colder than average does not indicate climate change. It is the change in average weather conditions from one period of time (30-50 years) to the next. Climate fluctuations are natural phenomena, but there is increasing evidence to suggest that human industrial activity affects the global climate, particularly in terms of global warming.

Causes of Climate Change

Go to site

From a much larger site 'Fundamentals of Physical Geography' set up by a Canadian University and covering many aspects of the area of study. The site is clear and well organized and contains maps and diagrams.

Climate Change Campaign

Go to site

Climate change is happening now and having a drastic effect upon the natural world, according to this dramatic Web site from the Worldwide Fund for Nature (WWF).

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climatology

study of climate, its global variations and causes.

Climatologists record mean daily, monthly, and annual temperatures and monthly and annual rainfall totals, as well as maximum and minimum values. Other data collected relate to pressure, humidity, sunshine, cold cover, and the frequency of days of frost, snow, hail, thunderstorms, and gales. The main facts are summarized in tables and climatological atlases published by nearly all the national meteorological services of the world. Climatologists also study climates of the past (paleoclimates) by gathering information from such things as tree rings, deep sea sediments, and ice cores - all of which record various climate factors as they form.

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climax community

group of plants and animals that is best able to exploit the environment in which it exists. It is brought about by succession (a change in the species present) and represents the point at which succession ceases to occur.

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clinical ecology

in medicine, ascertaining environmental factors involved in illnesses, particularly those manifesting nonspecific symptoms such as fatigue, depression, allergic reactions, and immune-system malfunctions, and prescribing means of avoiding or minimizing these effects.

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clinical psychology

branch of psychology dealing with the understanding and treatment of health problems, particularly mental disorders. The main problems dealt with include anxiety, phobias, depression, obsessions, sexual and marital problems, drug and alcohol dependence, childhood behavioural problems, psychoses (such as schizophrenia), mental disability, and brain disease (such as dementia) and damage. Other areas of work include forensic psychology (concerned with criminal behaviour) and health psychology.

Assessment procedures assess intelligence and cognition (for example, in detecting the effects of brain damage) by using psychometric tests.
Behavioural approaches are methods of treatment that apply learning theories to clinical problems.
Behaviour therapy helps people change unwanted behaviours (such as phobias, obsessions, sexual problems) and to develop new skills (such as improving social interactions).
Behaviour modification relies on operant conditioning, making selective use of rewards (such as praise) to change behaviour. This is helpful for children, the mentally disabled, and for patients in institutions, such as mental hospitals.
Cognitive therapy is an approach to treating emotional problems, such as anxiety and depression, by teaching people how to deal with negative thoughts and attitudes.
Counselling, developed by Carl Rogers, is widely used to help people solve their own problems.
Psychoanalysis, as developed by Sigmund Freud and Carl Jung, is little used by clinical psychologists today. It emphasizes childhood conflicts as a source of adult problems.

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clinometer

hand-held surveying instrument for measuring angles of slope.

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clint

one of a number of flat-topped limestone blocks that make up a limestone pavement. Clints are separated from each other by enlarged joints called grykes.

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clitoris

(Greek kleitoris 'little hill')

in anatomy, part of the female reproductive system. The glans of the clitoris is visible externally. It connects to a pyramid-shaped pad of erectile tissue. Attached to this are two 'arms' that extend backwards into the body towards the anus and are approximately 9 cm/3.5 in in length. Between these arms are the clitoral bulbs, lying one on each side of the vaginal cavity.

During sexual intercourse the clitoris swells and stimulation of it results in orgasm. In its swollen state it presses on the urethra and closes it preventing harmful bacteria from entering the bladder.

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clo

unit of thermal insulation of clothing. Standard clothes have an insulation of about 1 clo; the warmest clothing is about 4 clo per 2.5 cm/1 in of thickness. See also tog.

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cloaca

the common posterior chamber of most vertebrates into which the digestive, urinary, and reproductive tracts all enter; a cloaca is found in most reptiles, birds, and amphibians; many fishes; and, to a reduced degree, marsupial mammals. Placental mammals, however, have a separate digestive opening (the anus) and urinogenital opening. The cloaca forms a chamber in which products can be stored before being voided from the body via a muscular opening, the cloacal aperture.

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clock

any device that measures the passage of time, usually shown by means of pointers moving over a dial or by a digital display. A small timepiece worn on the wrist or carried is a watch. Nearly all modern clocks and watches are electronic and controlled by a vibrating quartz crystal. Mechanical timepieces are still made, however. Mechanical clocks consist of a train of wheels driven by a weight or by electricity and controlled by a pendulum. Mechanical watches are driven by a spring and controlled by a balance spring.

history

In ancient Egypt the time during the day was measured by a shadow clock, a primitive form of sundial, and at night the water clock was used. Up to the late 16th century the only clock available for use at sea was the sand clock, of which the most familiar form is the hourglass. During the Middle Ages various types of sundial were widely used, and portable sundials were in use from the 16th to the 18th century. Watches were invented in the 16th century – the first were made in Nuremberg, Germany, shortly after 1500 – but it was not until the 19th century that they became cheap enough to be widely available. The first known public clock was set up in Milan, Italy, in 1353. The timekeeping of both clocks and watches was revolutionized in the 17th century by the application of pendulums to clocks and of balance springs to watches.

types of clock

The **marine chronometer** was a mechanical precision timepiece of special design, used at sea for giving Greenwich mean time (GMT).
Electric timepieces were made possible by the discovery early in the 19th century of the magnetic effects of electric currents. One of the earliest and most satisfactory methods of electrical control of a clock was invented by Matthaeus Hipp in 1842. In one kind of electric clock, the place of the pendulum or spring-controlled balance wheel is taken by a small synchronous electric motor, which counts up the alternations (frequency) of the incoming electric supply and, by a suitable train of wheels, records the time by means of hands on a dial. The **quartz crystal** timepiece (made possible by the piezoelectric effect of certain crystals) has great precision, with a short-term variation in accuracy of about one-thousandth of a second per day. The **atomic clock**, used in scientific work, utilizes the natural resonance of certain atoms (for example, caesium) as a regulator controlling the frequency of a quartz crystal oscillator. Atomic clocks can be accurate to within one second in 30 million years (1 part in 10^{15}).

In 2005 an atomic clock was developed based on the frequency of strontium atom oscillations. Lasers were used to separate individual strontium atoms electromagnetically into a series of energy wells, preventing their oscillations form interfering with each other. This technique allowed the oscillations of a number of atoms to be measured at once, increasing the accuracy of the clock. The strontium 'optical lattice clock' can potentially keep time with an accuracy of 1 part in 10^{18}, or one second in 30 billion years.

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clock rate

frequency of a computer's internal electronic clock. Every computer contains an electronic clock, which produces a sequence of regular electrical pulses used by the control unit to synchronize the components of the computer and regulate the fetch-execute cycle by which program instructions are processed.

A fixed number of time pulses is required in order to execute each particular instruction. The speed at which a computer can process instructions therefore depends on the clock rate: increasing the clock rate will decrease the time required to complete each particular instruction.

Clock rates are measured in **megahertz** (MHz), or millions of pulses a second. Microcomputers commonly have a clock rate of 8-100 MHz. The overall performance of a microcomputer depends on many factors in addition to the clock rate.

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clone

exact replica – in genetics, any one of a group of genetically identical cells or organisms. An identical twin is a clone; so too are bacteria living in the same colony. 'Clone' also describes genetically engineered replicas of DNA sequences.

British scientists confirmed in February 1997 that they had cloned an adult sheep from a single cell to produce a lamb with the same genes as its mother. A cell was taken from the udder of the mother sheep, and its DNA combined with an unfertilized egg that had had its DNA removed. The fused cells were grown in a laboratory and then implanted into the uterus of a surrogate mother sheep. The resulting lamb, Dolly, came from an animal that was six years old. However, in 1999, Dolly was revealed not to be an exact clone – research showed her mitochondria to have come mainly from the egg cell rather than the udder cell. Dolly was put down at the early age of six in February 2003 when it was found that she had developed a progressive lung disease.

This was the first time cloning had been achieved using cells other then reproductive cells. The cloning breakthrough has ethical implications, as the same principle could be used with human cells and eggs. The news was met with international calls to prevent the cloning of humans. The UK, Spain, Germany, Canada, and Denmark already have laws against cloning humans, as do some individual states in the USA. France and Portugal also have very restrictive laws on cloning.

In 2003 scientists reported cloning a horse and a rat for the first time.

Understanding Cloning

introduction

Sexual reproduction is the means by which genetic variability is introduced in a population. A clone, however, refers to one or more offspring derived from a single ancestor, whose genetic composition is identical to that of the ancestor. Hence the offspring of organisms that reproduce asexually, such as microbes, some insects, and corals are clones, as are identical twins produced by the splitting of a single embryo. Long before anyone understood the mechanism of heredity, the genetic make-up of successive generations of certain plants was preserved by taking cuttings, because cloning in this way bestowed on the plants qualities such as disease resistance, high yield, and predictable growth. Although there is nothing unnatural about cloning per se, colloquial use of the term generally refers to the procedures used by modern science to create mammalian clones. This can be achieved by substituting the nucleus, which contains the genes, from one of the cells making up a mammal's body, for the nucleus of a fertilized egg, that is then brought to term. This technique was first used in 1997 to produce Dolly the sheep.

genetic modification

Interest in cloning livestock is largely allied to genetic modification – the ability to add new genes to an animal's normal repertoire or to modify one of its own genes. This might enable cloned farm animals to provide not only traditional products such as meat, milk, and hide, but also natural proteins for pharmaceutical use, or to serve as organ donors for human transplants. Also of interest is the rapid production of large animals carrying genetic defects that mimic human illnesses, such as cystic fibrosis. Although mice have provided some information, mice and humans have very different genes for cystic fibrosis. Sheep are expected to be more valuable for research into this condition because their lungs resemble those of humans. Moreover, because sheep live for years, scientists can evaluate their long-term responses to treatments.

gene therapy

Cloning could also help curtail transmission of genetic disease. Many scientists are now working on therapies that would supplement or replace defective genes in cells, but even successfully treated patients will still pass on defective genes to their offspring. If a couple was willing to produce an embryo that could be treated by advanced forms of gene therapy, nuclei from modified embryonic cells could be transferred to eggs to create children who would be entirely free of a given disease. Some of the most ambitious projects concerning cloning involve the production of human stem cells (embryonic cells from which all others are derived), that might be used to repair or replace tissue damaged by illness. Stem cells matched to an individual patient could theoretically be made by creating an embryo by nuclear transfer just for that purpose, using one of the patient's cells as the donor and a human egg as the recipient. Embryo-derived cells might be used to treat a variety of serious diseases caused by damage to cells, perhaps including acquired immune deficiency syndrome (AIDS) as well as Parkinson's disease, muscular dystrophy, and diabetes.

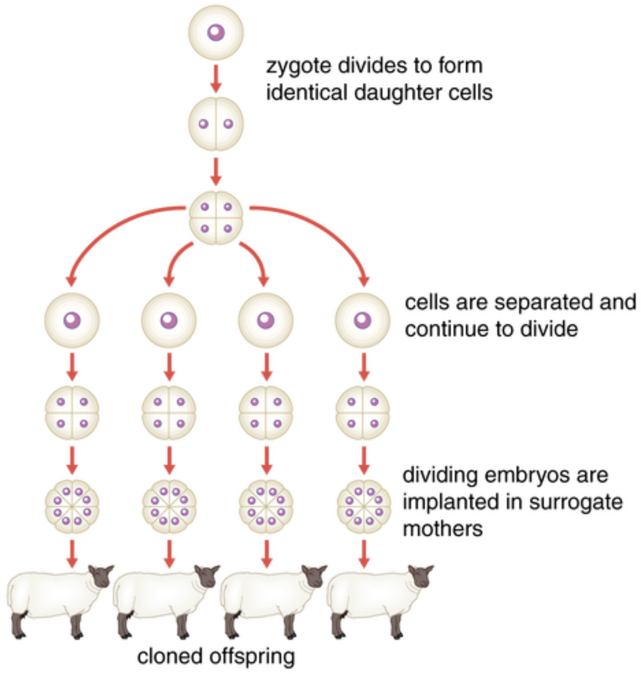
ethical concerns

All of these developments raise difficult ethical issues. It is important, however, to realize that in many cases it is genetic modification, and not cloning, that has opened the way for such practices. Cloning would be of limited interest, and certainly be of little commercial value, without genetic modification. Nonetheless, creating animals with genetic defects and human babies without them raises challenging problems. It seems on balance that society supports research on animals, provided that the illnesses being studied are serious and efforts are made to avoid unnecessary suffering. Opinion on gene therapy of human embryos is more opaque. Furthermore, the possibility of growing human embryos for their cells is deeply disturbing to some people who consider life to be sacred from conception, while others regard the embryo as a cluster of cells that does not become a sentient being until much later in development.

human cloning

Perhaps the most troubling question concerns the cloning of humans, which is technically feasible, although not yet a reality. Arguments in favour of permitting human cloning, for example to overcome human infertility, seem few and far between. Significantly, it is quite possible that cloned individuals would turn out to be at risk. The long-term effects of asking an 'old' adult cell nucleus to begin life again in an egg are not known. The nucleus of a skin cell could have accumulated many genetic mistakes of no consequence to its role in the skin, but when required to make a brand new organism these could prove disastrous in other tissues, or greatly increase the probability of developing cancer. The UK government regards the deliberate cloning of human beings as ethically unacceptable. Under UK law, cloning of individual humans cannot take place whatever the origin of the material and whatever technique is used. The recent joint Human Fertilization and Embryology Authority/Human Genetics Advisory Commission report, 'Cloning Issues in Reproduction, Science and Medicine', concurred with this view, citing serious ethical concerns about reproductive cloning as a means to relieve infertility, or for any other reason.

clone

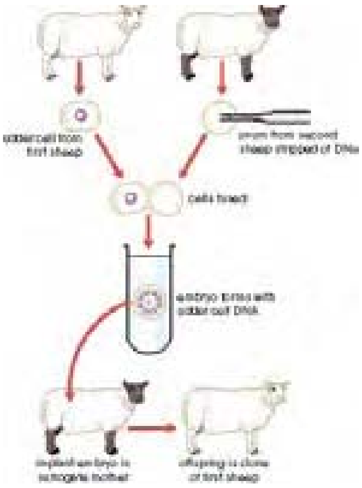

zygote divides to form identical daughter cells
cells are separated and continue to divide
dividing embryos are implanted in surrogate mothers
cloned offspring

mothers
cloned offspring

(Image © Research Machines plc)

The production of a clone (an exact replica) happens naturally when a zygote undergoes division. This is the process that brings about multiple births such as identical twins and triplets. Zygote division can be induced in vitro with the resulting embryos then implanted into surrogate mothers. The offspring are all clones of each other but not of their parents.

clone


udder cell from first sheep
ovum from second sheep stripped of DNA
cells fused
embryo forms with udder cell DNA
implant embryo in surrogate mother
offspring is clone of first sheep

(Image © Research Machines plc)

The cloning of Dolly the sheep by the Roslin Institute in Edinburgh was a genetic milestone. It was the first successful clone produced using genetic material from an adult (udder) cell rather than from a gamete (egg or sperm). The DNA from the udder cell was fused with an ovum stripped of its own DNA. The fused cells divided in vitro to form an embryo that was then implanted into a surrogate mother. The resulting lamb was a clone of the ewe that had provided the udder cell.

Cloning: key dates

1975	British scientist Derek Brownhall produces the first clone of a rabbit, in Oxford, England.
1981	Chinese scientists make the first clone of a fish (a golden carp).
1984	Allan Wilson and Russell Higuchi of the University of California, Berkeley, USA, clone genes from an extinct animal, the quagga.
1984	Sheep are successfully cloned.
1988	The first dairy cattle are produced by cloning embryos.
1996	US geneticists clone two rhesus monkeys from embryo cells.
1997	British geneticists clone an adult sheep. A cell is taken from the udder of the mother sheep and its DNA (deoxyribonucleic acid) is combined with an unfertilized egg that has had its DNA removed. The fused cells are grown in the laboratory and then implanted into the uterus of a surrogate mother sheep. The resulting lamb, Dolly, comes from an animal that is six years old. This is the first time cloning has been achieved using cells other than reproductive cells. The news is met with international calls to prevent the cloning of humans.
1997	US president Bill Clinton announces a ban on using federal funds to support human cloning research, and calls for a moratorium on this type of scientific research. He also asks the National Bioethics Advisory Commission to review and issue a report on the ramifications that cloning will have on humans.
1997	US genetic scientist Don Wolf announces the production of monkeys cloned from embryos. It is a step closer to cloning humans and raises acute philosophical issues.
1998	Doctors meeting at the World Medical Association's conference in Hamburg, Germany, call for a worldwide ban on human cloning. US president Clinton calls for legislation banning cloning the following day.
1998	Dolly, the sheep who was cloned in 1997, gives birth to a female lamb at the Roslin Institute in Edinburgh, Scotland.
1999	Dolly is revealed to be not an exact clone when her mitochondria are discovered to have come mainly from the egg rather than the udder cell.
2003	Dolly is put down aged 6, after suffering from a progressive lung disease. The average life expectancy of a sheep is 11-12 years.
2005	Huge advances in research into stem cell cloning in South Korea are admitted to have been fabricated.

Dr Frankenstein, I presume?

Go to site

Interview with the man who made the first cloned mammal using adult cells, Dolly. Embryologist Dr Ian Wilmut speaks to Andrew Ross about his worries and his future projects, about the distinction between science fiction and human cloning, and about what could go wrong with researching this delicate area.

Gene School

Go to site

Comprehensive online exploration of the discoveries and innovations of modern gene science. A useful page on the fundamentals of genetics is accompanied by links to news stories on genes and genetics. The brave new world of cloning is explained in another section, while an interactive page contains genetics-based games, quizzes, and experiments.

Hello Dolly

Go to site

Imaginative and humorous look at the issue of cloning, presented by the *Why Files*, an online magazine on the science behind the news. Genes, chromosomes, DNA, ethical considerations, and the 'lucky lamb' itself are all covered here. The magazine also features a series of interviews with specialists on genetics, bioethics, and other fields related to the sheep-cloning experiment.

I Can Do That

Go to site

Eureka! Science offers the 'I Can Do That!' Web pages as 'a painless way to find fun facts about DNA, RNA, cells, protein and cloning'. Interactive tests and printable worksheets accompany every section.

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closed

in mathematics, descriptive of a set of data for which an operation (such as addition or multiplication) done on any members of the set gives a result that is also a member of the set.

For example, the set of even numbers is closed with respect to addition, because two even numbers added to each other always give another even number.

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closed-circuit television

CCTV

localized television system in which programmes are sent over relatively short distances, the camera, receiver, and controls being linked by cable. Closed-circuit TV systems are used in department stores and large offices as a means of internal security, monitoring people's movements.

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clothes moth

moth whose larvae feed on clothes, upholstery, and carpets. The adults are small golden or silvery moths. The natural habitat of the larvae is in the nests of animals, feeding on remains of hair and feathers, but they have adapted to human households and can cause considerable damage, for example, the common clothes moth *Tineola bisselliella*.

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cloud

water vapour condensed into minute water particles that float in masses in the atmosphere. Clouds, like fogs or mists, that occur at lower levels, are formed by the cooling of air containing water vapour, which generally condenses around tiny dust particles.

Clouds are classified according to the height at which they occur, and by their shape.
Cirrus and **cirrostratus** clouds occur at around 10 km/33,000 ft. The former, sometimes called mares'-tails, consist of minute specks of ice and appear as feathery white wisps, while cirrostratus clouds stretch across the sky as a thin white sheet. Three types of cloud are found at 3–7 km/10,000–23,000 ft: cirrocumulus, altocumulus, and altostratus.
Cirrocumulus clouds occur in small or large rounded tufts, sometimes arranged in the pattern called mackerel sky.
Altocumulus clouds are similar, but larger, white clouds, also arranged in lines.
Altostratus clouds are like heavy cirrostratus clouds and may stretch across the sky as a grey sheet.
Stratocumulus clouds are generally lower, occurring at 2–6 km/6,500–20,000 ft. They are dull grey clouds that give rise to a leaden sky that may not yield rain. Two types of clouds, **cumulus** and **cumulonimbus**, are placed in a special category because they are produced by daily ascending air currents, which take moisture into the cooler regions of the atmosphere. Cumulus clouds have a flat base generally at 1.4 km/4,500 ft where condensation begins, while the upper part is dome-shaped and extends to about 1.8 km/6,000 ft. Cumulonimbus clouds have their base at much the same level, but extend much higher, often up to over 6 km/20,000 ft. Short heavy showers and sometimes thunder may accompany them.
Stratus clouds, occurring below 1–2.5 km/3,000–8,000 ft, have the appearance of sheets parallel to the horizon and are like high-level fogs.

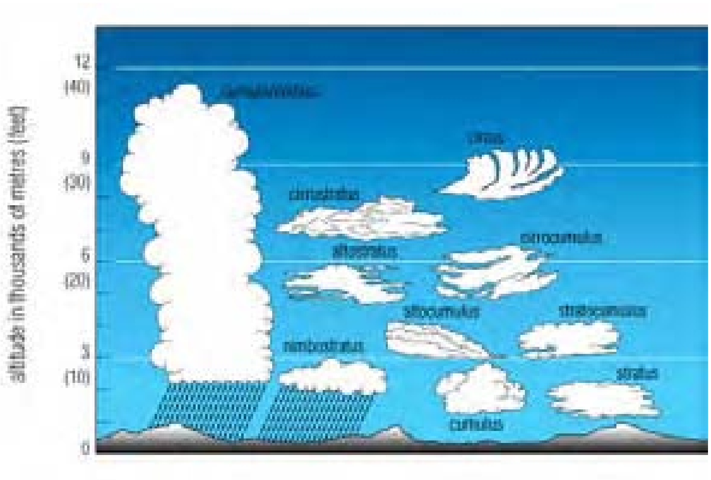
In addition to their essential role in the water cycle, clouds are important in the regulation of radiation in the Earth's atmosphere. They reflect short-wave radiation from the Sun, and absorb and re-emit long-wave radiation from the Earth's surface.

cloud

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Altocumulus clouds resemble the tufted cirrocumulus clouds of the classic 'mackerel sky', but they are rather larger. They will not necessarily appear larger to an observer on the ground, because they are at a greater altitude (the prefix *alto-* is Latin, meaning high). The mackerel pattern may also seem more regularly aligned.

cloud


altitude in thousands of metres (feet)
12
(40)
9
(30)
6
(20)
3
(10)
0
cumulonimbus
cirrus
cirrostratus
cirrocumulus
altostratus
altocumulus
stratocumulus
nimbostratus
stratus
cumulus

(Image © Research Machines plc)

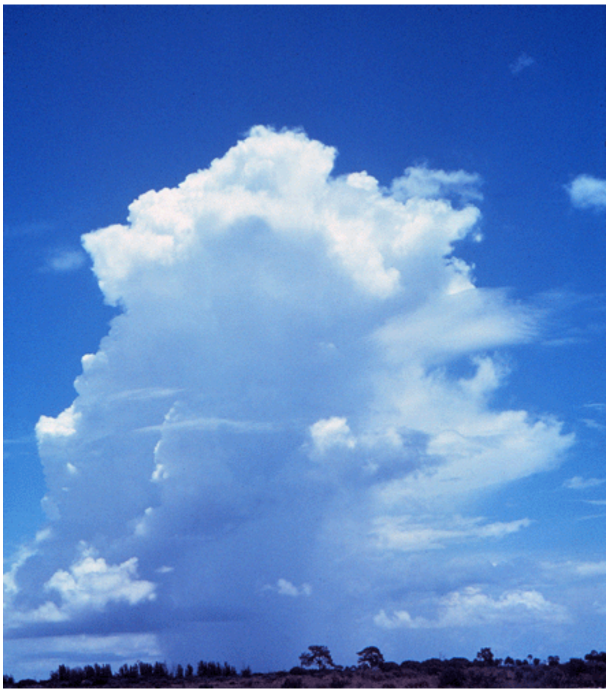
Standard types of cloud. The height and nature of a cloud can be deduced from its name. Cirrus clouds are at high levels and have a wispy appearance. Stratus clouds form at low level and are layered. Middle-level clouds have names beginning with 'alto'. Cumulus clouds, ball or cottonwool clouds, occur over a range of height.

cloud

(Image © Garret Nagle)

High-altitude clouds. Clouds are formed when moisture in the air condenses, and are composed of millions of water droplets suspended in air. Different types of cloud are found at high and low altitudes, and they are also affected by upper air movements, such as thermal winds.

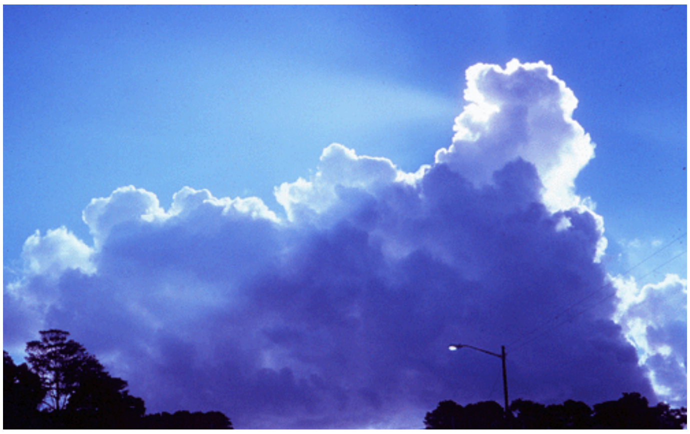
cumulus



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

This cumulus cloud has the classic domed stack shape that appears to rise threateningly high and suggests the possibility of a rain shower. But it would have to be rather broader and to rise perhaps three times higher still for it to become a cumulonimbus cloud, and for rain to become likely.

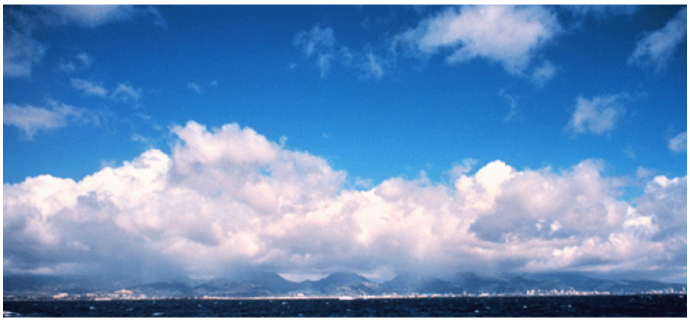
cloud



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Cumulus clouds, gathering together, do not necessarily threaten rain. They are named 'cumulus' because they gather together, or accumulate. Such clouds contain a high proportion of water vapour at around the altitude of condensation. The altitude of condensation depends on temperature and humidity; atmospheric pressure also influences temperature.

cloud



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

A bank of cumulus cloud, technically termed 'cumulus congestus'. This phenomenon is particularly prevalent over a coastline with hills or mountains immediately behind, and with a strong breeze normally blowing off the sea. Such banks are also found elsewhere as the first sign of a change in atmospheric pressure or the approach of a weather system.

Cloud types and heights

Cloud type	Average height		Description
	m	ft	
stratus	1,600	5,249	low parallel sheets
cumulus	2,000	6,562	flat-based and domed
nimbostratus	2,500	8,202	rounded, fluffy rain clouds
altocumulus	3,400	11,155	white clouds in lines
stratocumulus	3,600	11,811	dull grey, sometimes leaden
altostratus	5,200	17,060	extensive grey sheet
cirrocumulus	5,600	18,373	small/large rounded tufts ('mackerel sky')
cirrostratus	7,000	22,966	thin white sheet
cirrus	8,500	27,887	feather wisps ('mares' tails')
cumulonimbus	2,500-11,500	8,202-37,730	rounded rain clouds often reaching great heights

Clouds and Precipitation

Go to site

Illustrated guide to how clouds form and to the various different types. The site contains plenty of images and a glossary of key terms in addition to further explanations of the various types of precipitation.

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cloud chamber

apparatus, now obsolete, for tracking ionized particles. It consists of a vessel fitted with a piston and filled with air or other gas, saturated with water vapour. When the volume of the vessel is suddenly expanded by moving the piston outwards, the vapour cools and a cloud of tiny droplets forms on any nuclei, dust, or ions present. As fast-moving ionizing particles collide with the air or gas molecules, they show as visible tracks.

Much information about interactions between such particles and radiations has been obtained from photographs of these tracks. The system was improved upon by the the bubble chamber, which uses bubble formation in liquid hydrogen or helium, and by the spark chamber (see particle detector). The cloud chamber was devised in 1897 by Charles Thomson Rees Wilson (1869-1959) at Cambridge University.

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clove

dried, unopened flower bud of the clove tree. A member of the myrtle family, the tree is a native of the Maluku Islands, Indonesia. Cloves are used for flavouring in cookery and confectionery. Oil of cloves, which has tonic qualities and relieves wind, is used in medicine. The aroma of cloves is also shared by the leaves, bark, and fruit of the tree. (*Eugenia caryophyllus*, family Myrtaceae.)

Cloves

Go to site

Informative resource relating to cloves. It contains a detailed description of the tree, its constituents, and its habitat. There are also extensive notes on the possible medicinal uses of cloves, which include relieving nausea, acting as an antiseptic, and treating bronchial troubles.

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clover

any of an Old World group of low-growing leguminous plants (see legume), usually with leaves consisting of three leaflets and small flowers in dense heads. Sweet clover refers to various species belonging to the related genus *Melilotus*. (True clover genus *Trifolium*, family Leguminosae.)

Red Clover

Go to site

Informative resource relating to red clover. It contains a detailed description of the plant and its habitat. There are also extensive notes on the possible medicinal uses of red clover, which include acting as an antispasmodic and treating whooping cough.

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club moss

or lycopod

any of a group of mosslike plants that do not produce seeds but reproduce by spores. They are related to the ferns and horsetails. (Order Lycopodiales, family Pteridophyta.)

These plants have a wide distribution, but were far more numerous in Palaeozoic times, especially the Carboniferous period (363-290 million years ago), when members of the group were large trees. The species that exist now are all small in size.

Moss, Common Club

Go to site

Informative resource relating to common club moss. It contains a detailed description of the plant and its habitat. There are also extensive notes on the possible medicinal uses of common club moss, which include acting as a diuretic and treating diarrhoea, eczema, and rheumatism.

Club of Rome

informal international organization that aims to promote greater understanding of the interdependence of global economic, political, natural, and social systems. Members include industrialists, economists, and research scientists. Membership is limited to 100 people. It was established in 1968.

The organization, set up after a meeting at the Accademia dei Lincei, Rome, seeks to initiate new policies and take action to overcome some of the global problems facing humanity which traditional national organizations and short-term policies are unable to tackle effectively.

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clusec

unit for measuring the power of a vacuum pump.

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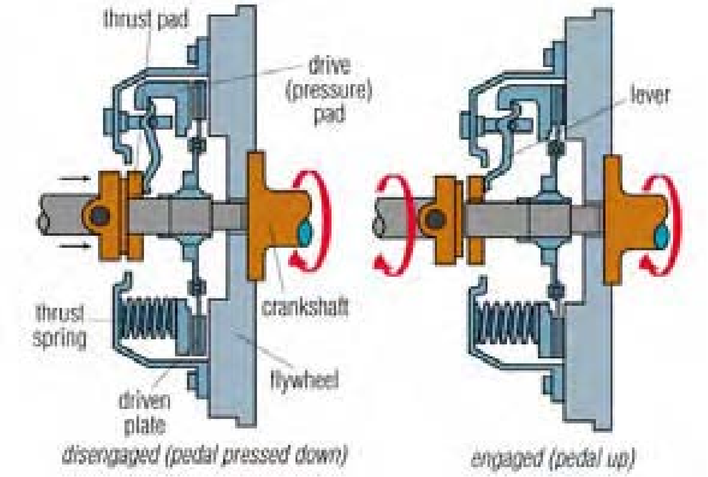
clutch

any device for disconnecting rotating shafts, used especially in a car's transmission system. In a car with a manual gearbox, the driver depresses the clutch when changing gear, thus disconnecting the engine from the gearbox.

The clutch consists of two main plates, a pressure plate and a driven plate, which is mounted on a shaft leading to the gearbox. When the clutch is engaged, the pressure plate presses the driven plate against the engine flywheel, and drive goes to the gearbox. Depressing the clutch springs the pressure plate away, freeing the driven plate. Cars with **automatic transmission** have no clutch. Drive is transmitted from the flywheel to the automatic gearbox by a liquid coupling or torque converter.

clutch



(Image © Research Machines plc)

The clutch consists of two main plates: a drive plate connected to the engine crankshaft and a driven plate connected to the wheels. When the clutch is disengaged, the drive plate does not press against the driven plate. When the clutch is engaged, the two plates are pressed into contact and the rotation of the crankshaft is transmitted to the wheels.

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cm

symbol for **centimetre**.

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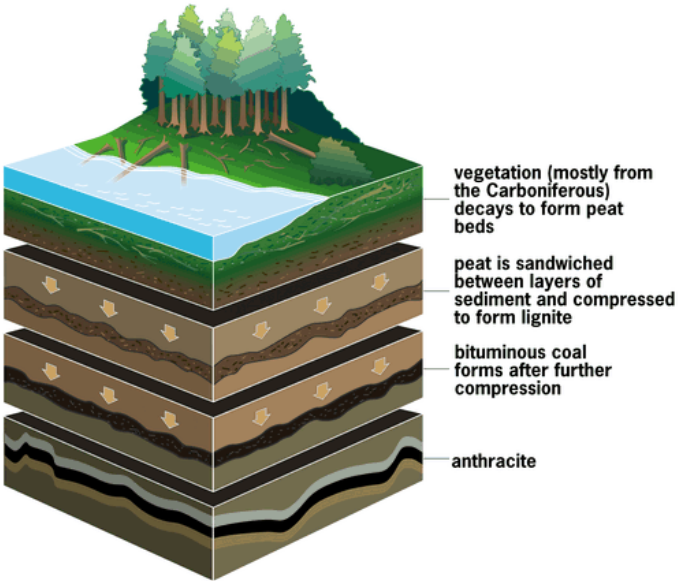
coagulation

in biology, another term for blood clotting, the process by which bleeding is stopped in the body.

coal

black or blackish mineral substance formed from the compaction of ancient plant matter in tropical swamp conditions. It is used as a fuel and in the chemical industry. Coal is classified according to the proportion of carbon it contains. The main types are anthracite (shiny, with about 90% carbon), **bituminous coal** (shiny and dull patches, about 75% carbon), and **lignite** (woody, grading into peat, about 50% carbon). Coal can be burned to produce heat energy, for example in power stations to produce electricity. Coal burning is one of the main causes of acid rain, which damages buildings and can be detrimental to aquatic and plant life.

coal


vegetation (mostly from the Carboniferous) decays to form peat beds
peat is sandwiched between layers of sediment and compressed to form lignite
bituminous coal forms after further compression
anthracite

(Image © Research Machines plc)

The formation of coal. Coal forms where vegetable matter accumulates but is prevented from complete decay and forms peat beds. Over time it becomes buried and compressed, forming lignite. Increased pressure and temperature produces bituminous coal with a higher carbon content. At great depths, high temperatures reduce methane and anthracite is formed with a very high carbon concentration.

coal gas

gas produced when coal is destructively distilled or heated out of contact with the air. Its main constituents are methane, hydrogen, and carbon monoxide. Coal gas has been superseded by natural gas for domestic purposes.

coal mining

extraction of coal from the Earth's crust. Coal mines may be opencast, adit, or deepcast. The least expensive is opencast but this may result in scars on the landscape.

coal tar

black oily material resulting from the destructive distillation of bituminous coal.

The fractional distillation of coal tar yields light oil, middle oil, heavy oil, and anthracene oil; the residue is called pitch. On further distillation a large number of substances are obtained, about 200 of which have been isolated. They are used as dyes and in medicines.

coast

meeting place of land and sea. The coast is changed by the physical processes of coastal erosion and coastal deposition, which include the action of waves, rain, wind, and frost.

coastal cliff

steep slope rising from the sea to a considerable height, and consisting of either bare rock or an accumulation of deposited material such as clay. The nature of the cliff depends on a number of factors such as the nature of the rock (its strength, weaknesses in the rock and bedding planes), its exposure to waves, and whether any coastal protection measures have been used.

Limestone has a well-developed jointing and bedding structure and forms geometric cliff profiles with steep, angular cliff faces, and flat tops. Coastal erosion causes complete blocks to fall away resulting in angular overhangs such as those at Tresilian Bay, Llantwit Major, Wales. The rate of cliff retreat is much more rapid in chalk, and steep cliffs are created by erosion and landslides. Cliffs can also be found in areas of softer rock such as the clay cliffs of Norfolk and Holderness, England.

The dip of rock bedding planes also affects the cliff profile. If beds dip vertically, a sheer cliff face will be formed, as at the Old Red Sandstone cliffs in Dyfed, Wales. If they dip steeply seaward then steep, shelving cliffs will occur, as at the cliffs at Tenby, Wales.

coastal cliff

(Image © Research Machines plc)

The lonely cliffs of western County Cork, in the Republic of Ireland, offer an undisturbed habitat for a variety of rare flowers. Temperatures here are mild, and there is a high average rainfall.

coastal cliff

(Image © Garret Nagle)

Cliffs on Portland Island, Dorset, England. Jointed rocks, such as the limestone shown here, are vulnerable to erosion, especially along the joint. In this photograph, the dark shadow in the centre marks a **geo**, a steep inlet opened up by the force of the sea. On top of the limestone there are beach deposits. They were deposited about 125,000 years ago under different climatic conditions, when the sea level was higher.

coastal cliff

(Image © Research Machines plc)

Sandstone outcrops with an east-to-west alignment form the rugged cliffs, deep bays, and long inlets of County Cork on Ireland's southwest coast.

coastal cliff

(Image © Garret Nagle)

Cliffs in coastal areas are produced by erosion. Steep cliffs, such as these on the Cape Peninsula, in the Western Cape province of South Africa, occur when the sea removes all the material eroded by the waves. In other places, if erosion is rapid but transport is limited, material builds up, and a low-angle slope develops.

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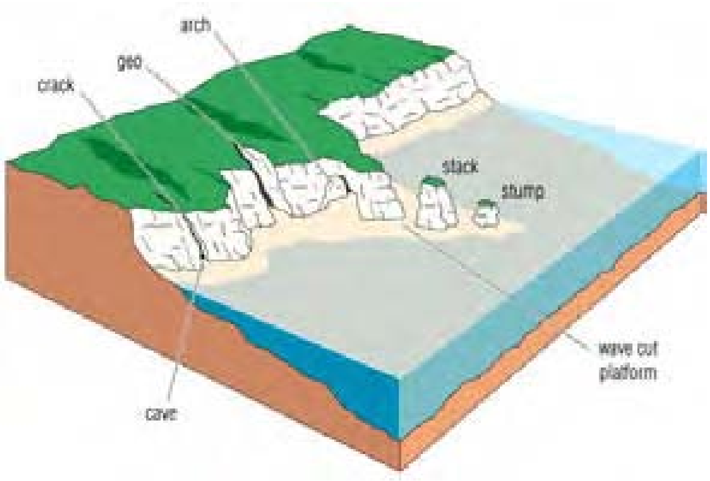
coastal erosion

the erosion of the land by the constant battering of the sea, primarily by the processes of hydraulic action, corrasion, attrition, and corrosion. Hydraulic action occurs when the force of the waves compresses air pockets in coastal rocks and cliffs. The air expands explosively, breaking the rocks apart. It is also the force of the water on the cliff. During severe gales this can be as high as 6 tonnes/cm^3 – the force of a bulldozer. Rocks and pebbles flung by waves against the cliff face wear it away by the process of corrasion, or abrasion as it is also known. Chalk and limestone coasts are often broken down by solution (also called corrosion). Attrition is the process by which the eroded rock particles themselves are worn down, becoming smaller and more rounded.

Frost shattering (or freeze-thaw), caused by the expansion of frozen water in cracks, and biological weathering, caused by the burrowing of rock-boring molluscs and plants, also lead to the breakdown of rock.

Where resistant rocks form headlands, the sea erodes the coast in successive stages. First it exploits weaknesses such as faults and cracks to form caves. Then it gradually wears away the interior of the caves and enlarges them. In some cases the roofs may be broken through to form blowholes. In other cases the caves at either side of a headland may unite to form a natural arch. When the roof of the arch collapses, a stack is formed. This may be worn down further to produce a stump. There are good examples of stacks at The Needles, Isle of Wight, England.

coastal erosion



(Image © Research Machines plc)

Typical features of coastal erosion: from the initial cracks in less resistant rock through to arches, stacks, and stumps that can occur as erosion progresses.

coastal erosion

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Coastlines are never truly static, although considerable human endeavour often goes into trying to make them so, with groynes and breakwaters and other forms of inshore barrier. This sea wall fortified with boulders to dissipate the force of the incoming tide is at Buzzards Bay, near Falmouth, Massachusetts, an inlet of Nantucket Sound.

coastal erosion

(Image © Garret Nagle)

Chesil Beach in Dorset, England, is one of many shingle beaches found in southern England. The sediment originally comes from 'periglacial' deposits (material moved in the last cold glacial phase). Wave action stimulates the geological process of attrition, in which the rugged, sharp stones are transformed into smaller rounded pebbles.

Coasts in Crisis

Go to site

Full text of a US Geological Survey publication. This detailed site uses intelligent text and photographs to show a coastline under siege. It describes the various types of coastline, methods of shoring them up, and the human and meteorological forces attacking the coast. This is an excellent resource for anyone studying coastal erosion, deposition, and protection.

Virtual Fieldwork

Go to site

Field studies are the best way to learn about geographical concepts; take the next best thing – an Internet field trip – by selecting from this page. The choices include coastal erosion in Kent, UK, and coastal sand dunes and management in north Wales, UK. Users are able to study digital photographs of the area, read the accompanying notes, then take a short test to find out how much they have learned.

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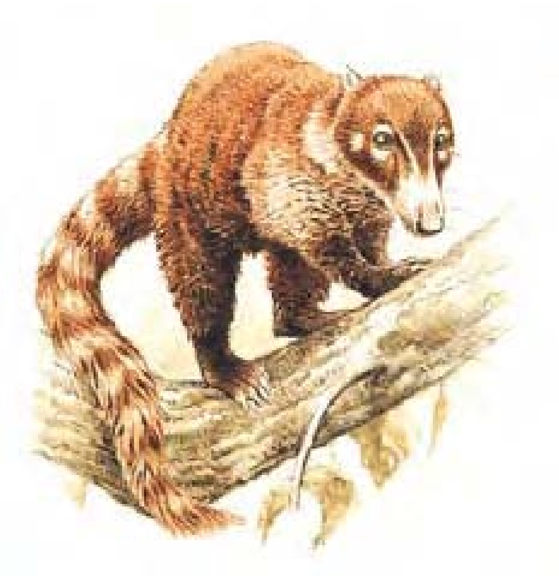
coati

or coatimundi

any of several species of carnivores of the genus *Nasua*, in the same family, Procyonidae, as the raccoons. A coati is a good climber and has long claws, a long tail, a good sense of smell, and a long, flexible piglike snout used for digging. Coatis live in packs in the forests of South and Central America.

The common coati *Nasua nasua* of South America is about 60 cm/2 ft long, with a tail about the same length.

coati



(Image © Research Machines plc)

The coati *Nasua nasua* is about 60 cm/24 in long, and has a tail of about the same length. It feeds on insects, fruit, and small vertebrates. Coatis live in groups of 30 or more, consisting of females and young; males live apart from the pack, and may only join a group for a short time during the mating season.

coati

(Image © Corel)

A coati feeds on the forest floor. Coatis are carnivorous mammals found in the forests of South and Central America where they forage for insects, fruit, and small mammals. Related to the racoon, coatis have panda-like eye markings, ringed tails, and a white-tipped black snout; the colour of their fur varies from deep brown to yellow.

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coaxial cable

electric cable that consists of a solid or stranded central conductor insulated from and surrounded by a solid or braided conducting tube or sheath. It can transmit the high-frequency signals used in television, telephone, and other telecommunications transmissions.

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cobalt

chemical symbol Co

(German Kobalt 'evil spirit')

hard, lustrous, grey, metallic element, atomic number 27, relative atomic mass 58.933. It is found in various ores and occasionally as a free metal, sometimes in metallic meteorite fragments. It is used in the preparation of magnetic, wear-resistant, and high-strength alloys; its compounds are used in inks, paints, and varnishes.

The isotope Co-60 is radioactive (half-life 5.3 years) and is produced in large amounts for use as a source of gamma rays in industrial radiography, research, and cancer therapy. Cobalt was named in 1730 by Swedish chemist Georg Brandt (1694-1768); the name derives from the fact that miners considered its ore malevolent because it interfered with copper production.

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cobalt-60

radioactive (half-life 5.3 years) isotope produced by neutron radiation of cobalt in heavy-water reactors, used in large amounts for gamma rays in cancer therapy, industrial radiography, and research, substituting for the much more costly radium.

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cobalt chloride

$CoCl_2$

compound that exists in two forms: the hydrated salt ($CoCl_2.6H_2O$), which is pink, and the anhydrous salt, which is blue. The anhydrous form is used as an indicator because it turns pink if water is present. When the hydrated salt is gently heated the blue anhydrous salt is reformed.

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cobalt ore

cobalt is extracted from a number of minerals, the main ones being **smaltite**, $(CoNi)As_3$; **linnaeite**, Co_3S_4; **cobaltite**, CoAsS; and **glaucodot**, (CoFe)AsS.

All commercial cobalt is obtained as a by-product of other metals, usually associated with other ores, such as copper. The Democratic Republic of Congo (formerly Zaire) is the largest producer of cobalt, and it is obtained there as a by-product of the copper industry. Other producers include Canada and Morocco. Cobalt is also found in the manganese nodules that occur on the ocean floor, and was successfully refined in 1988 from the Pacific Ocean nodules, although this process has yet to prove economic.

COBOL

acronym for common business-oriented language

high-level computer-programming language, designed in the late 1950s for commercial data-processing problems; it has become the major language in this field. COBOL features powerful facilities for file handling and business arithmetic. Program instructions written in this language make extensive use of words and look very much like English sentences. This makes COBOL one of the easiest languages to learn and understand.

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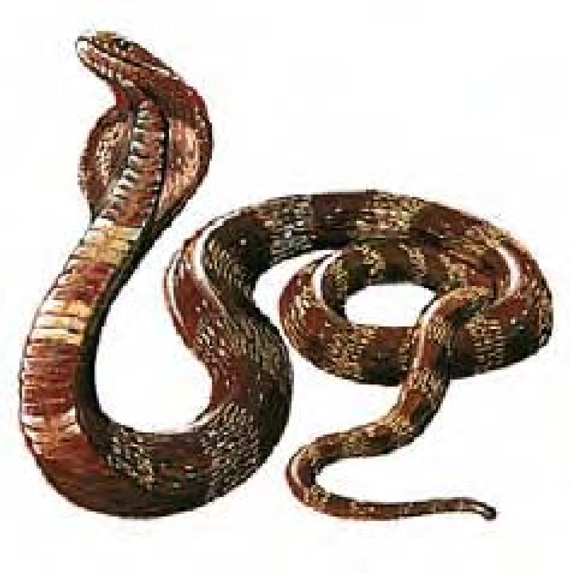
cobra

any of several poisonous snakes, especially the genus *Naja*, of the family Elapidae, found in Africa and southern Asia, species of which can grow from 1 m/3 ft to over 4.3 m/14 ft. The neck stretches into a hood when the snake is alarmed. Cobra venom contains nerve toxins powerful enough to kill humans.

The Indian cobra *Naja naja* is about 1.5 m/5 ft long, and found over most of southern Asia. Some individuals have 'spectacle' markings on the hood. The hamadryad *N. hannah* of southern and southeast Asia can be 4.3 m/14 ft or more, and eats snakes. The ringhals *Hemachatus hemachatus* of South Africa and the black-necked cobra *N. nigricollis*, of the African savannah are both about 1 m/3 ft long. Both are able to spray venom towards the eyes of an attacker. A species of cobra, *Naja manadalayensis*, was identified in Myanmar in 2000. It is a 'spitting' cobra (able to project its venom). This makes a total of four African species and six Asian.

cobra



(Image © Research Machines plc)

The Indian cobra feeds on rodents, lizards, and frogs. As well as biting, the Indian cobra can defend itself by spitting venom through its fangs. The venom, reaching a distance of 2 m/6.5 ft, causes severe pain and damage if it enters the eyes of prey.

King Cobra

Go to site

Cleverly presented National Geographic guide to the king cobra. The behaviour of this ferocious predator is explained by clicking on various parts of a cobra's body entwined through the site. There are a number of stunning photographs.

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coca

South American shrub belonging to the coca family, whose dried leaves are the source of the drug cocaine. It was used as a holy drug by the Andean Indians. (*Erythroxylon coca*, family Erythroxylaceae.)

Coca, Bolivian

Go to site

Informative resource relating to Bolivian coca. It contains a detailed description of the plant, its constituents, and its habitat. There are also extensive notes on the possible medicinal uses of Bolivian coca, which include acting as a stimulant and local anaesthetic. However, as the site points out, the dangers of the drug far outweigh its benefits.

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cocaine

$C_{17}H_{21}NO_4$

alkaloid extracted from the leaves of the coca tree. It has limited medical application, mainly as a local anaesthetic agent that is readily absorbed by mucous membranes (lining tissues) of the nose and throat. It is both toxic and addictive. Its use as a stimulant is illegal. crack is a derivative of cocaine.

Cocaine was first extracted from the coca plant in Germany in the 19th century. Most of the world's cocaine is produced from coca grown in Peru, Bolivia, Colombia, and Ecuador. Estimated annual production totals 215,000 tonnes, with most of the processing done in Colombia. Side effects of cocaine use include spasm of coronary artery causing chest pain. Long-term use may cause mental and physical deterioration. In August 2001, a UK-based company was given permission by the US Food and Drug Administration (FDA) to begin trials of a cocaine vaccine. The vaccine produces antibodies in the bloodstream that counter the cocaine before it affects the brain.

Cocaine Anonymous World Services

Go to site

Details of the work of the global organization for recovering cocaine addicts. There is information about their work and practical advice on kicking the habit. There is also a self-test for those who think they might be addicted.

---

coccolithophorid

microscopic, planktonic marine alga, which secretes a calcite shell. The shells (coccoliths) of coccolithophores are a major component of deep sea ooze. Coccolithophores were particularly abundant during the late Cretaceous period and their remains form the northern European chalk deposits, such as the white cliffs of Dover.

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coccus

plural cocci

member of a group of globular bacteria, some of which are harmful to humans. The cocci contain the subgroups **streptococci**, where the bacteria associate in straight chains, and **staphylococci**, where the bacteria associate in branched chains.

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cochineal

red dye obtained from the cactus-eating Mexican scale insect*Dactylopius coccus*, used in colouring food and fabrics. There are approximately 70,000 bugs per pound of cochineal.

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cochlea

part of the inner ear. It is equipped with approximately 10,000 hair cells, which move in response to sound waves and thus stimulate nerve cells to send messages to the brain. In this way they turn vibrations of the air into electrical signals.

---

cockatiel

Australian parrot *Nymphicus hollandicus*, about 20 cm/8 in long, with greyish or yellow plumage, yellow cheeks, a long tail, and a crest like a cockatoo. Cockatiels are popular as pets and aviary birds.

Cockatiel Society

Go to site

Resource for owners of cockatiels, including a wide variety of articles on caring for the birds, a 'Frequently Asked Questions' page, extensive information on breeding cockatiels, and a 'Just for fun' section.

---

cockatoo

any of several crested parrots, especially of the genus *Cacatua*, family Psittacidae, of the order Psittaciformes. They usually have light-coloured plumage with tinges of red, yellow, or orange on the face, and an erectile crest on the head. They are native to Australia, New Guinea, and nearby islands.

There are about 17 species, one of the most familiar being the sulphur-crested cockatoo *C. galerita* of Australia and New Guinea, about 50 cm/20 in long, white with a yellow crest and dark beak.

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cockchafer

or maybug

European beetle *Melolontha melolontha*, of the scarab family, up to 3 cm/1.2 in long, with clumsy, buzzing flight, seen on early summer evenings. Cockchafers damage trees by feeding on the foliage and flowers.

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cockle

any of over 200 species of bivalve mollusc with ribbed, heart-shaped shells. Some are edible and are sold in Western European markets.

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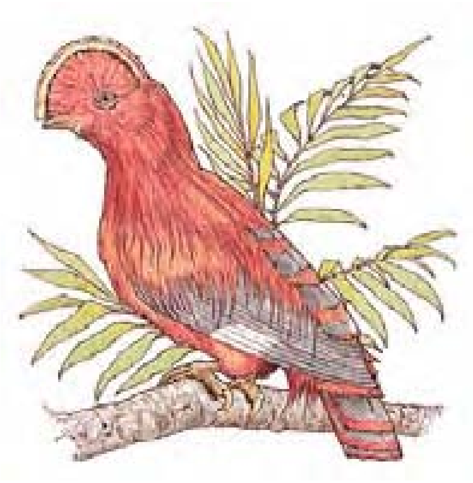
cock-of-the-rock

South American bird of the genus *Rupicola*. It belongs to the family Cotingidae, which also includes the cotingas and umbrella birds. There are two species: *R. peruviana*, the Andean cock-of-the-rock, and *R. rupicola*, the Guyanan cock-of-the-rock. The male has brilliant orange plumage including the head crest, the female is a duller brown. Males display at a communal breeding area.

cock-of-the-rock



(Image © Research Machines plc)

The Guyanan cock-of-the-rock lives in forested ravines in northern South America. The brightly coloured males clear an area of ground and use it as a communal display ground, spreading wings, tail, and crest to attract mates.

---

cockroach

any of numerous insects of the family Blattidae, distantly related to mantises and grasshoppers. There are 3,500 species, mainly in the tropics. They have long antennae and biting mouthparts. They can fly, but rarely do so.

The common cockroach, or black-beetle *Blatta orientalis*, is found in human dwellings, is nocturnal, omnivorous, and contaminates food. The German cockroach *Blattella germanica* and American cockroach *Periplaneta americana* are pests in kitchens, bakeries, and warehouses. In Britain only two innocuous species are native, but several have been introduced with imported food and have become severe pests. They are very difficult to eradicate. Cockroaches have a very high resistance to radiation, making them the only creatures likely to survive a nuclear holocaust.

cockroach

In the tropical species *Perisphaerus*, the female carries her blind young under her body, and nourishes them by secreting a fluid into wells at the base of four of her legs. The young suck up this fluid using their drinking-straw-shaped mouthparts.

Cockroaches

Go to site

General information about the cockroach from its early evolution to the present day. The site includes its life history, its relationship with humans, and even how to keep a cockroach as a pet.

Roach Anatomy

Go to site

Elaborate and graphical presentation of the anatomy of a cockroach in two parts. The site offers detailed descriptions of the mouth, the salivary glands, the heart, the lungs, the midgut, the malphigian tubules, the brain, etc. It also involves audio and video clips and a 'clickable' cockroach.

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cocktail effect

effect of two toxic, or potentially toxic, chemicals when taken together rather than separately. Such effects are known to occur with some mixtures of drugs, with the active ingredient of one making the body more sensitive to the other.

This sometimes occurs because both drugs require the same enzyme to break them down. Chemicals such as pesticides and food additives are only ever tested singly, not in combination with other chemicals that may be consumed at the same time, so no allowance is made for cocktail effects.

'Gulf War syndrome' may have resulted from the cocktail effect of an anti-nerve gas drug and two different insecticides.

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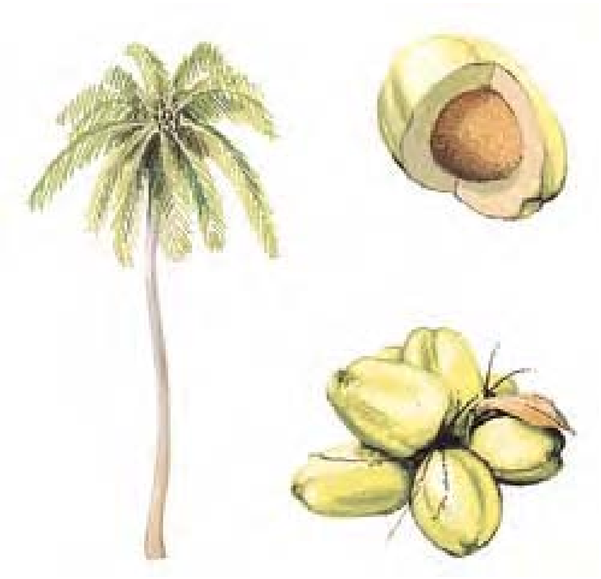
coconut

fruit of the coconut palm, which grows throughout the lowland tropics. The fruit has a large outer husk of fibres, which is removed and used to make coconut matting and ropes. Inside this is the nut which is exported to temperate countries. Its hard shell contains white flesh and clear coconut milk, both of which are tasty and nourishing. (*Cocos nucifera*, family Arecaceae.)

The white flesh of the coconut can be eaten fresh, or it can be dried before extracting the oil which makes up nearly two-thirds of it. The oil is used to make soap and margarine and in cooking; the remains are used in cattle feed.

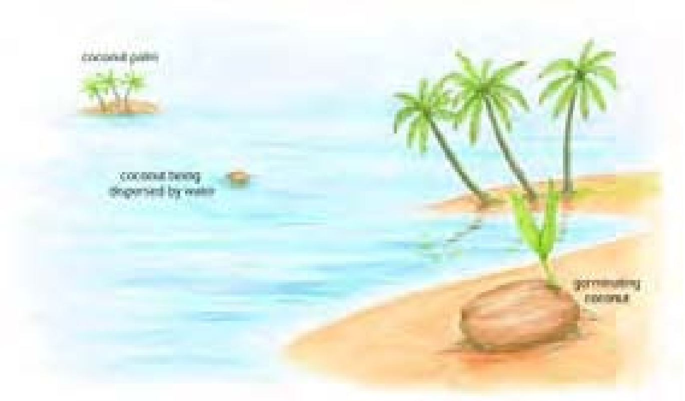
coconut



(Image © Research Machines plc)

The coconut palm can grow up to 24 m/80 ft in height. Ripe nuts are harvested by climbing the tree - sometimes monkeys are trained for the job - or allowing the nuts to fall naturally. The outer fibrous husk of the fruit is removed to reveal the nut.

coconut



(Image © Research Machines plc)

A coconut begins to germinate after washing up on a beach. The outer husk of the coconut is very buoyant and seeds can be dispersed hundreds of kilometres by water.

coconut palm

(Image © Corel)

Coconuts ripening on the palm. A versatile fruit with many uses, the coconut's outer husk of fibres is used to make matting and rope; the white flesh of the fruit can be eaten raw, or dried to produce copra from which coconut oil is extracted, which in turn is used in the manufacture of soaps and margarine.

Coconut

Go to site

Interesting information about coconuts from Britain's prestigious Kew Gardens. This account of 'God's greatest gift to man' looks at the many products derived from coconuts.

cocoon

pupa-case of many insects, especially of moths and silkworms. This outer web or ball is spun from the mouth by caterpillars before they pass into the chrysalis state.

cod

any fish of the family Gadidae, especially the Atlantic cod *Gadus morhua*, found in the North Atlantic and Baltic. It is brown to grey with spots, with a white underbelly, and can grow to 1.5 m/5 ft in length.

The main cod fisheries are in the North Sea, and off the coasts of Iceland and Newfoundland, Canada. Much of the catch is salted and dried. Formerly one of the cheapest fish, decline in numbers from overfishing has made it one of the most expensive.

codeine

opium derivative that provides analgesia in mild to moderate pain. It also suppresses the cough centre of the brain. It is an alkaloid, derived from morphine but less toxic and addictive.

codominance

in genetics, the failure of a pair of alleles, controlling a particular characteristic, to show the classic recessive-dominant relationship. Instead, aspects of both alleles may show in the phenotype. For example, the human blood group AB shows the phenotype effect of both A and B codominant genes.

The snapdragon shows codominance in respect to colour. Two alleles, one for red petals and the other for white, will produce a pink colour if the alleles occur together as a heterozygous form.

codon

or coding triplet

in genetics, a triplet of bases (see base pair) in a molecule of DNA or RNA that directs the placement of a particular amino acid during the process of protein (polypeptide) synthesis. As each of the three positions can be filled by any of the four bases, there are $4^3 = 64$ codons in the genetic code.

coefficient

number part in front of an algebraic term, signifying multiplication. For example, in the expression $4x^2 + 2xy - x$, the coefficient of x^2 is 4 (because $4x^2$ means $4 \times x^2$), that of xy is 2, and that of x is -1 (because $-1 \times x = -x$).

In general algebraic expressions, coefficients are represented by letters that may stand for numbers; for example, in the equation $ax^2 + bx + c = 0$, a, b, and c are coefficients, which can take any number.

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coefficient of relationship

probability that any two individuals share a given gene by virtue of being descended from a common ancestor. In sexual reproduction of diploid species, an individual shares half its genes with each parent, with its offspring, and (on average) with each sibling; but only a quarter (on average) with its grandchildren or its siblings' offspring; an eighth with its great-grandchildren, and so on.

In certain species of insects (for example honey bees), females have only one set of chromosomes (inherited from the mother), so that sisters are identical in genetic make-up; this produces a different set of coefficients. These coefficients are important in calculations of inclusive fitness.

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coelacanth

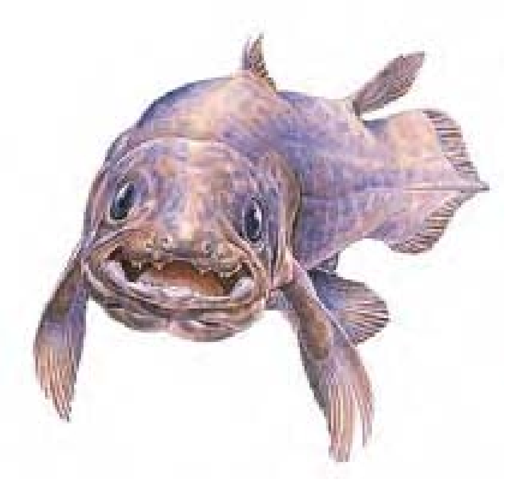
large dark brown to blue-grey fish that can grow to about 2 m/6 ft in length, and weigh up to 73 kg/160 lb. It has bony, overlapping scales, and muscular lobe (limblike) fins sometimes used like oars when swimming and for balance while resting on the sea floor. They feed on other fish, and give birth to live young rather than shedding eggs as most fish do. Coelacanth fossils exist dating back over 400 million years and coelacanth were believed to be extinct until one was caught in 1938 off the coast of South Africa. For this reason they are sometimes referred to as 'living fossils'. Populations have since been discovered off the Comoros Islands in the Indian Ocean, the island of Sulawesi in Indonesia, and Sodwana Bay on the northeast coast of South Africa.

Coelacanths were listed as endangered in 1991, and in May 2000 were placed on the Convention on International Trade in Endangered Species (CITES) Appendix I, which bans all trade in the species.

classification

Coelacanths belong to the animal phylum Chordata, superclass Pisces (fish), class Sarcopterygii, subclass Crossopterygii, order Actinistia or coelacanthiformes, represented by a single family Lateimeriidae. There is only one known surviving species of coelacanth, *Latimeria chalumnae*.

coelacanth



(Image © Research Machines plc)

Until 1938 the coelacanth was believed to have been extinct for over 65 million years. Individual fish may live to be 60 years old.

Dinofish.com

Go to site

Contains much historical information about the discovery, study, and conservation of the coelacanth, a 400-million-year-old species of fish, as well as recent news and listings of scientific articles. Also on the site is a virtual swimming coelacanth, some online videos, and a shop for coelacananth enthusiasts!

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coelenterate

any freshwater or marine organism of the phylum Coelenterata, having a body wall composed of two layers of cells. They also possess stinging cells. Examples are jellyfish, hydra, and coral.

coeliac disease

disease in which the small intestine fails to digest and absorb food. The disease can appear at any age but has a peak incidence in the 30-50 age group; it is more common in women. It is caused by an intolerance to gluten (a constituent of wheat, rye and barley) and characterized by diarrhoea and malnutrition. Treatment is by a gluten-free diet.

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coelom

in all but the simplest animals, the fluid-filled cavity that separates the body wall from the gut and associated organs, and allows the gut muscles to contract independently of the rest of the body.

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coevolution

evolution of those structures and behaviours within a species that can best be understood in relation to another species. For example, some insects and flowering plants have evolved together: insects have produced mouthparts suitable for collecting pollen or drinking nectar, and plants have developed chemicals and flowers that will attract insects to them. Parasites often evolve and speciate with their hosts.

Coevolution occurs because both groups of organisms, over millions of years, benefit from a continuing association, and will evolve structures and behaviours that maintain this association.

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coffee

drink made from the roasted and ground beanlike seeds found inside the red berries of any of several species of shrubs, originally native to Ethiopia and now cultivated throughout the tropics. It contains a stimulant, caffeine. (Genus *Coffea*, family Rubiaceae.)

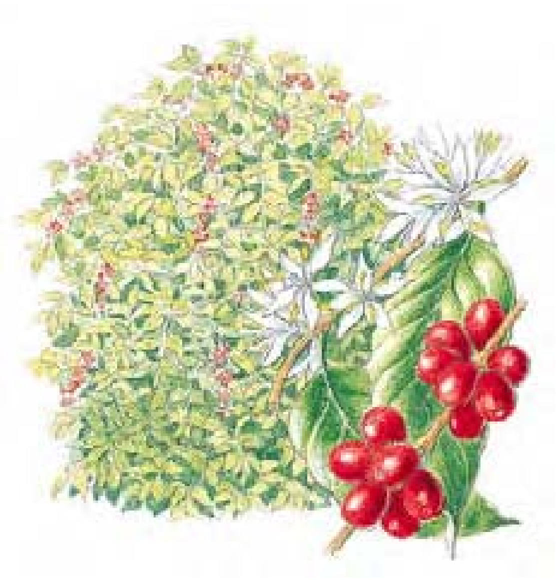
cultivation

The shrub, naturally about 5 m/17 ft high, is pruned to about 2 m/7 ft; it is fully fruit-bearing in 5 or 6 years, and lasts for 30 years. Coffee grows best on frost-free hillsides with moderate rainfall. The world's largest producers are Brazil, Colombia, and Côte d'Ivoire; others include Indonesia (Java), Ethiopia, India, Hawaii, and Jamaica. The Association of Coffee Producing Countries (ACPC) was founded in 1993 to represent its 28 members, of whom the 14 ratified members produce over 60% of world coffee supply. Since the 1990s the world coffee market has suffered from over-supply, and in September 2001 the price of coffee sank to its lowest level in three decades as the ACPC scrapped a failed buffer-stock scheme. Tens of thousands of labourers were laid off in Latin America as coffee prices fell below production costs.

history

Coffee drinking began in Arab regions in the 14th century but did not become common in Europe until three hundred years later, when the first coffee houses were opened in Vienna, and soon after in Paris and London. In the American colonies, coffee became the substitute for tea when tea was taxed by the British.

coffee



(Image © Research Machines plc)

The coffee plant *Coffea arabica* is a small tree, but is pruned into a large bush to make harvesting easier. It produces sweet-smelling white flowers; these are followed by green berries which turn red when ripe. Each berry contains two seeds, which are processed to make coffee for drinking.

coffee beans

(Image © Corel)

Coffee beans ripening in the Blue Mountains, Jamaica. Coffee was first imported to Jamaica in 1728 and rapidly gained importance as a cash crop. The unique soil of the Blue Mountains region produces a quality of coffee which has gained a reputation among connoisseurs as one of the best in the world.

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cognition

in psychology, a general term covering the functions involved in synthesizing information - for example, perception (seeing, hearing, and so on), attention, memory, and reasoning.

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cognitive therapy

or cognitive behaviour therapy

treatment for emotional disorders such as depression and anxiety states. It encourages the patient to challenge the distorted and unhelpful thinking that is characteristic of depression, for example. The treatment may include behaviour therapy.

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cohesion

in physics, a phenomenon in which interaction between two surfaces of the same material in contact makes them cling together (with two different materials the similar phenomenon is called adhesion). According to kinetic theory, cohesion is caused by attraction between particles at the atomic or molecular level. Surface tension, which causes liquids to form spherical droplets, is caused by cohesion.

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coil

in medicine, another name for an intrauterine device.

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coke

clean, light fuel produced, along with town gas, when coal is strongly heated in an airtight oven. Coke contains 90% carbon and makes a useful domestic and industrial fuel (used, for example, in the iron and steel industries).

The coke-making process was patented in England in 1622, but it was only in 1709 that Abraham Darby devised a commercial method of production.

Coke, Thomas William (1754-1842)

1st Earl of Leicester

English agriculturalist and politician who was renowned for his innovations in both arable farming and animal husbandry. A long-serving member of Parliament for Norfolk (1776-1806 and 1807-32), he introduced new strains of crops and made improvements to the breeding of cattle and sheep on his extensive farms. His innovations included regular manuring of the soil, the cultivation of fodder crops in association with corn, and the drilling of wheat and turnips.

cola

or kola

any of several tropical trees, especially *Cola acuminata*. In West Africa the nuts are chewed for their high caffeine content, and in the West they are used to flavour soft drinks. (Genus *Cola*, family Sterculiaceae.)

cold, common

minor disease of the upper respiratory tract, caused by a variety of viruses. Symptoms are headache, chill, nasal discharge, sore throat, and occasionally cough. Research indicates that the virulence of a cold depends on psychological factors and either a reduction or an increase of social or work activity, as a result of stress, in the previous six months.

There is little immediate hope of an effective cure since the viruses transform themselves so rapidly.

Childhood Infections - Common Cold

Go to site

Useful information about the common cold. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on possible ways to prevent the spreading of the infection and details of what to do should the symptoms occur.

cold-blooded

of animals, dependent on the surrounding temperature; see poikilothermy.

cold dark matter

in cosmology, unseen material consisting of slow-moving particles believed by some cosmologists to make up the bulk of the matter in the universe. See dark matter.

cold fusion

in nuclear physics, the supposed fusion of atomic nuclei at room temperature. If cold fusion were possible it would provide a limitless, cheap, and pollution-free source of energy, and it has therefore been the subject of research around the world. Few physicists believe it is possible.

In 1989 Martin Fleischmann and Stanley Pons of the University of Utah, USA, claimed that they had achieved cold fusion in the laboratory, but their results could not be substantiated. The University of Utah announced in 1998 that they would allow the cold fusion patent to elapse, given that the work of Pons and Fleischmann has never been reproduced.

cold-working

method of shaping metal at or near atmospheric temperature.

coleoptile

the protective sheath that surrounds the young shoot tip of a grass during its passage through the soil to the surface. Although of relatively simple structure, most coleoptiles are very sensitive to light, ensuring that seedlings grow upwards.

colic

spasmodic attack of pain in the abdomen, usually coming in waves. Colicky pains are caused by the painful muscular contraction and subsequent distension of a hollow organ; for example, the bowels, gall bladder (biliary colic), or ureter (renal colic).

Intestinal colic is due to partial or complete blockage of the intestine, or constipation; **infantile colic** is usually due to wind in the intestine.

colitis

inflammation of the colon (large intestine) with diarrhoea (often bloody). It is usually due to infection or some types of bacterial dysentery.

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collagen

protein that is the main constituent of connective tissue. Collagen is present in skin, cartilage, tendons, and ligaments. Bones are made up of collagen, with the mineral calcium phosphate providing increased rigidity.

Collagen is made by fibroblast cells that are found in connective tissue. The collagen molecule consists of three protein chains, each about 1,000 amino acids in length, that are entwined in a triple helix. There are 15 known types of collagen that can be divided into fibrillar and nonfibrillar.
Fibrillar collagens are found in cartilage, tendons, skin, and bones and the fibrillar structure gives these great strength.
Nonfibrillar collagens are found separating the basement membranes, the epithelial layers that line tube and in the cornea. They form networks and sheets.

collagen therapy

Collagen is used cosmetically to enhance lips and smooth out wrinkles. The collagen, which is extracted mainly from cow hides, is injected into the skin. For wrinkle treatment it is injected into the dermis over six sessions, which have to be repeated after several months as the implants degrade.

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collective farm

Russian kolkhoz

farm in which a group of farmers pool their land, domestic animals, and agricultural implements, retaining as private property enough only for the members' own requirements. The profits of the farm are divided among its members. In cooperative farming, farmers retain private ownership of the land.

Collective farming was first developed in the USSR in 1917, where it became general after 1930. Stalin's collectivization drive 1929–33 wrecked a flourishing agricultural system and alienated the Soviet peasants from the land: 15 million people were left homeless, 1 million of whom were sent to labour camps and some 12 million deported to Siberia. In subsequent years, millions of those peasants forced into collectives died. Collective farming is practised in other countries; it was adopted from 1953 in China, and Israel has a large number of collective farms.

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collective unconscious

in psychology, a shared pool of memories, ideas, modes of thought, and so on, which, according to the Swiss psychiatrist Carl Jung, comes from the life experience of one's ancestors, indeed from the entire human race. It coexists with the personal unconscious, which contains the material of individual experience, and may be regarded as an immense depository of ancient wisdom.

Primal experiences are represented in the collective unconscious by archetypes, symbolic pictures, or personifications that appear in dreams and are the common element in myths, fairy tales, and the literature of the world's religions. Examples include the serpent, the sphinx, the Great Mother, the anima (representing the nature of woman), and the mandala (representing balanced wholeness, human or divine).

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collenchyma

plant tissue composed of relatively elongated cells with thickened cell walls, in particular at the corners where adjacent cells meet. It is a supporting and strengthening tissue found in nonwoody plants, mainly in the stems and leaves.

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collie

any of several breeds of sheepdog originally bred in Britain. They include the border collie, the bearded collie, and the rough collie and its smooth-haired counterpart.

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collimator

optical device for producing a nondivergent beam of light, or any device for limiting the size and angle of spread of a beam of radiation or particles. The term is also used for a small telescope attached to a larger optical instrument to fix its line of sight.

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collinear

in mathematics, lying on the same straight line.

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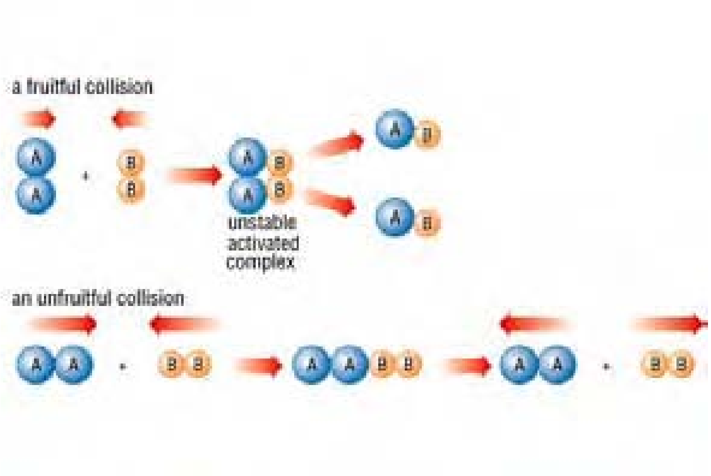
collision theory

theory that explains how chemical reactions take place and why rates of reaction alter. For a reaction to occur the reactant particles must collide. Only a certain fraction of the total collisions cause chemical change; these are called **successful collisions**. The successful collisions have sufficient energy (activation energy) at the moment of impact to break the existing bonds and form new bonds, resulting in the products of the reaction. Increasing the concentration of the reactants and raising the temperature bring about more collisions and therefore more successful collisions, increasing the rate of reaction.

When a catalyst undergoes collision with the reactant molecules, less energy is required for the chemical change to take place, and hence more collisions have sufficient energy for reaction to occur. The reaction rate therefore increases.

collision theory



(Image © Research Machines plc)

Collision theory explains how chemical reactions occur and why rates of reaction differ. For a reaction to occur, particles must collide. If the collision causes a chemical change it is referred to as a fruitful collision.

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colloid

substance composed of extremely small particles of one material (the dispersed phase) evenly and stably distributed in another material (the continuous phase). The size of the dispersed particles (1-1,000 nanometres across) is less than that of particles in suspension but greater than that of molecules in true solution. Colloids involving gases include **aerosols** (dispersions of liquid or solid particles in a gas, as in fog or smoke) and **foams** (dispersions of gases in liquids).

Those involving liquids include **emulsions** (in which both the dispersed and the continuous phases are liquids) and **sols** (solid particles dispersed in a liquid). Sols in which both phases contribute to a molecular three-dimensional network have a jellylike form and are known as **gels**; gelatin, starch 'solution', and silica gel are common examples.

Steel is a solid colloid.

Milk is a natural emulsion of liquid fat in a watery liquid; synthetic emulsions such as some paints and cosmetic lotions have chemical emulsifying agents to stabilize the colloid and stop the two phases from separating out. Colloids were first studied thoroughly by the British chemist Thomas Graham, who defined them as substances that will not diffuse through a semipermeable membrane (as opposed to what he termed crystalloids, solutions of inorganic salts, which will diffuse through).

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colobus

or guereza

large tree-dwelling African monkey characterized by the almost complete suppression of the thumb. There are five species divided into two groups: the black-and-white colobus and the red colobus. They live in groups and feed on fruit, leaves, flowers, and twigs. A further species, Miss Waldron's red colobus, *Procolobus badius waldroni*, was officially declared extinct in autumn 2000.

Black-and-white colobus monkeys are slightly larger than red colobus, with a head and body length of 62.5 cm/24.5 in and a long tail (80 cm/31.5 in).

classification

Colobuses are in the genus *Colobus*, family Cercopithecidae, order Primates.

Colombo, Matteo Realdo (c. 1516-1559)

Italian anatomist who was the first European to describe pulmonary circulation, the process of blood circulating from the heart to the lungs and back, and oxygenation of the blood.

This showed that Galen's teachings were wrong, and was of help to William Harvey in his work on the heart and circulation. Colombo was a pupil of Andreas Vesalius and his successor as professor of surgery at the University of Padua in 1543. He later became the first professor of anatomy at the University of Padua in 1546. Colombo is also remembered for his 'discovery' of the clitoris.

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colon

in anatomy, the main part of the large intestine, between the caecum and rectum. Water and mineral salts are absorbed from undigested food in the colon, and the residue passes as faeces towards the rectum.

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colonization

in ecology, the spread of species into a new habitat, such as a freshly cleared field, a new motorway verge, or a recently flooded valley. The first species to move in are called **pioneers**, and may establish conditions that allow other animals and plants to move in (for example, by improving the condition of the soil or by providing shade). Over time a range of species arrives and the habitat matures; early colonizers will probably be replaced, so that the variety of animal and plant life present changes. This is known as succession.

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colonoscopy

medical procedure involving the insertion of a **colonoscope** (fibre-optic viewing instrument) into the rectum, to detect abnormalities within the colon. Patients undergoing colonoscopy are given an enema to empty the bowel, before being sedated. Colonoscopies detect cancerous tumours and precancerous polyps.

Colorado beetle

or potato beetle

North American black and yellow striped beetle that is a pest on potato crops. Although it was once a serious pest, it can now usually be controlled by using insecticides. It has also colonized many European countries.

classification

Colarado beetles *Leptinotarsa decemlineata* are in the family Chrysomelidae, order Coleoptera, class Insecta, phylum Arthropoda.

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colour

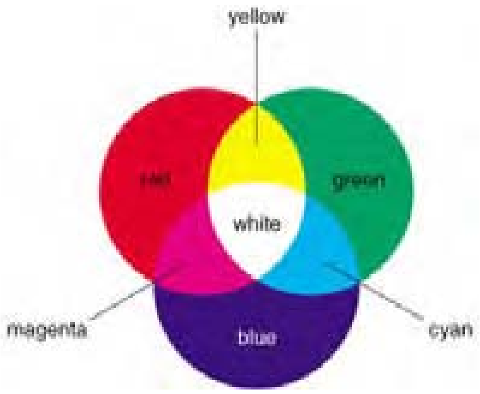
in physics, wavelength, or mixture of wavelengths, of light emitted or reflected from an object; in psychology, the subjective visual response to that combination of wavelengths. Visible white light consists of electromagnetic radiation of various wavelengths, and if a beam is refracted through a prism, it can be spread out into the visible spectrum (the part of the electromagnetic spectrum that can be detected by the human eye), in which the various colours correspond to different wavelengths. From long to short wavelengths (from about 700 to 400 nanometres) the colours are conventionally divided into red, orange, yellow, green, blue, indigo, and violet, though they merge smoothly into each other.

The colour of grass is green because grass absorbs some colours from the spectrum and those that it transmits or reflects are predominantly of wavelengths corresponding to green. A sheet of white paper reflects all the colours of the spectrum from its surface; black objects absorb all the colours of the spectrum.

Almost all colours can be visually matched by mixing proportions of red, green, and blue light. These are known as the **additive primary colours**. Different colour filters can also produce light of different colours. For example, a red filter transmits predominantly red light, the remaining colours of the spectrum being largely absorbed by the filter.

Mixing red, green, and blue light in the correct proportions produces white light. When these colours are mixed in different proportions, so-called secondary colours are formed; for example, blue + red = magenta, red + green = yellow, and green + blue = cyan. Yellow light is reflected from the surfaces of some flowers as the petals absorb blue light. Red and green light are reflected back, and these mix to give the sensation of yellow. However, yellow is also seen when monochromatic (single-wavelength) light of about 600 nanometres is reflected.

colour



(Image © Research Machines plc)

The mixing of the primary (red, blue, and green) coloured beams of light. All the colours mixed together produce white.

optics

To remember the additive and subtractive mixtures of colours:

Better **g**et **r**eady **w**hen **Y**our **m**other **c**omes **b**ack

Blue + **g**reen + **r**ed = **w**hite (additive) **y**ellow + **m**agenta + **c**yan = **b**lack (subtractive)

Colour Matters

Go to site

Examination of the interaction between colour and the disciplines of physiology, psychology, philosophy, architecture, and optics.

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colour blindness

hereditary defect of vision that reduces the ability to discriminate certain colours, usually red and green. The condition is sex-linked, affecting men more than women.

In the most common types of colour blindness there is confusion among the red-yellow-green range of colours; for example, many colour-blind observers are unable to distinguish red from yellow or yellow from green. Most cases of the condition are congenital and caused by a recessive gene variant located on the X chromosome. This implies that most women with the gene will only be carriers, while all men who inherit the variant will be affected by colour blindness. The gene defect disables one of the three colour receptors in the retina.

Lead poisoning and toxic conditions caused by excessive smoking can also lead to colour blindness. Between 2% and 6% of men and less than 1% of women are colour-blind.

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colour index

in astronomy, measure of the colour of a star made by comparing its brightness through different coloured filters. It is defined as the difference between the measurements of the magnitude of the star given by two standard photometric filters. Colour index is directly related to the surface temperature of a star and its spectral classification.

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colouring

food additive used to alter or improve the colour of processed foods. Colourings include artificial colours, such as tartrazine and amaranth, which are made from petrochemicals, and the 'natural' colours such as chlorophyll, caramel, and carotene. Some of the natural colours are actually synthetic copies of the naturally occurring substances, and some of these, notably the synthetically produced caramels, may be injurious to health.

Colt, Samuel (1814-1862)

US gunsmith who in 1835 invented the revolver that bears his name. With its rotating cylinder which turned, locked, and unlocked by cocking the hammer, the Colt was superior to other revolving pistols, and it revolutionized military tactics.

mass production for war

Colt built a large factory in Hartford, Connecticut in 1854. He introduced mass-production techniques, and his weapons had interchangeable parts, making them easy to maintain and repair. During the Crimean War 1853–56 he also manufactured arms in Pimlico, London. By 1855 he had the largest private armoury in the world. When the American Civil War broke out in 1861, he supplied thousands of guns to the US government.

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coltsfoot

perennial plant belonging to the daisy family. The single yellow flower heads have many narrow rays (not petals), and the stems have large purplish scales. The large leaf, up to 22 cm/9 in across, is shaped like a horse's foot and gives the plant its name. Coltsfoot grows in Europe, northern Asia, and North Africa, often on bare ground and in waste places, and has been introduced to North America. It was formerly used in medicine. (*Tussilago farfara*, family Compositae.)

Coltsfoot

Go to site

Informative resource relating to coltsfoot. It contains a detailed description of the plant, its constituents, and its habitat. There are also extensive notes on the possible medicinal uses of coltsfoot, which include treating coughs and acting as a demulcent.

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colugo

or flying lemur

Southeast Asian climbing mammal of the genus *Cynocephalus*, order Dermoptera, about 60 cm/2 ft long including the tail. It glides between forest trees using a flap of skin that extends from head to forelimb to hindlimb to tail. It may glide 130 m/425 ft or more, losing little height. It feeds largely on buds and leaves, and rests hanging upside down under branches.

There are two species, *C. variegatus* of Indochina and Indonesia, and *C. volans* of the Philippines.

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columbine

any of a group of plants belonging to the buttercup family. All are perennial herbs with divided leaves and hanging flower heads with spurred petals. (Genus *Aquilegia*, family Ranunculaceae.)

The wild columbine (*Aquilegia vulgaris*), with blue flowers, has been developed by repeated crossing to produce modern garden species (*A. x hybrida*), with larger flowers and a wider range of colours. The eastern columbine (*A. canadensis*), with red flowers, is native to eastern North America.

Columbine

Go to site

Information on the plant columbine, including a detailed description of the plant and its habitat. There are also extensive notes on the possible medicinal uses of columbine, which include acting as an astringent (although it should be noted that the plant can be poisonous).

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columbium

symbol Cb

former name for the chemical element niobium. The name is still used occasionally in metallurgy.

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coma

in astronomy, hazy cloud of gas and dust that surrounds the nucleus of a comet.

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coma

in medicine, a state of deep unconsciousness from which the subject cannot be roused. Possible causes include head injury, brain disease, liver failure, cerebral haemorrhage, and drug overdose.

Coma

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page documents the revolution taking place in the medical industry regarding the treatment of coma patients. This site includes a detailed geography of the brain and an interview with renowned neurosurgeon Dr Jamshid Ghajar. You can also go 'On call' with Dr Ghajar at a New York City hospital and follow the case of a boy who has suffered head trauma. Read a transcript of the final scene from the hospital drama *Chicago Hope*, and click on the underlined words to learn what the technical jargon really means.

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coma

in optics, one of the geometrical aberrations of a lens or mirror, in which rays from an object not in the centre of the field of view make a comet-shaped spot on the image plane instead of meeting at a point.

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combe

or coombe

steep-sided valley found on the scarp slope of a chalk escarpment. The inclusion of 'combe' in a placename usually indicates that the underlying rock is chalk.

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combination

in mathematics, a selection of a number of objects from some larger number of objects when no account is taken of order within any one arrangement. For example, 123, 213, and 312 are regarded as the same combination of three digits from 1234. Combinatorial analysis is used in the study of probability.

The number of ways of selecting r objects from a group of n is given by the formula:

$n!/[r!(n - r)!]$ (see factorial). This is usually denoted by ${}^nC_r$.

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combine harvester

machine used for harvesting cereals and other crops, so called because it combines the actions of reaping (cutting the crop) and threshing (beating the ears so that the grain separates).

A combine, drawn by horses, was first built in Michigan in 1836. Today's mechanical combine harvesters are capable of cutting a swath of up to 9 m/30 ft or more.

combine harvester

(Image © Research Machines plc)

The first combine harvester designed for European conditions was developed by the German firm CLAAS in the 1930s. In 1953, the same firm began producing the first self-propelled harvester. The combine harvester is so-called because it is both a grain-harvesting machine and a threshing machine. The same machine cuts, threshes, and cleans the grain in one operation.

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combustion

burning, defined in chemical terms as the rapid combination of a substance with oxygen, accompanied by the evolution of heat and usually light. A slow-burning candle flame and the explosion of a mixture of petrol vapour and air are extreme examples of combustion. Combustion is an exothermic reaction as heat energy is given out.

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comet

small, icy body orbiting the Sun, usually on a highly elliptical path. A comet consists of a central nucleus a few miles across, and has been likened to a dirty snowball because it consists mostly of ice mixed with dust. As the comet approaches the Sun the nucleus heats up, releasing gas and dust which form a tenuous coma, up to 60,000 mi/100,000 km wide, around the nucleus. Gas and dust stream away from the coma to form one or more tails, which may extend for millions of miles. US astronomers concluded in 1996 that there are two distinct types of comet: one rich in methanol and one low in methanol. Evidence for this comes in part from observations of the spectrum of the comet Hyakutake.

Comets are believed to have been formed at the birth of the Solar System. Billions of them may reside in a halo (the **Oort cloud**) beyond Pluto. The gravitational effect of passing stars pushes some towards the Sun, when they eventually become visible from Earth. Most comets swing around the Sun and return to distant space, never to be seen again for thousands or millions of years, although some, called **periodic comets**, have their orbits altered by the gravitational pull of the planets so that they reappear every 200 years or less. Periodic comets are thought to come from the Kuiper belt, a zone just beyond Neptune. Of the 800 or so comets whose orbits have been calculated, about 160 are periodic. The brightest is Halley's Comet. The one with the shortest known period is Encke's Comet, which orbits the Sun every 3.3 years. A dozen or more comets are discovered every year, some by amateur astronomers.

Comet Hale-Bopp

introduction

The appearance of the Hale-Bopp comet in the skies of the northern hemisphere in February 1997 excited scientists and the public alike; but nobody could have foreseen that by the time it had disappeared from our skies, 41 people would have taken their lives because of its presence.

comets throughout history

Comets have been viewed as harbingers of doom for thousands of years: their inexplicable appearance in an otherwise orderly sky perplexed ancient astronomers. Now they are known to be chunks of rock, dust, ice, and other chemicals, following enormously elliptical orbits around the Sun, which take them within the Earth's orbit before they swing past into the darkness of space beyond the most distant planet, Pluto. As a comet nears the Sun, its body is heated by solar radiation causing some of its constituent chemicals to boil off into space, producing the characteristic 'tail'. This tail is pushed away from the Sun by the pressure of the 'solar wind': thus the tail's direction is not related to the direction of travel, only to the position of the Sun. This elliptical orbit means that a comet travels through a regular path; each comet differs only in how long it takes to appear. Halley's Comet, for example, turns up every 76 years; its last visit was in 1986. In 1996, many people were disappointed when the comet Hyakutake, discovered by an amateur Japanese astronomer, turned out to be a drab show. Hale-Bopp, also discovered by amateur astronomers, takes roughly 4,000 years to complete its orbit. It first became visible in the northern hemisphere in February 1997, because its orbit is tilted in relation to ours - so that it approached from 'above' the plane of the solar system.

ablaze in the night sky

Astronomers and the general public were delighted. 'The comet of the century', commented the scientists. It quickly became so bright that outside the light pollution of cities it was easily visible at night without telescopes or binoculars, and most notably early in the morning. Beautiful time-lapse photographs - taken in deserts, over monuments such as Stonehenge (which was seeing the comet for at least the second time), and open country - filled newspapers, showing off its dual blue (dust) and yellow (gas) tails stretching for up to 20 million miles. It was, astronomers agreed, one of the brightest comets in the past 500 years. On the Internet, the discussion about the comet drew outlandish comments from some people - including some who said that the comet was being shadowed by a UFO that was hiding behind it in order to approach the Earth. Scientists laughed it off as the sort of misconception that can be commonplace on the global network. 'If I was in a UFO and wanted to sneak up on earth, I wouldn't do it behind the most-watched celestial object for years', said one. The comet Hale-Bopp grew brighter by the day. Its closest approach to the Earth was on 22 March, when it flew by just 123 million miles away from us; its closest approach to the Sun was on 1 April, when it was just 85 million miles away from it. (The Earth is 93 million miles from the Sun.)

Heaven's Gate

However, on Wednesday 26 March, the idea that Hale-Bopp was simply a cosmic phenomenon all changed. It was late in the afternoon when San Diego police drove to a five-bedroom Spanish mansion at 18241 Colina Norte, after receiving two anonymous phone calls telling them to check on the residents. They had no reason to be suspicious: anyone who knew the house had heard that it was the centre for a group of people who made their living programming Web pages for corporate customers: not unusual for San Diego. Arriving there, the police found the front doors locked, the windows shut and blinds drawn. A side door was unlocked - and through there they found ten dead men on the floor. The bodies were already decomposing. In all, the corpses of 21 women and 18 men, passports and IDs tucked in the top pockets of their shirts, were discovered. It had been a mass suicide, timed to coincide with Hale-Bopp's closest approach to Earth. Videotapes made by the suicides, who had dressed in matching black with crewcut hair, showed that despite the name of their business - WWW Higher Source - they were quite simply a cult. They believed their leader, who told them that the comet was really the cloak for a UFO; they believed the time had come to 'shed their earthly containers' (bodies) and regain their true identities as angels from another planet. They died in a mass suicide carried out in three waves over a period of days, using a mixture of alcohol and phenobarbitol (swallowed with pudding or apple sauce) and plastic bags over their heads; the last survivors took the bags off the earlier dead and draped them with purple scarves. Each had videotaped a statement saying they were 'going to a better place'. The cult called themselves 'Heaven's Gate', and had its own Web site, which had been crammed with invisible text to give it a high profile on the Internet for anyone searching for information about UFOs. The site invited people to join them in their mission. Sadly, two more people did, committing suicide in April and May, in the belief that they would join the group in leaving on the comet. Yet away from the obsessed, the comet brought good news to makers of binoculars and telescopes, and of camera tripods: people wanted to get pictures of the comet of the century.

Undoubtedly, it fulfilled all expectations.

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comfrey

any of a group of plants belonging to the borage family, with rough, hairy leaves and small bell-shaped flowers (blue, purple-pink, or white). They are found in Europe and western Asia. (Genus *Symphytum*, family Boraginaceae.)

The European species (*Symphytum officinale*) was once used to make ointment for treating wounds and various ailments, and is still sometimes used as a poultice which is applied to the skin to treat inflammation. It grows up to 1.2 m/4 ft tall and has hairy, winged stems, lanceolate (tapering) leaves, and white, yellowish, purple, or pink flowers in drooping clusters.

Comfrey

Go to site

Informative resource relating to the plant comfrey. It contains a detailed description of the plant, its constituents. and its habitat. There are also extensive notes on the cultivation of comfrey, as well as on its possible medicinal uses, which include treating coughs and acting as an astringent.

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command language

in computing, a set of commands and the rules governing their use, by which users control a program. For example, an operating system may have commands such as SAVE and DELETE, or a payroll program may have commands for adding and amending staff records.

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commensalism

in biology, a relationship between two species whereby one (the commensal) benefits from the association, whereas the other neither benefits nor suffers. For example, certain species of millipede and silverfish inhabit the nests of army ants and live by scavenging on the refuse of their hosts, but without affecting the ants.

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commercial farming

production of crops for sale and profit, although the farmers and their families may use a small amount of what they produce. Profits may be reinvested to improve the farm. Large-scale commercial farming is agribusiness; see also plantation and ranching. The opposite of commercial farming is subsistence farming where no food is produced for sale.

Common Agricultural Policy

CAP

system of financial support for farmers in European Union (EU) countries, a central aspect of which is the guarantee of minimum prices for part of what they produce. The objectives of the CAP were outlined in the Treaties of Rome (1957): to increase agricultural productivity, to provide a fair standard of living for farmers and their employees, to stabilize markets, and to assure the availability of supply at a price that was reasonable to the consumer. The CAP has been criticized for its role in creating overproduction, and consequent environmental damage, and for the high price of food subsidies.

history

The policy, applied to most types of agricultural product, was evolved and introduced between 1962 and 1967, but was later amended to take account of changing conditions and the entry of additional member states. At the heart of the CAP is a price support system based on setting a target price for a commodity, imposing a levy on cheaper imports, and intervening to buy produce at a predetermined level to maintain the stability of the internal market. When the CAP was devised, the six member states were net importers of most essential agricultural products, and the intervention mechanism was aimed at smoothing out occasional surpluses caused by an unusually productive season. However, the CAP became extremely expensive in the 1970s and 1980s due to overproduction of those agricultural products that were subsidized. In many years, far more was produced than could be sold and it had to be stored, creating 'mountains' and 'lakes' of produce. This put the CAP under intense financial and political strain, and led to reforms in the 1990s that substantially replaced guaranteed prices with compensation to farmers if prices fell. The CAP remains one of the most important EU policies, with agricultural expenditure accounting for half of the 90 billion euros allocated towards the annual budget of the European Community in 2002.

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common denominator

denominator that is a common multiple of, and hence exactly divisible by, all the denominators of a set of fractions, and which therefore enables their sums or differences to be found.

For example, 2/3 and 3/4 can both be converted to equivalent fractions of denominator 12, 2/3 being equal to 8/12 and 3/4 to 9/12. Hence their sum is 17/12 and their difference is 1/12. The **lowest common denominator** (lcd) is the smallest common multiple of the denominators of a given set of fractions.

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common logarithm

another name for a logarithm to the base ten.

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communication

in biology, the signalling of information by one organism to another, usually with the intention of altering the recipient's behaviour. Signals used in communication may be **visual** (such as the human smile or the display of colourful plumage in birds), **auditory** (for example, the whines or barks of a dog), **olfactory** (such as the odours released by the scent glands of a deer), **electrical** (as in the pulses emitted by electric fish), or **tactile** (for example, the nuzzling of male and female elephants).

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communications satellite

relay station in space for sending telephone, television, telex, and other messages around the world. Messages are sent to and from the satellites via ground stations. Most communications satellites are in geostationary orbit, appearing to hang fixed over one point on the Earth's surface.

The first satellite to carry TV signals across the Atlantic Ocean was Telstar, which was launched into low Earth orbit by the USA on 10 July 1962. The world is now linked by the Intelsat system of communications satellites. Other satellites are used by individual countries for internal communications, or for business or military use. A new generation of satellites, called **direct-broadcast satellites**, are powerful enough to transmit directly to small domestic aerials. The power for such satellites is produced by solar cells. The total energy requirement of a satellite is small; a typical communications satellite needs about 2 kW of power, the same as an electric heater.

Personal Information and Surveillance

introduction

When George Orwell wrote his novel *Nineteen Eighty-Four* (1949) and the phrase 'Big Brother is watching you' passed into the language, few could have foreseen the extent to which modern technology would pry into our lives. Orwell's hero, Winston Smith, was observed by a giant TV screen. Nowadays technology is so compact that we can conceal a video camera in a smoke detector. Big Brother was the ruler of a totalitarian state. Today he is as likely to represent a supermarket or a bank, anxious to discover Winston's preference in beans or bonds, the better to target him with personal offers. The extent to which we and our personal data are monitored is breathtaking. Today Winston would appear, on average, in 300 different databases. If he lived or worked in a city, he could expect to be filmed every day by more than 300 closed circuit television (CCTV) cameras belonging to 30 different networks.

personal data on the market

Personal data are becoming a currency, which we are invited to trade for cash, convenience, or both. Supermarkets and petrol stations hand out loyalty cards, offering gifts and discounts in return for the ability to track our movements and record what we buy. Web sites demand personal details before letting us in, or promise to save us time with a 'personalized' experience. The increasing power of computers, and the increasing desperation of businesses to find a competitive advantage, has spawned the science of 'customer relationship management' – combining information from various databases to build up detailed pictures of individuals, for use in 'precision marketing' (tailored to each individual). It can also be used for the reverse – getting rid of unprofitable or unreliable customers, who may be turned down for loans, credit, and so on, in decisions made entirely by the computer. Credit reference agencies maintain similar databases, and when people ask to see their personal files, about one in a hundred find a mistake. The Internet will really enable precision marketing. As well as asking for information, Web sites can track where we go, when, and how long we stay. When we return, we can be shown things calculated to be of particular interest; if we do not return we can be e-mailed to ask why not. Most Web surfers cannot be personally identified by the sites they visit, but proposed changes in Internet technical standards could make this possible. Even now Web sites can leave files on our computers, called 'cookies', that identify us if we come back.

monitored by technology

We are increasingly likely to be betrayed by our own appliances. Whenever our mobile phone or pager is switched on, the network knows exactly where we are. A security feature in Intel's Pentium III processor allows individual PCs to be identified when connected to the Internet, though only if users choose to switch on the feature. Software publishers are able to identify users' PCs when they register their software online. Music software can scan our hard disks for recorded music (including pirated copies) and tell publishers' Web sites what we have got. We are increasingly under surveillance at work. Telephone calls are routinely recorded. Special software can track where staff go on the Internet and scan e-mails for incriminating words or phrases, from offensive language to secret code names of new products. If Winston Smith worked in a modern call centre, the system could even know when he went to the lavatory. On the street, we are watched by an estimated 1 million CCTV cameras. Opponents argue that these are ineffective, driving crime into other areas or failing to identify criminals. But the technology is being enhanced. So-called 'neural networks' (computers that emulate the human brain) are being used by airports and local authorities to compare CCTV pictures with mugshots of known criminals. Likely offenders can be apprehended on the spot, or picked out in crowd scenes such as football matches.

Some systems create a three-dimensional image and even claim to see through disguises.

the role of the police

Neither technique is foolproof, however, so there is still a place for the bobby on the beat. Many officers can connect online to the Police National Computer in Hendon, which holds around 6 million criminal records and 4 million finger prints - these can now be taken using an electronic scanner instead of the traditional ink-pad. Software called Watson has also been developed to compare records of reported crimes with known criminals and their habits, linking offences with likely suspects. The ability of technology to track and identify us increases apace. The most powerful commercial satellites can identify objects on the ground as small as a tea tray - information that can be bought by anyone. Military satellites can tell what is on the tray. Soon computers will be able to read our bodies like a passport. Cash machines and security systems are being trained to recognize us from our faces, voices, finger prints, and even our eyes, instead of from PIN numbers and swipe cards. And silicon identification chips, costing only a few pounds, can be injected beneath the skin. Already common for matching pets with their owners, they are beginning to be inserted in people, for example in breast implants.

protection or privacy?

So should we welcome these Big Brother technologies? Or should we be appalled and afraid? The issue is by no means clear-cut. We want to feel safe on the streets - but we do not want our private actions filmed and replayed. We want to guard personal information - but we expect to be treated as individuals by organizations with which we deal. Attempts to protect our privacy can backfire. Restrictions on use of personal data can force marketing and credit reference agencies to use 'inferred data' - guessed from things such as our names and postcode, so we may be denied credit just because we live in a 'bad' neighbourhood. The opposite of one-to-one marketing on the Internet is junk e-mail, or 'spam', which annoys millions of people and generates almost no returns. The bottom line is that there is no point in technology for its own sake, however clever. It is the probity of those who use it, and the benefit to the individual, which count. Would Winston Smith have been impressed if the rats that terrorized him in room 101 had been injected with silicon chips identifying them as the property of Big Brother? Probably not.

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community

in ecology, an assemblage of plants, animals, and other organisms living within a circumscribed area. Communities are usually named by reference to a dominant feature such as characteristic plant species (for example, an oak-hickory community), or a prominent physical feature (for example, a freshwater-pond community).

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commutative operation

in mathematics, an operation that is independent of the order of the numbers or symbols concerned. For example, addition is commutative: the result of adding 4 + 2 is the same as that of adding 2 + 4; subtraction is not as 4 - 2 = 2, but 2 - 4 = -2. Compare associative operation and distributive operation.

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commutator

device in a DC (direct-current) electric motor that reverses the current flowing in the armature coils as the armature rotates.

A DC generator, or dynamo, uses a commutator to convert the AC (alternating current) generated in the armature coils into DC. A commutator consists of opposite pairs of conductors insulated from one another, and contact to an external circuit is provided by carbon or metal brushes.

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compact disc

or CD

disk for storing digital information, about 12 cm/4.5 in across, mainly used for music, when it can have over an hour's playing time. A laser beam etches the compact disc with microscopic pits that carry a digital code representing the sounds; the pitted surface is then coated with aluminium. During playback, a laser beam reads the code and produces signals that are changed into near-exact replicas of the original sounds.

CD-ROM, or **compact-disc read-only memory**, is used to store written text, pictures, and video clips in addition to music. The disks are ideal for large works, such as catalogues and encyclopedias. CD-I, or **Compact-Disc Interactive**, is a form of CD-ROM used with a computerized reader, which responds intelligently to the user's instructions.

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comparative anatomy

study of the similarity and differences in the anatomy of different groups of animals. It helps to reveal how animals are related to each other and how they have changed through evolution.

Structures are **homologous** if they have arisen from the same ancestral structure through evolution, but perform either similar or different functions in modern animals. Examples of homologous structures are the wings of birds, the human arm, and the forelimb of whales.

Analogous structures have developed from different ancestral structures, but perform similar functions, such as the wings of insects and those of birds.

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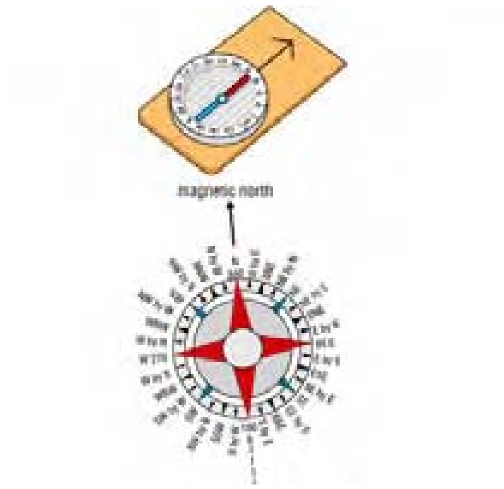
compass

any instrument for finding direction. The most commonly used is a magnetic compass, consisting of a thin piece of magnetic material with the north-seeking pole indicated, free to rotate on a pivot and mounted on a compass card on which the points of the compass are marked. When the compass is properly adjusted and used, the north-seeking pole will point to the magnetic north, from which true north can be found from tables of magnetic corrections.

Compasses not dependent on the magnet are gyrocompasses, dependent on the gyroscope, and radiocompasses, dependent on the use of radio. These are unaffected by the presence of iron and by magnetic anomalies of the Earth's magnetic field, and are widely used in ships and aircraft. See navigation.

compass



(Image © Research Machines plc)

As early as 2500 BC, the Chinese were using pieces of magnetic rock, magnetite, as simple compasses. By the 12th century, European navigators were using compasses consisting of a needle-shaped magnet floating in a bowl of water.

compass points

To remember the points of the compass, in the correct order:

Nobody **e**ver **s**wallows **w**hales or **N**ever **e**at **s**hredded **w**heat or **N**ever **e**at **s**limy **w**orms or **N**ever **e**at **s**oggy **w**affles or **N**ever **e**at **s**our **w**atermelon

Place the first letter of each word in a clockwise circle starting at the 12 o'clock (north) position

---

compensation point

in biology, the point at which there is just enough light for a plant to survive. At this point all the food produced by photosynthesis is used up by respiration. For aquatic plants, the compensation point is the depth of water at which there is just enough light to sustain life (deeper water = less light = less photosynthesis).

---

competition

in ecology, the interaction between two or more organisms, or groups of organisms, that use a common resource in short supply. There can be competition between members of the same species and competition between members of different species. Competition invariably results in a reduction in the numbers of one or both competitors, and in evolution contributes both to the decline of certain species and to the evolution of adaptations.

The resources in short supply for which organisms compete may be obvious things, such as mineral salts for animals and plants, or light for plants. However, there are less obvious resources. For example, competition for suitable nesting sites is important in some species of birds. Competition results in a reduction in breeding success for one or other organism(s). Because of this it is one of the most important aspects of natural selection, which may result in evolutionary change if the environment is changing. Competition also results in the distribution of organisms we see in habitats. It is believed that organisms tend to occur where the pressures of competition are not as great as in other areas. In agriculture cultivation methods are designed to reduce competition. For example, a crop of wheat is sown at a density that minimizes competition within the same species. The plants are grown far enough apart to reduce competition between the roots of neighbouring wheat plants for soil mineral nutrients. The spraying of the ground to kill weeds reduces competition between the wheat and weed plants. Some weeds would grow taller than the wheat and deprive it of light.

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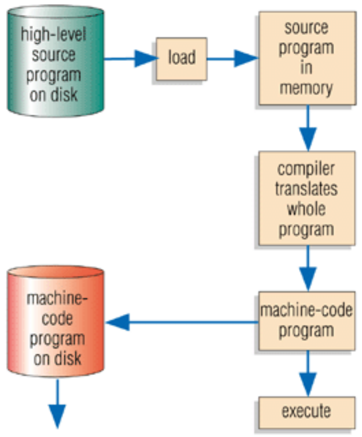
compiler

computer program that translates programs written in a high-level language into machine code (the form in which they can be run by the computer). The compiler translates each high-level instruction into several machine-code instructions - in a process called **compilation** - and produces a complete independent program that can be run by the computer as often as required, without the original source program being present.

Different compilers are needed for different high-level languages and for different computers. In contrast to using an interpreter, using a compiler adds slightly to the time needed to develop a new program because the machine-code program must be recompiled after each change or correction. Once compiled, however, the machine-code program will run much faster than an interpreted program.

compiler


high-level source program on disk
load
source program in memory
compiler translates whole program
machine-code program
machine-code program on disk
execute

(Image © Research Machines plc)

The process of compilation; a program written in a high-level language is translated into a program that can be run without the original source being present.

---

complement

in mathematics, the set of the elements within the universal set that are not contained in the designated set. For example, if the universal set is the set of all positive whole numbers and the designated set *S* is the set of all even numbers, then the complement of *S* (denoted *S* ') is the set of all odd numbers.

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complementary angles

two angles that add up to 90°.

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complementary medicine

in medicine, systems of care based on methods of treatment or theories of disease that differ from those taught in most Western medical schools. See medicine, alternative.

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complementary number

in number theory, the number obtained by subtracting a number from its base. For example, the complement of 7 in numbers to base 10 is 3. Complementary numbers are necessary in computing, as the only mathematical operation of which digital computers (including pocket calculators) are directly capable is addition. Two numbers can be subtracted by adding one number to the complement of the other; two numbers can be divided by using successive subtraction (which, using complements, becomes successive addition); and multiplication can be performed by using successive addition.

---

complementation

in genetics, the interaction that can occur between two different mutant alleles of a gene in a diploid organism, to make up for each other's deficiencies and allow the organism to function normally.

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complex

in psychology, a group of ideas and feelings that have become repressed because they are distasteful to the person in whose mind they arose, but are still active in the depths of the person's unconscious mind, continuing to affect his or her life and actions, even though he or she is no longer fully aware of their existence. Typical examples include the Oedipus complex and the inferiority complex.

---

complex number

in mathematics, a number written in the form $a + ib$, where a and b are real numbers and i is the square root of -1 (that is, $i^2 = -1$); i used to be known as the 'imaginary' part of the complex number. Some equations in algebra, such as those of the form

$x^2 + 5 = 0$

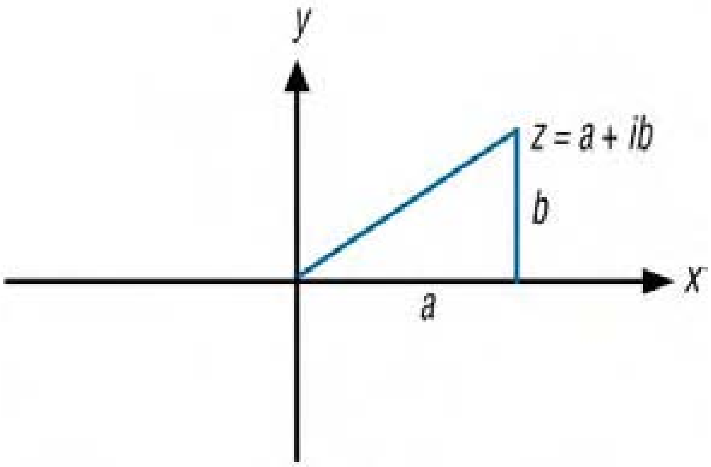
cannot be solved without recourse to complex numbers, because the real numbers do not include square roots of negative numbers.

The sum of two or more complex numbers is obtained by adding separately their real and imaginary parts, for example:

$(a + bi) + (c + di) = (a + c) + (b + d)i$

Complex numbers can be represented graphically on an Argand diagram, which uses rectangular Cartesian coordinates in which the x-axis represents the real part of the number and the y-axis the imaginary part. Thus the number $z = a + ib$ is plotted as the point (a, b). Complex numbers have applications in various areas of science, such as the theory of alternating currents in electricity.

complex number



(Image © Research Machines plc)

A complex number can be represented graphically as a line whose end-point coordinates equal the real and imaginary parts of the complex number. This type of diagram is called an Argand diagram after the French mathematician Jean Argand (1768-1822) who devised it.

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component

in mathematics, one of the vectors produced when a single vector is resolved into two or more parts. The vector sum of the components gives the original vector.

---

component

in physics, one of two or more vectors, normally at right angles to each other, that add together to produce the same effect as a single resultant vector. Any vector quantity, such as force, velocity, or electric field, can be resolved into components chosen for ease of calculation. For example, the weight of a body resting on a slope can be resolved into two force components; one normal to the slope and the other parallel to the slope.

Compositae

daisy family, comprising dicotyledonous flowering plants characterized by flowers borne in composite heads (see capitulum). It is the largest family of flowering plants, the majority being herbaceous. Birds seem to favour the family for use in nest 'decoration', possibly because many species either repel or kill insects (see pyrethrum). Species include the daisy and dandelion; food plants such as the artichoke, lettuce, and safflower; and the garden varieties of chrysanthemum, dahlia, and zinnia.

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composite

in industry, any purpose-designed engineering material created by combining materials with complementary properties into a composite form. Most composites have a structure in which one component consists of discrete elements, such as fibres, dispersed in a continuous matrix. For example, lengths of asbestos, glass, or carbon steel, or 'whiskers' (specially grown crystals a few millimetres long) of substances such as silicon carbide may be dispersed in plastics, concrete, or steel.

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compost

organic material decomposed by bacteria under controlled conditions to make a nutrient-rich natural fertilizer for use in gardening or farming. A well-made compost heap reaches a high temperature during the composting process, killing most weed seeds that might be present.

Compost

Go to site

Informative guide to compost from the Virginia Cooperative Extension. It first describes exactly what compost is and what its benefits are. Then it gives detailed information about making your own compost.

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compound

chemical substance made up of two or more elements bonded together, so that they cannot be separated by physical means. Compounds are held together by ionic or covalent bonds.

The name of a compound may give a clue to its composition. If the name ends in -ide (with the notable exceptions of hydroxides and ammonium chloride) it usually contain two elements. For example calcium oxide is a compound of calcium and oxygen.

If the name ends in -ate or -ite the compound contains oxygen; compounds ending in -ate have a greater proportion of oxygen than those ending in -ite. For example, sodium sulphate (Na_2SO_4) contains more oxygen than does sodium sulphite (Na_2SO_3).

If the name starts with per- the compound contains extra oxygen. For example, hydrogen peroxide H_2O_2 contains one more oxygen than hydrogen oxide (water) H_2O.

The prefix thio- indicates that the compound contains an atom of sulphur in place of oxygen. For example, sodium thiosulphate ($Na_2S_2O_3$) contains one more sulphur and one less oxygen than the more common sodium sulphate (Na_2SO_4).

The proportions of the different elements in a compound are shown by the chemical formula of that compound. For example, a molecule of sodium sulphate, represented by the formula Na_2SO_4 contains two atoms of sodium, one of sulphur, and four of oxygen.

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compound interest

interest calculated by computing the rate against the original capital plus reinvested interest each time the interest becomes due. When simple interest is calculated, only the interest on the original capital is added.

For example, 10% compound interest on £2,000 over three years can be calculated as follows:

$2,000 \times 1.1^3 = 2,662$

where the multiplier is arrived at by 1 ± the percentage as a decimal, with the power being the number of years over which the interest is to be calculated.

Compound interest

This table assumes that interest is calculated annually and takes no account of taxation.

Value of £100 after:	Interest rate											
	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
3 months	101.0	101.3	101.5	101.8	102.0	102.3	102.5	102.8	103.0	103.3	103.5	103.8
6 months	102.0	102.5	103.0	103.5	104.0	104.5	105.0	105.5	106.0	106.5	107.0	107.5
1 year	104.0	105.0	106.0	107.0	108.0	109.0	110.0	111.0	112.0	113.0	114.0	115.0
2 years	108.2	110.3	112.4	114.5	116.6	118.8	121.0	123.2	125.4	127.7	130.0	132.3

3 years	112.5	115.8	119.1	122.5	126.0	129.5	133.1	136.8	140.5	144.3	148.2	152.1
4 years	117.0	121.6	126.2	131.1	136.0	141.2	146.4	151.8	157.4	163.0	168.9	174.9
5 years	121.7	127.6	133.8	140.3	146.9	153.9	161.1	168.5	176.2	184.2	192.5	201.1
6 years	126.5	134.0	141.9	150.1	158.7	167.7	177.2	187.0	197.4	208.2	219.5	231.3
7 years	131.6	140.7	150.4	160.6	171.4	182.8	194.9	207.6	221.1	235.3	250.2	266.0
8 years	136.9	147.7	159.4	171.8	185.1	199.3	214.4	230.5	247.6	265.8	285.3	305.9
9 years	142.3	155.1	168.9	183.8	199.9	217.2	235.8	255.8	277.3	300.4	325.2	351.8
10 years	148.0	162.9	179.1	196.7	215.9	236.7	259.4	283.9	310.6	339.5	370.7	404.6
15 years	180.1	207.9	239.7	275.9	317.2	364.2	417.7	478.5	547.4	625.4	713.8	813.7
20 years	219.1	265.3	320.7	387.0	466.1	560.4	672.7	806.2	964.6	1,152.3	1,374.3	1,636.7
25 years	266.6	338.6	429.2	542.7	684.8	862.3	1,083.5	1,358.5	1,700.0	2,123.1	2,646.2	3,291.9

---

compressor

machine that compresses a gas, usually air, commonly used to power pneumatic tools, such as road drills, paint sprayers, and dentist's drills. Compressed air expands when the pressure is removed, thus supplying the power to drive the tool.

Compressors are grouped into either positive displacement machines (which use a mechanical means of compression) or dynamic machines (which produce compression by creating high air speeds and thus high levels of kinetic energy, which is then converted into static pressure by a diffuser).

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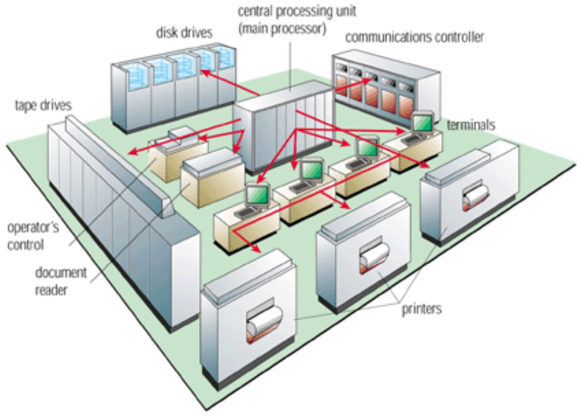
computer

programmable electronic device that processes data and performs calculations and other symbol-manipulation tasks. There are three types: the digital computer, which manipulates information coded as binary numbers (see binary number system); the analogue computer, which works with continuously varying quantities; and the **hybrid computer**, which has characteristics of both analogue and digital computers. In common usage, when someone refers to a 'computer', they tend to mean a digital computer.

There are four types of digital computer, corresponding roughly to their size and intended use.
Microcomputers (personal computers, or PCs) are the smallest and most common, used at home, in small businesses, and in schools. They are usually single-user machines.
Minicomputers (or mid-range computers) are found in medium-sized businesses and university departments. They may support from around 10 to 200 users at once, although these have now largely been replaced by networks of microcomputers.
Mainframes (or enterprise servers), which can often service many hundreds of users simultaneously, are found in large organizations, such as national companies and government departments.
Supercomputers are mostly used for highly complex scientific tasks, such as analysing the results of nuclear physics experiments and weather forecasting.

mainframe



(Image © Research Machines plc)

A mainframe computer. Functionally, it has the same component parts as a microcomputer, but on a much larger scale. The central processing unit is at the hub, and controls all the attached devices.

Computing: key dates

c. 2500 BC	The people of Mesopotamia (now Iraq) develop a positional numbering (place-value) system, in which the value of a digit depends on its position in a number.
876 BC	A symbol for zero is used for the first time, in India.
c. 190 BC	Chinese mathematicians use powers of 10 to express magnitudes.
1614	Scottish mathematician John Napier invents logarithms, which enable lengthy calculations involving multiplication and division to be carried out by addition and subtraction.

1615	William Oughtred in the UK invents the slide rule.
1623	Wilhelm Schickard in Germany invents the mechanical calculating machine.
1642	Blaise Pascal in France produces a mechanical calculating machine, the Pascaline, which uses rotating wheels to do arithmetic.
1672-74	German mathematician Gottfried Leibniz builds his first calculator, the Stepped Reckoner.
1679	Leibniz introduces binary arithmetic, in which only two symbols are used to represent all numbers.
1805	Joseph-Marie Jacquard in France develops an automatic loom controlled by punch cards.
1820	The first mass-produced calculator, the Arithometer, is developed by Charles Thomas de Colmar.
1823	Charles Babbage in the UK constructs a Difference Engine for calculating logarithms and trigonometric functions. Later he develops but fails to complete an Analytical Engine, which has the elements of a mechanical computer.
1854	George Boole in the UK publishes his system of symbolic logic, now called Boolean algebra.
1886	William Burroughs in the USA develops the first commercially successful mechanical adding machine.
1890	Herman Hollerith develops tabulating machines using punched cards for use in the US Census. Hollerith's company is one of the parts from which IBM (International Business Machines) is formed in 1924, and punched cards - first exploited by Joseph-Marie Jacquard in 1805 - are widely used in data processing until the 1970s.
1904	Ambrose Fleming in the UK invents the diode valve, which allows the flow of electricity in one direction only.
1907	Charles Krumm introduces the forerunner of the teleprinter.
1924	The Computing-Tabulating-Recording Company changes its name to International Business Machines (IBM).
1936	Alan Turing in the UK develops the idea that all solvable problems can be solved using algorithms. He writes a seminal paper, 'On Computable Numbers', that influences John von Neumann and the development of computing.
1937	The first binary adding machine is constructed from telephone relays, strips of tin, bulbs, and other items by George Stibitz, an engineer at the Bell Telephone Laboratories in New Jersey, USA. He calls it the Model K because it is built on his kitchen table.
1938	Konrad Zuse, working in his parents' living room in Berlin, Germany, completes the Z1, the first binary calculating machine. Binary logic later becomes the standard method of operation for electronic computers.
1940	Stibitz and a team at Bell Laboratories, USA, complete the construction of the Complex Number Calculator, a full-scale relay calculator based on the development of his kitchen-table ideas.
1941	Zuse assembles the Z3, the first program-controlled electromechanical calculator. The German High Command rejects his proposal to build an electronic computer using valves (vacuum tubes).
1942	John Atanasoff and Clifford Berry complete the ABC or Atanasoff-Berry Calculator, one of the first electronic calculating machines. In 1973, a US judge decides that this is enough of a computer to invalidate patents on the ENIAC, which is widely considered to be the first electronic computer.
1943	An electronic computer, Colossus, is constructed at Bletchley Park, England, to help with wartime code-breaking. Colossus is operational before ENIAC, but its development is kept secret for 32 years.
1944	John von Neumann and Oscar Morgenstern develop game theory in the USA.
	In the USA, the Harvard University Mark I or Automatic Sequence Controlled Calculator, partly financed by IBM, becomes the first program-controlled calculator.
1945	ENIAC (Electronic Numerical Integrator Analyzer And Computer) - often considered to be the first electronic computer - is completed by J Presper Eckert and John W Mauchly at the Moore School at the University of Pennsylvania. A valve-based machine, it can be reprogrammed using cables and plugboards, that is, essentially by rewiring it. However, Eckert and Mauchly have already proposed building a computer that can store and run programs: EDVAC (Electronic Discrete Variable Computer). John von Neumann's description of the project, 'First Draft of a Report on the EDVAC', is widely circulated and stimulates the building of similar machines following what becomes known as the 'von Neumann architecture'.
1946	Eckert and Mauchly leave the Moore School to found the first commercial computer company, which leads to the UNIVAC (Universal Automatic Computer) and the US mainframe computer industry.
1947	William Shockley, John Bardeen, and Walter Brattain invent the junction germanium transistor at Bell Labs.
1948	IBM's SSEC (Selective Sequence Electronic Calculator), an electro-mechanical system, runs a stored program on 27 January, while Manchester University's Mark I prototype runs the first stored program on an electronic computer on 21 June.
1949	EDSAC (Electronic Delay Storage Automatic Calculator), the first full-scale electronic stored program computer, goes into operation at Cambridge University, England, ahead of Eckert and Mauchly's BINAC (Binary Automatic Computer), which is more than a year behind schedule.
1951	First commercially produced computers are delivered: a Ferranti Mark I going to Manchester University in February, and Eckert and Mauchly's first UNIVAC to the US Census Bureau in March.
	Whirlwind, the first real-time computer, is designed at MIT by Jay Forrester and Ken Olsen for the US air-defence system.
	Grace Murray Hopper of Remington Rand, USA, invents the first compiler computer program.
1952	EDVAC is completed at the Institute for Advanced Study, Princeton, USA, by John von Neumann and others.
	G W Dummer of the Royal Radar Establishment in the UK describes an integrated circuit that may be the first computer chip, but his prototype does not work.
1954	The silicon transistor is developed by Gordon Teal of Texas Instruments, USA.
	The first operating system is developed by Gene Amdahl for the IBM 704 computer.
	George Devol files a patent for a robotic arm controlled by programs written on punched cards.
1956	The computer programming language FORTRAN (Formula Translation) is devised.
	A computer chess program scores its first victory over a human being.
1957	Digital Equipment Corporation is founded by Ken Olsen.
1958	The first integrated circuit, containing five components, is built by US electrical physicist Jack Kilby of Texas Instruments.

1959	The planar transistor, which is built up in layers, or planes, is designed by Robert Noyce of Fairchild Semiconductor Corporation, USA.
	The computer programming language COBOL (Common Business-Oriented Language) is devised, having wide application in commercial computing.
1960	The first small computer, the PDP-1, is developed by Digital Equipment Corporation.
1962	Ivan Sutherland, a graduate student at MIT, USA, demonstrates Sketchpad, a program that uses a light pen to create drawings.
	IBM's Benoit Mandelbrot invents fractal images, by using a computer to repeat the same mathematical pattern over and over again.
1963	The PDP-8, the first mass-produced minicomputer, is launched by Digital Equipment Corporation (DEC).
1964	Launch of IBM System/360, the first compatible family of computers.
	John Kemeny and Thomas Kurtz of Dartmouth College invent BASIC (Beginner's All-Purpose Symbolic Instruction Code), a computer language similar to FORTRAN.
1965	The first supercomputer, the CD6600, is developed by Seymour Cray at Control Data Corporation in the USA.
	The Advanced Research Projects Agency (ARPA) in the USA sponsors research into a 'cooperative network of time-sharing computers' which eventually becomes the Internet.
	Ted Nelson coins the term 'hypertext' and starts to imagine a global network of computers with jump-linked texts, like the World Wide Web.
1966	*Computer Weekly*, the world's first weekly computer publication, is launched in the UK.
	Charles Kao suggests using optical fibres for telecommunications.
1967	The first floppy disk drive is built at IBM.
1968	Doug Engelbart of the Stanford Research Institute, California, demonstrates the first hypertext computer system controlled by a mouse.
	Intel Corporation is founded in California by Robert Noyce and Gordon Moore to launch the first commercial 1K random access memory (RAM) chip.
1969	Researchers at four US campuses - Stanford Research Institute, the University of California at Santa Barbara and Los Angeles, and the University of Utah - link their computers to form the ARPANET, which is the starting point of the Internet.
	At Bell Labs, Ken Thomson and Dennis Ritchie begin the development of the Unix operating system.
1970	The 8-inch floppy disk drive is introduced by IBM.
	Gene Amdahl, a former IBM S/360 mainframe designer, leaves to form Amdahl Corporation to develop the first computer that is 'plug compatible' with an IBM system.
1971	The first microprocessor or 'computer on a chip', the Intel 4004, is developed by Marcian 'Ted' Hoff and others at Intel in California, USA.
	The Pascal computer language is developed by Niklaus Wirth.
	The Poketronic, the first pocket calculator, is launched in the USA.
1972	The first coin-operated video game, Pong, is installed by Nolan Bushnell, who founds Atari in California.
	Intel launches the 8008, the first 8-bit microprocessor.
1973	The first hard disk drive, code-named Winchester, is introduced by IBM.
	University College, London, and the Royal Radar Establishment in Norway become the first overseas sites connected to the ARPANET.
	Ethernet networking is developed by Bob Metcalfe, who outlines the ideas in his Harvard PhD thesis.
	The first commercial mouse-operated computer, the Alto workstation, is developed at Xerox's Palo Alto Research Center (PARC).
	Toshiba Corporation develops Japan's first microprocessor, the 12-bit TLCS-12.
1974	The C computer language is developed at Bell Labs by Brian Kernighan and Dennis Ritchie.
	CLIP-4, the first computer with a parallel architecture, is developed by John Backus at IBM.
	Creative Computing magazine is launched in the USA to cater for home computer hobbyists.
	MYCIN, an 'expert system' computer program, proves to be as good as doctors at diagnosing cases of meningitis on ten test cases.
1975	The first commercially successful personal computer, the Altair 8800, is launched in kit form by MITS in New Mexico, USA. The Altair - a name inspired by the Star Trek television series - is based on an Intel 8080 8-bit microprocessor, and uses a version of the BASIC computer language supplied by Microsoft, a company founded by William H (Bill) Gates and Paul Allen for that purpose.
	Cray Research launches the Cray 1 supercomputer, designed by Seymour Cray. The principles of RISC processing are developed by John Cocke at IBM.
1976	Apple Computer is founded in California by Steve Jobs and Steve Wozniak, who show Wozniak's Apple I computer at the Homebrew Computer Club.
	Adventure or *Colossal Caves*, the first adventure game, is developed by Crowther and Woods.
	The first fault-tolerant computer is launched by Tandem.
1977	The first home computers are launched in the USA for the mass market, including the Apple II, the Commodore PET (Personal Electronic Transactor), and the Tandy-Radio Shack TRS-80.
	CP/M (Control Program/Microcomputers), the first popular operating system for microcomputers, is launched by Gary Kildall of Digital Research.
	The first optical fibre communications cable is installed in California.
	Atari launches the VCS (Video Computer System), the first popular home games console.
1978	The first spreadsheet, VisiCalc, is developed by Dan Bricklin and Bob Frankston.
	Speak and Spell, the first toy with built-in speech synthesis, is launched by Texas Instruments.
	Space Invaders, a coin-operated video game, is introduced by Taito of Japan.
	The 8086 processor - foundation of the x86 line - is launched by Intel.
1979	After several years of trials, the Prestel videotext system is launched by the UK's Post Office to deliver information to television sets via a phone line and modem.

	CompuServe and The Source, time-sharing online services, are launched in the USA.
	Ethernet local area networking is announced by Xerox, Digital Equipment Corporation, and Intel.
	The Micromodem 100 modem is introduced in the USA by Hayes Microcomputer Products.
	Usenet is set up between two US universities using UUCP, the Unix-to-Unix Copy Program.
	MUD, the first multi-user adventure game, is developed by Richard Bartle and Roy Trubshaw at the University of Essex, England.
	The Atari 400 and 800, the first home computers designed for playing games, are launched by Atari.
1980	Clive Sinclair's Sinclair Electronics enters the UK computer market with the Sinclair ZX80, the first computer for less than £100.
1981	The IBM Personal Computer or PC is launched by IBM, based on an Intel 8088 microprocessor and Microsoft's BASIC and Disk Operating System (DOS), which IBM licenses but does not buy.
	Warner Amex, CompuServe, and Atari combine to launch the first cable TV information service in Columbus, Ohio.
	Xerox launches the Xerox Star, the first commercial computer with a graphical user interface, a mouse, an object-oriented software system, and built-in Ethernet networking.
	Adam Osborne introduces the first portable (luggable) computer, the Osborne 1: it weighs 11 kg/24 lb.
	The Teletel communications network, where small Minitel computer terminals are provided instead of printed telephone directories, is introduced in France.
1982	TCP/IP - a communications protocol proposed by Vint Cerf and Bob Kahn in 1974 - is made the standard for the ARPANET: this marks the beginning of the Internet as a network of networks.
	Compaq introduces the first portable computer compatible with the IBM PC.
	Intel announces the 80286 processor.
	The first shareware software - a communications program called PC-Talk - is distributed by Andrew Fluegelman.
	The Computer Museum is founded in Boston, USA.
	AT&T, a US telephone company, is broken up by the US Justice Department, creating the 'Baby Bells' or RBOCs (Regional Bell Operating Companies), but a long-running anti-trust case against computer giant IBM is abandoned.
1983	Apple launches Lisa, its first mouse-operated computer with a graphical user interface inspired by work at Xerox PARC.
	Microsoft, similarly inspired, announces a graphical 'interface manager' called Windows, and ships a mouse with its first word processor, Microsoft Word.
	Novell introduces the NetWare network operating system for local area networks of personal computers.
	Gavilan unveils the first portable computer with a touchpad panel that works as a mouse.
	Commodore launches the SX-64, the first portable computer with a colour screen.
	IBM announces the IBM PC Junior, a home-oriented version of the PC.
1984	Apple launches the Macintosh computer, with a built-in black and white screen, using a long television commercial created to be shown only once, during the US Super Bowl football final.
	IBM launches the IBM PC AT (Advanced Technology), which sets the standard for PC-compatibility for the following decade.
	Novelist William Gibson coins the term 'cyberspace' in an influential work of science fiction, *Neuromancer*.
	The first commercial publication on CD-ROM is developed by The Library Corporation for IBM PC-compatible computers.
	Microsoft launches MSX, an 8-bit home-computer standard adopted by 14 manufacturers including Sony and Canon.
1985	The first mass-market mouse-driven 16-bit colour computers are launched in the USA by Atari (Atari ST) and Commodore (Amiga), while Microsoft ships the first version of Windows for IBM-compatible PCs. The Atari uses Digital Research's GEM (Graphical Environment Manager) interface, which is also available for IBM PCs.
	Intel announces the 386 processor.
	In the UK, Inmos announces the T414 transputer, the first off-the-shelf microprocessor for building parallel computers, and Acorn announces the ARM (Acorn RISC Machine) processor.
	In Japan, a mechanic is the first person to be killed by a malfunctioning robot.
1986	The first Unix workstation based on a RISC processor, the PC RT or 6150, is launched by IBM. Hewlett-Packard launches the Spectrum family of RISC-based computers.
1987	IBM tries to take back control of the microcomputer industry by launching a range of PS/2 (Personal System/2) personal computers running a new OS/2 operating system developed with Microsoft. IBM's strategy, called Systems Application Architecture (SAA), also includes its proprietary mainframe computers and minicomputers.
	Apple introduces the Macintosh II line with separate system boxes and colour monitors.
	In the UK, Acorn launches the Archimedes, the first mass-market computer based on a RISC processor.
1988	Apple launches a lawsuit against Microsoft and Hewlett-Packard, arguing that their programs - Windows and NewWave - infringe copyrights on its Macintosh interface.
	The 'Gang of Nine' computer manufacturers, led by Compaq, announce the development of the EISA (Extended Industry Standard Architecture) as an alternative to the incompatible MCA (Micro Channel Architecture) used in IBM's PS/2 systems.
	NeXT unveils a cube-shaped Unix workstation, the first computer with an erasable optical disk drive replacing the floppy disk drive.
1989	Intel announces the 486 processor and its first RISC processor, the i860.
	The first pocket-sized PC-compatible computers are announced by Atari (Portfolio) and Poqet (Poqet PC).
	The first hand-held games console, the GameBoy, is launched in Japan by Nintendo.
	GRiD Systems introduces the GridPad, a large portable computer with a touch-sensitive screen, stylus, and handwriting recognition software instead of a keyboard.
	Headstart Technologies launches a PC with a built-in CD-ROM drive.

	Wafer-scale silicon memory chips, able to store 200 million characters, are announced by Anamartic. World chess champion Garry Kasparov beats Deep Thought, a chess-playing computer developed at Carnegie-Mellon University, in a two-game match.
1990	Microsoft releases Windows 3, a popular windowing environment for PCs. Dragon Systems ships Dragon Dictate, the first speech recognition system designed for personal computers. The first remotely operated machine, a toaster, is connected to the Internet.
1990-91	A prototype of the World Wide Web is developed at CERN, Europe's particle physics research centre, by Tim Berners-Lee, who posts his code on the Internet in the alt.hypertext newsgroup.
1991	PenPoint, the first operating system designed for pen-based computers, is released by Go Corporation of the USA, which is developing a handheld electronic organizer.
1992	Philips launches the CD-I (Compact-Disc Interactive) player, based on CD audio technology, to provide interactive multimedia programs for home users.
1993	Intel launches its 586 processor, but because a judge has ruled that rival manufacturers can use x86 designations, it calls it the Pentium. Microsoft unveils a 'New Technology' version of Windows, called Windows NT. Apple introduces the Newton MessagePad handheld computer, described as a 'Personal Digital Assistant' (PDA), with built-in handwriting recognition. Mosaic, the first graphical browser for the World Wide Web, is released free of charge by the National Centre for Supercomputing Applications (NCSA) at the University of Illinois, USA. US president Bill Clinton and Socks, the Internet's First Cat, arrive online with the launch of the White House's Web site. Apple finally loses its five-year look-and-feel lawsuit against Microsoft and Hewlett-Packard. In the UK, an electronic version of the *Guardian* newspaper is launched for those with impaired vision. The newspaper is transmitted overnight to a PC in the user's home and printed out in Braille or spoken by a speech synthesizer.
1994	Cyberia is opened in London, England, providing coffee with Internet access: it claims to be the world's first cybercafé.
1995	Microsoft launches Windows 95 to replace Windows 3. Intel launches the Pentium Pro microprocessor for servers. Sun Microsystems releases the Java computer language. Sound is added to the World Wide Web when Progressive Networks releases RealAudio, an audio streaming technology.
1996	Microsoft launches the Windows CE operating systems for handheld computers and consumer electronics products. Matsushita Electric Industrial Co Ltd and Toshiba launch the world's first commercial DVD (Digital Versatile Disk, or Digital Video Disk) players. IBM's computer Deep Blue, developed from the Deep Thought chess machine, beats Russian grandmaster Garry Kasparov at chess: it is the first time a computer has beaten a human grand master in tournament play, but Kasparov wins the match 4-2.
1997	Intel introduces the Pentium II processor. In the USA, an attempt to bring legislation to control the Internet, intended to prevent access to obscene material, is rejected as unconstitutional. IBM's Deep Blue chess machine defeats grandmaster Garry Kasparov in a match by 3.5-2.5.
1998	The first tournament is held in a new league for professional players of computer games. Microsoft launches Windows 98, an upgrade to its Windows 95 program. It integrates its World Wide Web browser program Internet Explorer into the package, angering rival browser manufacturers, principally Netscape.
1999	Microsoft unveils Venus, whereby people in Shenzhen, China, can access the Internet through their TVs. The Melissa virus spreads via e-mail to more than 100,000 computers around the world. Microsoft is forced to shut down its free e-mail service, Hotmail, when a hacker's Web page allows users to access the messages of any of its 40 million users. The entire *Encyclopaedia Britannica*, with the addition of archived news updates from current media sources, is launched on the Internet, with free access.
2000	Microsoft launches Windows 2000, a new version of its successful Windows program, but containing code that has been completely rewritten to take full advantage of advances in PC development over the past decade. After a long-running dispute between the US government and Microsoft over its unfair marketing of Internet Explorer, Judge Thomas Penfield Jackson recommends that the corporation be broken up into two separate companies. Auction of 3G mobile phone licenses brings in £22.8 billion for the UK government. BT Cellnet launches the first pre-pay WAP phone service. The Love Bug virus strikes 45 million computers worldwide, causing US$10 billion worth of damage. BT's ADSL broadband service begins.
2001	The ruling that Microsoft is to be broken up is reversed, but dispute continues over whether the company has broken antitrust laws.
2002	Researchers at IBM develop the world's smallest transistor. It is only six nanometres long, a tenth of the size of a transistor in a standard microprocessor.
2004	Google, the worlds most popular search engine, floats on the stock market.
2005	Blue Gene/L, made by IBM, becomes the first supercomputer capable of over 100 trillion operations per second. Voice communication over the web using Voice Over Internet Protocol (VoIP) becomes significant.
2006	Google and Dell sign an agreement to put google software on to Dell computers, potentially challenging the dominance of Microsoft.

Go to site

Well-designed interactive museum, examining the history, development, and future of computer technology. As well as plenty of illustrations and detailed explanations, it is possible to change your route through the museum by indicating whether you are a kid, student, adult, or educator.

The Hutchinson Dictionary of Computers, Multimedia, and the Internet

Go to site

A clear and concise explanation of essential words and phrases, ranging from the historic to today's jargon. There is also a searchable database of over 1,800 definitions, articles, illustrations, and features.

OC: Free Online Dictionary of Computing

Go to site

Authoritative source of definitions of acronyms and jargon in computing and Internet use. Not only useful for computing terms, this one-stop source provides links to other resources on the Web and also covers related areas, such as communications.

Webopedia

Go to site

Comprehensive encyclopedia of computer terms. It is fully searchable and articles can be found by topic or keyword. The key terms in each article are cross-referenced, and there are a number of links to relevant Web sites after each article. The encyclopedia highlights the new terms that have been added, and there is a 'Term of the day'.

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computer-aided design

use of computers to create and modify design drawings; see CAD.

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computer-aided manufacturing

use of computers to regulate production processes in industry; see CAM.

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computer art

art produced with the help of a computer. From the 1950s the aesthetic use of computers became increasingly evident in most artistic disciplines, including film animation, architecture, and music.

Computer graphics (CG) has been the most developed area, with the 'paint-box' computer liberating artists from the confines of the canvas. It is now also possible to program computers in advance to generate graphics, music, and sculpture, according to 'instructions' which may include a pre-programmed element of unpredictability. In this last function, computer technology has been seen as a way of challenging the elitist nature of art by putting artistic creativity within relatively easy reach of anyone owning a computer.

Museum of Computer Art

Go to site

This site presents a range of computer art from 'Scanned acrylics and oils', to 'Fractal art', and 'Algorithmic art', produced by a number of different artists. This is an interesting site introducing a different and modern form of art.

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computer-assisted learning

use of computers in education and training; see CAL.

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computer game

or video game

any computer-controlled game in which the computer (sometimes) opposes the human player. Computer games typically employ fast, animated graphics on a VDU (visual display unit) and synthesized sound.

Commercial computer games became possible with the advent of the microprocessor in the mid-1970s and rapidly became popular as amusement-arcade games, using dedicated chips. Available games range from chess to fighter-plane simulations.

Some of the most popular computer games in the early 1990s were id Software's *Wolfenstein 3D*, *Doom*, and *Quake*, which were designed to be played across networks including the Internet. A whole subculture developed around those particular games, as users took advantage of id Software's help to create their own additions to the games. Later games such as *EverQuest* and *Runescape* are examples of Massively Multi-Player On-line Role Playing Games (MMORPGs), where game play takes place in virtual on-line worlds with millions of players and has given rise to subcultures and synthetic economies.

With the introduction and rapid adoption of games consoles such as the Microsoft Xbox and Sony PlayStation, as well as the boom in home computing, the computer games industry has undergone a period of massive expansion. The industry has however been criticized for releasing many violent games with little intellectual content.

Game FAQs

Go to site

Comprehensive set of guides and 'walk throughs' for computers and console games. Read reviews of popular and unreleased games, find solutions to specific gaming questions, and chat with other gamers.

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computer generation

any of the five broad groups into which computers may be classified chronologically: **first generation**, the earliest computers, developed in the 1940s and 1950s, made from valves and wire circuits; **second generation** from the late 1950s to the early 1960s, based on transistors and printed circuits; **third generation** from the early 1960s to 1970, using integrated circuits and often sold as families of computers, such as the IBM 360 series; and **fourth generation**, from the 1970s and currently still in use, using microprocessors, large-scale and very large-scale integration (LSI and VLSI), and sophisticated programming languages.

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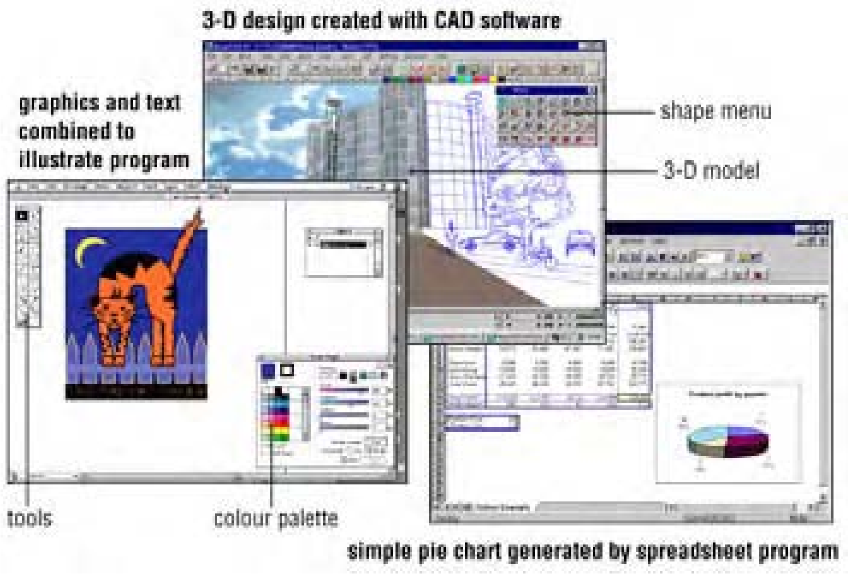
computer graphics

CG

use of computers to display and manipulate information in pictorial form. Input may be achieved by scanning an image, by drawing with a mouse or stylus on a graphics tablet, or by drawing directly on the screen with a light pen.

The output may be as simple as a pie chart, or as complex as an animated sequence in a science fiction film, or a seemingly three-dimensional engineering blueprint. The drawing is stored in the computer as raster graphics or vector graphics.

computer graphics


3-D design created with CAD software
graphics and text combined to illustrate program
shape menu
3-D model
tools
colour palette
simple pie chart generated by spreadsheet program

(Image © Research Machines plc)

Some examples of the kinds of graphic design that can be achieved using computers. Text and graphics may be combined within an illustration package, and sophisticated three-dimensional drawings can be created using a computer-aided design (CAD) system.

Computer Graphics World

Go to site

Packed with articles, reviews, and up-to-date information. The home page of *Computer Graphics World* magazine carries comprehensive coverage of the latest graphics news and events. This easily navigated Web site features an impressive and well-documented image gallery.

Exploratories Project

Go to site

Brown University project that introduces visitors to research into Web-based education. The Exploratories use two- and three-dimensional explorable worlds to offer learning experiences not attainable with conventional educational methods. Aimed at teachers and researchers, the site offers guided tours of subjects such as computer graphics, and links to sites of educational interest.

OptiView

Go to site

Essential bookmark for all devoted (or aspiring) Web writers, which offers a convenient wizard for reducing the size of GIF images, with trouble-free, instant delivery of up to 90% reductions.

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computerized axial tomography

medical technique, usually known as CAT scan, for noninvasive investigation of disease or injury.

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computer program

coded instructions for a computer; see program.

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computer simulation

representation of a real-life situation in a computer program. For example, the program might simulate the flow of customers arriving at a bank. The user can alter variables, such as the number of cashiers on duty, and see the effect.

More complex simulations can model the behaviour of chemical reactions or even nuclear explosions. The behaviour of solids and liquids at high temperatures can be simulated using quantum simulation. Computers also control the actions of machines – for example, a flight simulator models the behaviour of real aircraft and allows training to take place in safety. Computer simulations are very useful when it is too dangerous, time consuming, or simply impossible to carry out a real experiment or test.

Society For Modeling and Simulation International

Go to site

Detailing the structure and activities of the Society for Computer Simulation. There is information about the society's journals, forthcoming conferences, and membership. The Web site links to governmental and research facilities with an interest in computer simulation.

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computer terminal

device whereby the operator communicates with the computer; see terminal.

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computing device

any device built to perform or help perform computations, such as the abacus, slide rule, or computer.

The earliest known example is the abacus. Mechanical devices with sliding scales (similar to the slide rule) date from ancient Greece. In 1642, French mathematician Blaise Pascal built a mechanical adding machine and in 1672-74 German mathematician Gottfried Leibniz produced a machine to carry out multiplication. The first mechanical computer, the analytical engine, was designed by British mathematician Charles Babbage in 1835. For the subsequent history of computing, see computer.

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concave

of a surface, curving inwards, or away from the eye. For example, a bowl appears concave when viewed from above. In geometry, a concave polygon is one that has an interior angle greater than 180°. Concave is the opposite of convex.

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concave lens

lens that possesses at least one surface that curves inwards. It is a diverging lens, spreading out those light rays that have been refracted through it. A concave lens is thinner at its centre than at its edges, and is used to correct short-sightedness (myopia).

After light rays have passed through the lens, they appear to come from a point called the principal focus. The distance between the principle focus and the lens is the focal length. A more curved lens will have a smaller focal length and will be a more powerful lens. The image formed by a concave lens is virtual, upright, and smaller than the object, and it cannot be projected onto a screen. The lens formula is used to work out the position and nature of an image formed by a lens: $1/u + 1/v = 1/f$, where u and v are the distances of the object and image from the lens, respectively, and f is the focal length of the lens.

concave mirror

curved mirror that reflects light from its inner surface, the curve being inward. It may be either circular or parabolic in section. A concave mirror converges parallel light rays inward to the point of principal focus. The image formed by a concave mirror is real (reduced and inverted) if the object is not too close to the mirror. A real image is formed at the point of convergence. If the object is close to the mirror then the image formed will be virtual, enlarged, and upright, as the rays of light cannot converge to a point.

Only a parabolic concave mirror has a true, single-point principal focus for parallel rays. For this reason, parabolic mirrors are used as reflectors to focus light in telescopes, or to focus microwaves in satellite communication systems. The reflector behind a spot lamp or car headlamp is parabolic.

concentration

in chemistry, the amount of a substance (solute) present in a specified amount of a solution. Either amount may be specified as a mass or a volume (liquids only). Common units used are moles per cubic decimetre, grams per cubic decimetre, grams per 100 cubic centimetres, and grams per 100 grams.

The term also refers to the process of increasing the concentration of a solution by removing some of the substance (solvent) in which the solute is dissolved. In a **concentrated solution**, the solute is present in large quantities. Concentrated brine is around 30% sodium chloride in water; concentrated caustic soda (caustic liquor) is around 40% sodium hydroxide; and concentrated sulphuric acid is 98% acid.

concentric circles

two or more circles that share the same centre.

conch

name applied to various shells, but especially to the fountain shell, a species of gastropod mollusc in the order Mesogastropoda.

Concorde

the only supersonic airliner, which cruises at Mach 2, or twice the speed of sound, about 2,170 kph/1,350 mph. Concorde, the result of Anglo-French cooperation, made its first flight in 1969 and entered commercial service seven years later. It is 62 m/202 ft long and has a wing span of nearly 26 m/84 ft. Developing Concorde cost French and British taxpayers £2 billion. It was permanently grounded in October 2003, due to falling demand and safety issues.

A Concorde aircraft owned by Air France crashed on 25 July 2000, soon after taking off from Charles de Gaulle airport, Paris. All passengers and crew, totalling 109 people, were killed on board, as well as five people on the ground. It was later discovered that debris on the runway may have pierced a tyre which exploded and tore the fuel tank, which then caused a fire. Air France immediately grounded all Concorde aircraft; British Airways continued to fly until 15 August, when it was announced that the Civil Aviation Authority (CAA) was about to revoke the aircraft's certificate of airworthiness. Concorde resumed commercial flights on 7 November 2001 after a year of intensive checks and improvements.

Supersonic Spies

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page explores the future of supersonic air travel and offers glimpses of what the next generation of supersonic aeroplanes may look like. Watch a video clip of what NASA expects tomorrow's planes will look like in flight. Find out about the innovative features that keep the *Concorde* aloft. You can download a transcript of the television programme, and there is a list of resources for further reference.

Unofficial Concorde Home Page

Go to site

Features a detailed and illustrated history of Concorde, together with a large amount of technical information, a gallery, and also a guide to further study. This site is also available in French.

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concrete

building material composed of cement, stone, sand, and water. It has been used since Roman times. Since the late 19th century, it has been increasingly employed as an economical alternative to materials such as brick and wood, and has been combined with steel to increase its tension capacity.

Reinforced concrete and prestressed concrete are strengthened by combining concrete with another material, such as steel rods or glass fibres. The addition of carbon fibres to concrete increases its conductivity. The electrical resistance of the concrete changes with increased stress or fracture, so this 'smart concrete' can be used as an early indicator of structural damage.

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concurrent lines

two or more lines passing through a single point; for example, the diameters of a circle are all concurrent at the centre of the circle.

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concussion

temporary unconsciousness resulting from a blow to the head. It is often followed by amnesia for events immediately preceding the blow.

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condensation

in organic chemistry, a reaction in which two organic compounds combine to form a larger molecule, accompanied by the removal of a smaller molecule (usually water). This is also known as an addition-elimination reaction. Polyamides (such as nylon) and polyesters (such as Terylene) are made by condensation polymerization.

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condensation

conversion of a vapour to a liquid. This is frequently achieved by letting the vapour come into contact with a cold surface. It is the process by which water vapour turns into fine water droplets to form a cloud.

Condensation in the atmosphere occurs when the air becomes completely saturated and is unable to hold any more water vapour. As air rises it cools and contracts - the cooler it becomes the less water it can hold. Rain is frequently associated with warm weather fronts because the air rises and cools, allowing the water vapour to condense as rain. The temperature at which the air becomes saturated is known as the **dew point**. Water vapour will not condense in air if there are not enough condensation nuclei (particles of dust, smoke, or salt) for the droplets to form on. It is then said to be supersaturated. Condensation is an important part of the water cycle.

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condensation polymerization

polymerization reaction in which one or more monomers, with more than one reactive functional group, combine to form a polymer with the elimination of water or another small molecule.

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condenser

laboratory apparatus used to condense vapours back to liquid so that the liquid can be recovered. It is used in distillation and in reactions where the liquid mixture can be kept boiling without the loss of solvent.

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condenser

in electronic circuits, a former name for a capacitor.

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condenser

in optics, a lens or combination of lenses with a short focal length used for concentrating a light source onto a small area, as used in a slide projector or microscope substage lighting unit. A condenser can also be made using a concave mirror.

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conditioning

in psychology, two major principles of behaviour modification.

In **classical conditioning**, described by Russian psychologist Ivan Pavlov, a new stimulus can evoke an automatic response by being repeatedly associated with a stimulus that naturally provokes that response. For example, the sound of a bell repeatedly associated with food will eventually trigger salivation, even if sounded without food being presented. In **operant conditioning**, described by US psychologists Edward Lee Thorndike (1874-1949) and B F Skinner, the frequency of a voluntary response can be increased by following it with a reinforcer or reward.

condom

or sheath or prophylactic

barrier contraceptive, made of rubber, which fits over an erect penis and holds in the sperm produced by ejaculation. It is an effective means of preventing pregnancy if used carefully, preferably with a spermicide. A condom with spermicide is 97% effective; one without spermicide is 85% effective as a contraceptive. Condoms can also give some protection against sexually transmitted diseases, including AIDS.

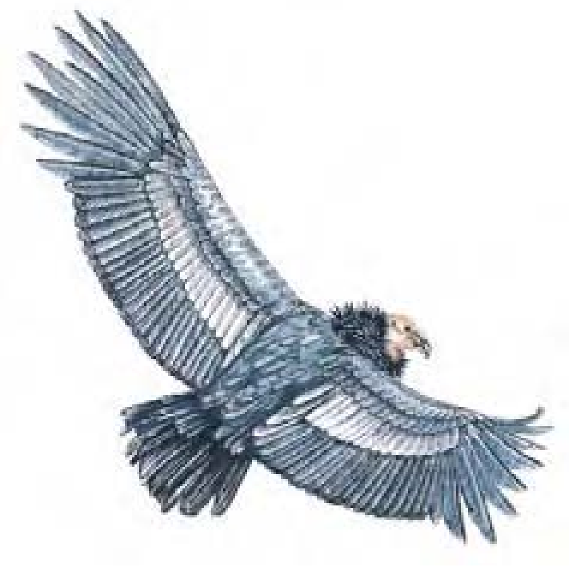
In 1996 the European Union agreed a standard for condoms, which is 17 cm/6.7 in long; although the width can be variable, a regular width was agreed as 5.2 cm/2 in.

condor

name given to two species of birds in separate genera. The **Andean condor** *Vultur gryphus*, has a wingspan up to 3 m/10 ft, weighs up to 13 kg/28 lb, and can reach up to 1.2 m/3.8 ft in length. It is black, with some white on the wings and a white frill at the base of the neck. It lives in the Andes at heights of up to 4,500 m/14,760 ft, and along the South American coast, and feeds mainly on carrion. The **Californian condor** *Gymnogyps californianus* is a similar bird, with a wingspan of about 3 m/10 ft. It feeds entirely on carrion, and is on the verge of extinction.

The Californian condor lays only one egg at a time and may not breed every year. In 1994, only 89 Californian condors remained, of which only four were in the wild. It became the subject of a special conservation effort, and by July 1995 the number had increased to 104.

condor



(Image © Research Machines plc)

The Californian condor is one of the largest and heaviest birds in the world. It can soar to great heights and glide as far as 16 km/10 mi without moving its wings.

Condorcet, Marie Jean Antoine Nicolas de Caritat (1743-1794)

Marquis de Condorcet

French philosopher, mathematician, and politician, associated with the Encyclopédistes. In *Esquisse d'un tableau des progrès de l'esprit humain/Historical Survey of the Progress of Human Understanding* (1795), he traced human development from barbarity to the brink of perfection. As a mathematician he made important contributions to the theory of probability.

Although a keen supporter of the French Revolution, Condorcet opposed the execution of Louis XVI, and was imprisoned and poisoned himself. The *Esquisse* was written in prison. He also wrote in support of pacifism, sexual equality, and social services.

conductance

ability of a material to carry an electrical current, usually given the symbol *G*. For a direct current, it is the reciprocal of resistance: a conductor of resistance *R* has a conductance of 1/*R*. For an alternating current, conductance is the resistance *R* divided by the impedance*Z*: *G* = *R*/*Z*. Conductance was formerly expressed in reciprocal ohms (or mhos); the SI unit is the siemens (S).

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conduction, electrical

flow of charged particles through a material giving rise to electric current. Conduction in metals involves the flow of negatively charged free electrons. Conduction in gases and some liquids involves the flow of ions that carry positive charges in one direction and negative charges in the other. Conduction in a semiconductor such as silicon involves the flow of electrons and positive holes.

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conduction, heat

flow of heat energy through a material without the movement of any part of the material itself (compare conduction, electrical). Heat energy is present in all materials in the form of the kinetic energy of their constituent vibrating particles, and may be conducted from one particle to the next in the form of this vibration.

Different materials conduct heat at different rates. This rate is called the thermal conductivity. A good conductor of heat, such as steel, will have a high thermal conductivity and poor conductor of heat, such as air, will have a low thermal conductivity. In general, non-metals, such as wood or glass, are poor conductors of heat.

In the construction industry, the thermal conductivities of the materials to be installed need to be known. A low thermal conductivity indicates that a material is a poor conductor of heat and therefore a good insulator. For example, foam is used to insulate lofts, the air trapped in the foam making it a good insulator. Bricks used in outer walls have tiny air spaces, again allowing air to be trapped and making the bricks good insulators. Insulation can also be achieved with double-glazed windows, with the space between the two glass panes containing air or a vacuum.

heat transfer

To remember the principles of heat transfer:

Conduction - imagine a line of passengers on a bus being asked to move down by the **conductor**, each passenger causing the next to bustle along (analogy for the movement/vibration of atoms that is passed along, causing heat to be transferred)
Convection - consider **vector**, a disease-carrying insect, e.g. a mosquito, which travels in swarms (very much like the movement of convection currents)
Radiation - heat radiation is a form of radiation - (think of nuclear fallout or the Sun's radiation) and thus travels in waves undetected until they fall upon another body

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conductor

any material that conducts heat or electricity (as opposed to an insulator, or nonconductor). A good conductor has a high electrical or heat conductivity, and is generally a substance rich in loosely-held free electrons, such as a metal. Copper and aluminium are good conductors. A poor conductor (such as the non-metals glass, porcelain, and rubber) has few free electrons and resists the flow of electricity or heat. Carbon is exceptional in being non-metallic and yet (in some of its forms) a relatively good conductor of heat and electricity. Substances such as silicon and germanium, with intermediate conductivities that are improved by heat, light, or impurities, are known as semiconductors.

Liquids (including water) can also be electrical conductors. Electricity (current) can flow by the movement of charged ions through a solution or a molten salt (electrolyte). This process is called electrolysis.

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cone

in botany, the reproductive structure of the conifers and cycads; also known as a strobilus. It consists of a central axis surrounded by numerous, overlapping, scalelike, modified leaves (sporophylls) that bear the reproductive organs. Usually there are separate male and female cones, the former bearing pollen sacs containing pollen grains, and the larger female cones bearing the ovules that contain the ova or egg cells. The pollen is carried from male to female cones by the wind (anemophily). The seeds develop within the female cone and are released as the scales open in dry atmospheric conditions, which favour seed dispersal.

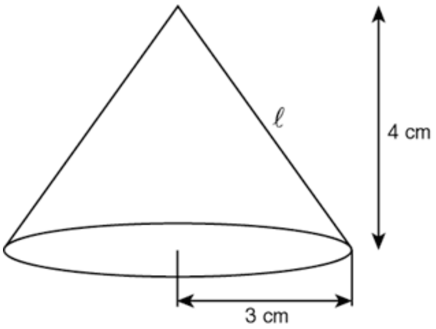
In some groups (for example, the pines) the cones take two or even three years to reach maturity. The cones of junipers have fleshy cone scales that fuse to form a berrylike structure. One group of angiosperms, the alders, also bear conelike structures; these are the woody remains of the short female catkins, and they contain the alder fruits.

cone

in geometry, a pyramid with a circular base. If the point (vertex) is directly above the centre of the circle, it is known as a **right circular cone**. The volume (V) of this cone is given by the formula $V = 1/3\pi r^2 h$ where h is the perpendicular height and r is the base radius.

A right circular cone is generated by rotating an isosceles triangle about its line of symmetry. The distance from the edge of the base of a cone to the vertex is called the slant height. In a right circular cone of slant height l, the curved surface area is $\pi r l$, and the area of the base is πr^2. Therefore the total surface area $A = \pi r l + \pi r^2 = \pi r(l + r)$.

For example, to find the volume and surface area of a cone with a perpendicular height of 4 cm and radius of 3 cm:

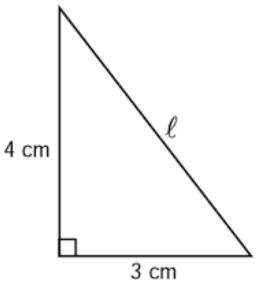


Volume = $1/3\pi r^2 h$, so

$V = 1/3\pi \times 3^2 \times 4$

$V = 37.7$ cm^3 (to 1 decimal place)

Surface area = $\pi r(l + r)$. First the slant length (l) is calculated:



Using Pythagoras' theorem,

$l^2 = h^2 + r^2$, so

$l^2 = 4^2 + 3^2 = 16 + 9 = 25$, so

$l = 5$ cm

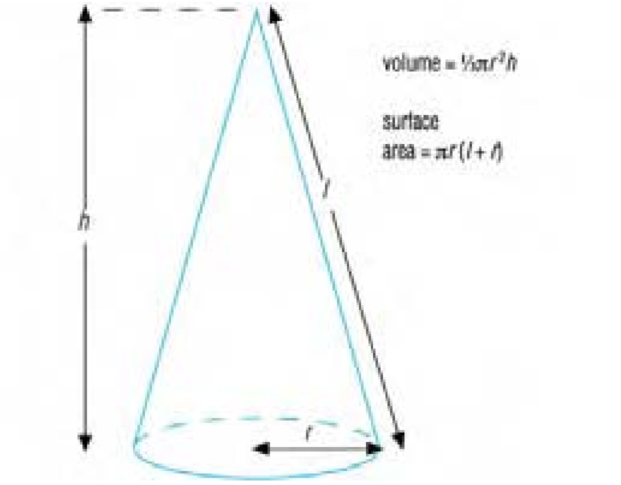
The surface area can now be calculated:

$A = \pi r(l + r)$, so

$A = \pi \times 3(3 + 5) = 3\pi \times 8 = 24\pi$, so

$A = 75.4$ cm^2 (to 1 decimal place)

cone


volume = $\frac{1}{3}\pi r^2 h$
surface area = $\pi r(l + r)$
h
l
r

(Image © Research Machines plc)

The volume and surface area of a cone are given by formulae involving a few simple dimensions.

congenital disease

in medicine, a disease that is present at birth. It is not necessarily genetic in origin; for example, congenital herpes may be acquired by the baby as it passes through the mother's birth canal.

conger

any large marine eel of the family Congridae, especially the genus *Conger*. Conger eels live in shallow water, hiding in crevices during the day and active by night, feeding on fish and crabs. They are valued for food and angling.

congestion

in traffic, the overcrowding of a route, leading to slow and inefficient flow. Congestion on the roads is a result of the large increase in car ownership. It may lead to traffic jams and long delays as well as pollution. Congestion within urban areas may also restrict accessibility.

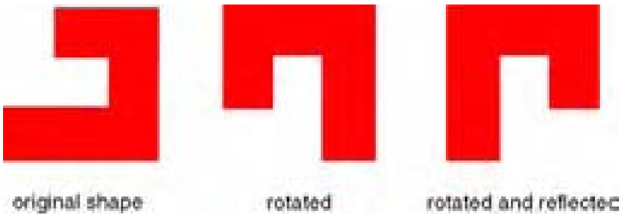
conglomerate

in geology, a type of sedimentary rock composed of rounded fragments ranging in size from pebbles to boulders, cemented together in a finer sand or clay material.

congruent

in geometry, having the same shape and size (and area), as applied to two-dimensional or solid figures. With plane congruent figures, one figure will fit on top of the other exactly, though this may first require rotation, translation, or reflection of one of the figures.

congruent



(Image © Research Machines plc)

Congruent shapes are the same size and the same shape. Both B and C are the same size and shape as A, so they are said to be congruent to A.

conical

having the shape of a cone.

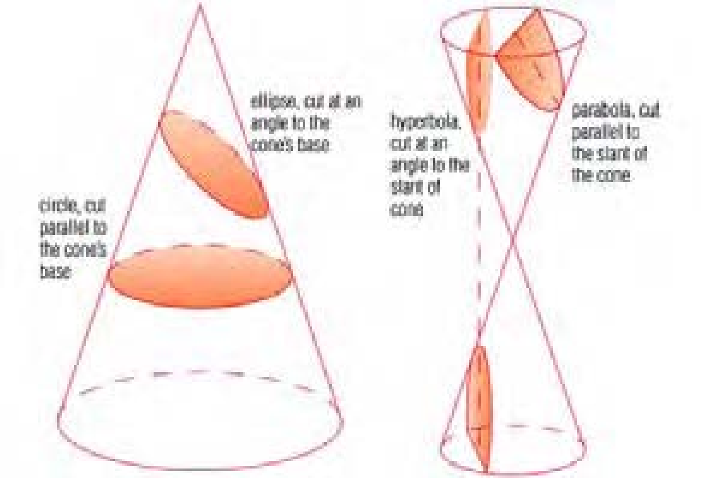
---

conic section

curve obtained when a conical surface is intersected by a plane. If the intersecting plane cuts both extensions of the cone, it yields a hyperbola; if it is parallel to the side of the cone, it produces a parabola. Other intersecting planes produce circles or ellipses.

The Greek mathematician Apollonius of Perga wrote eight books with the title *Conic Sections*, which superseded previous work on the subject by Aristarchus and Euclid.

conic section


ellipse, cut at an angle to the cone's base
circle, cut parallel to the cone's base
hyperbola, cut at an angle to the slant of cone
parabola, cut parallel to the slant of the cone

(Image © Research Machines plc)

The four types of curve that may be obtained by cutting a single or double right-circular cone with a plane (two-dimensional surface).

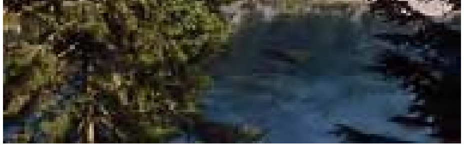
---

conifer

any of a large number of cone-bearing trees or shrubs. They are often pyramid-shaped, with leaves that are either scaled or needle-shaped; most are evergreen. Conifers include pines, spruces, firs, yews, junipers, monkey puzzles, and larches. (Order Coniferales.)

Conifers belong to the gymnosperm or naked-seed-bearing group of plants. The reproductive organs are the male and female cones, and pollen is scattered in the wind. The seeds develop in the female cones. The processes of reaching maturity, fertilization, and seed ripening may take several years. Most conifers grow quickly and can survive in poor soil, on steep slopes, and in short growing seasons. Coniferous forests are widespread in Scandinavia and upland areas of the UK such as the Scottish Highlands, and are often planted in afforestation schemes. Conifers also grow in woodland.

conifer



(Image © Garret Nagle)

Coniferous trees surround a glacial lake, among the Dolomite mountains in Italy. Forests in mountainous areas are often coniferous, because this type of evergreen tree is well suited to the soil, weather, and other environmental factors found at high altitudes.

conifer

(Image © Garret Nagle)

In many mountain areas there are large areas of coniferous forest. This is because temperatures are low, and the soil thin and acidic. Evergreen trees are also able to photosynthesize at low temperatures, and their conical shape helps them to get rid of snow during winter. Their wide roots also help them to survive rocking by high winds, and they are able to cling to steep slopes such as the one pictured.

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conjugate

in mathematics, a term indicating that two elements are connected in some way; for example, (a + ib) and (a - ib) are conjugate complex numbers.

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conjugate angles

two angles that add up to 360°.

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conjugation

in biology, temporary union of two single cells (or hyphae in fungi) with at least one of them receiving genetic material from the other: the bacterial equivalent of sexual reproduction. A fragment of the DNA from one bacterium is passed along a thin tube, the pilus, into another bacterium.

---

conjugation

in organic chemistry, the alternation of double (or triple) and single carbon-carbon bonds in a molecule - for example, in penta-1,3-diene, $H_2C{=}CH{-}CH{=}CH{-}CH_3$. Conjugation imparts additional stability as the double bonds are less reactive than isolated double bonds.

---

conjunction

in astronomy, alignment of two celestial bodies as seen from Earth. A superior planet (or other object) is in conjunction when it lies behind the Sun. An inferior planet (or other object) comes to **inferior conjunction** when it passes between the Earth and the Sun; it is at **superior conjunction** when it passes behind the Sun.

Planetary conjunction takes place when a planet is closely aligned with another celestial object, such as the Moon, a star, or another planet.

Because the orbital planes of the inferior planets are tilted with respect to that of the Earth, they usually pass either above or below the Sun at inferior conjunction. If they line up exactly, a transit will occur.

conjunctiva

membrane covering the front of the vertebrate eye. It is continuous with the epidermis of the eyelids, and lies on the surface of the cornea.

conjunctivitis

inflammation of the conjunctiva, the delicate membrane that lines the inside of the eyelids and covers the front of the eye. Symptoms include redness, swelling, and a watery or pus-filled discharge. It may be caused by infection, allergy, or other irritant.

connective tissue

in animals, tissue made up of a noncellular substance, the extracellular matrix, in which some cells are embedded. Skin, bones, tendons, cartilage, and adipose tissue (fat) are the main connective tissues. There are also small amounts of connective tissue in organs such as the brain and liver, where they maintain shape and structure.

connectivity

in mathematics, measure of how well connected places are in a transport network. A simple measure is the beta index.

conservation

in the life sciences, action taken to protect and preserve the natural world, usually from pollution, overexploitation, and other harmful features of human activity. The late 1980s saw a great increase in public concern for the environment, with membership of conservation groups, such as Friends of the Earth, Greenpeace, and the US Sierra Club, rising sharply and making the green movement an increasingly-powerful political force. Globally the most important issues include the depletion of atmospheric ozone by the action of chlorofluorocarbons (CFCs), the build-up of carbon dioxide in the atmosphere (thought to contribute to the greenhouse effect), and deforestation.

Conservation may be necessary to prevent an endangered species from dying out in an area or even becoming extinct. But conservation of particular habitats may be as important, if not more important. Habitat loss is believed to be the main cause of the great reduction of biodiversity and the rate of extinction occurring on Earth. There is concern about loss of species and biodiversity, because living organisms contribute to human health, wealth, and happiness in several ways. Humans often enjoy being in natural environments, especially those who spend much of their lives in towns and cities. Human cultures may be dependent on the natural environment to sustain them and maintain a stable society. This is particularly true of societies in the developing world. The spread of desert into arid areas around the Sahara has probably contributed to the unstable societies of some areas there. There is also an economic argument for conservation. It is believed that many undiscovered useful chemicals may exist within organisms on Earth that could be developed into important drugs - but when a plant or animal becomes extinct, the chemicals it contains are also lost.

Conservation: key events

1627	Last surviving aurochs, long-horned wild cattle that previously roamed Europe, southwest Asia, and North Africa, become extinct in Poland.
1664	A Dutch mandate is drawn up to protect forest in Cape Colony, South Africa.
1681	The last dodo dies on the island of Mauritius.
1764	The British establish forest reserves on Tobago, after deforestation in Barbados and Jamaica result in widespread soil erosion.
1769	The French pass conservation laws in Mauritius.
1868	First laws are passed in the UK to protect birds.
1948	The International Union for Conservation of Nature and Natural Resources (IUCN) is founded, with its sister organization, the World Wildlife Fund (WWF).
1970	The Man and the Biosphere Programme is initiated by UNESCO, providing for an international network of biosphere reserves.
1971	The Convention on Wetlands of International Importance (especially concerned with wildfowl habitat) is signed in Ramsar, Iran, and starts a List of Wetlands of International Importance.

1972	The Convention Concerning the Protection of the World Cultural and Natural Heritage is adopted in Paris, France, providing for the designation of World Heritage Sites.
1972	The UN Conference on the Human Environment held in Stockholm, Sweden, leads to the creation of the UN Environment Programme (UNEP).
1973	The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is signed in Washington, DC.
1974	The world's largest protected area, the Greenland National Park covering 97 million hectares, is created.
1980	The World Conservation Strategy, launched by the IUCN with the WWF and UNEP, shows how conservation contributes to development.
1982	The first herd of ten Arabian oryx bred from a 'captive breeding' programme is released into the wild in Oman. The last wild oryx was killed in 1972.
1986	The first 'Red List' of endangered animal species is compiled by IUCN.
1989	International trade in ivory is banned under CITES legislation in an effort to protect the African elephant from poachers. The Montreal Protocol on substances that deplete the ozone layer comes into force.
1992	The UN convenes the 'Earth Summit' in Rio de Janeiro, Brazil, to discuss global planning for a sustainable future. The Convention on Biological Diversity and the Convention on Climate Change are opened for signing.
1995	The Arabian oryx conservation programme (began 1962), the most successful attempt at reintroducing zoo-bred animals to the wild, comes to an end as the last seven animals are flown from the USA to join the 228-strong herd in Oman.
1996	The World Wide Fund for Nature has 5 million members in 28 countries.
1997	The world ban on the ivory trade is lifted in June 1997 at the tenth CITES convention. Trade is scheduled to resume in 1999 with Zimbabwe, Botswana, and Namibia the only countries allowed to export.
2005	The Kyoto Treaty, first negotiated in 1997, comes into force.

British Trust for Conservation Volunteers (BTCV)

Go to site

BTCV is the largest organization in the UK promoting practical conservation work by volunteers. Their Web site details 'Conservation opportunities' - volunteering, holidays, training, and employment - as well as information about 'BTCV enterprises' and links to other environmental resources.

Earthwatch Institute

Go to site

Earthwatch Institute promotes conservation through scientific field research, creating partnerships between scientists, educators, and the public. Members have the opportunity to work with distinguished researchers in a range of different fields; the site includes details of how to join, as well as news of current expeditions and research progress.

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conservation of energy

principle that states that in a chemical reaction, the total amount of energy in the system remains unchanged. Energy can be transferred from one form into another but cannot be created or destroyed.

In a chemical reaction, for each component there may be changes in energy due to change of physical state, changes in the nature of chemical bonds, and either an input or output of energy. However, there is no net gain or loss of energy. This is true outside of chemical reactions; for example the chemical energy of a battery is transferred into the electrical energy in a circuit, which can then be transferred into the heat and light energy of a bulb, but the total amount of energy is constant.

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conservation of mass

in chemistry, the principle that states that in a chemical reaction the sum of all the masses of the substances involved in the reaction (reactants) is equal to the sum of all of the masses of the substances produced by the reaction (products) - that is, no matter is gained or lost.

---

conservation of momentum

in mechanics, a law that states that total momentum is conserved (remains constant) in all collisions, providing no external resultant force acts on the colliding bodies. The principle may be expressed as an equation used to solve numerical problems: total momentum before collision = total momentum after collision.

---

constant

in mathematics, a fixed quantity or one that does not change its value in relation to variables. For example, in the algebraic expression $y^2 = 5x - 3$, the numbers 3 and 5 are constants. In physics, certain quantities are regarded as universal constants, such as the speed of light in a vacuum.

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constantan

or eureka

high-resistance alloy of approximately 40% nickel and 60% copper with a very low coefficient of thermal expansion (measure of expansion on heating). It is used in electrical resistors.

---

constant composition, law of

in chemistry, the law that states that the proportions of the amounts of the elements in a pure compound are always the same and are independent of the method by which the compound was produced.

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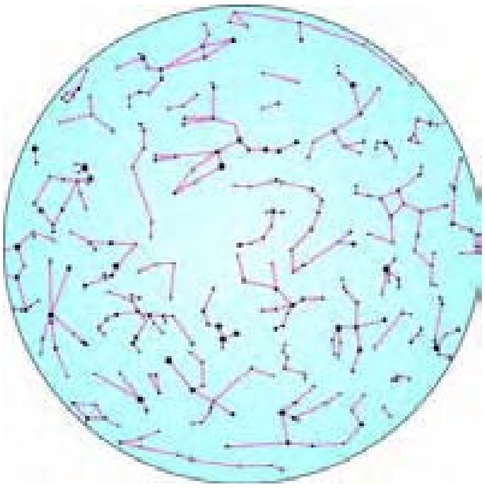
constellation

one of the 88 areas into which the sky is divided for the purposes of identifying and naming celestial objects. The first constellations were simple, arbitrary patterns of stars in which early civilizations visualized gods, sacred beasts, and mythical heroes.

The constellations used in scientific astronomy today are derived from a list of 48 known to the ancient Greeks, who inherited some from the Babylonians. The current list of 88 constellations was adopted by the International Astronomical Union, astronomy's governing body, in 1930. Traditional Chinese astronomy used different constellations; for example, the zodiac was divided into 28 'mansions' rather than the 12 constellations familiar in the West.

constellation



(Image © Research Machines plc)

The constellations as they appear in the southern and northern hemispheres' skies. The sky is divided into 88 areas for the purposes of identifying and naming celestial objects. The first constellations were simple, arbitrary patterns of stars in which early civilizations visualized gods, sacred beasts, and mythical heroes.

Stars and Constellations

Go to site

Hugely informative site on stars and constellations. It includes star charts of all major stars and constellations, details of the origins of the various names, photographs of galaxies and the Milky Way, and details on what stars can be seen at any given time.

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constipation

in medicine, the infrequent emptying of the bowel. The intestinal contents are propelled by peristaltic contractions of the intestine in the digestive process. The faecal residue collects in the rectum, distending it and promoting defecation. Constipation may be due to illness, alterations in food consumption, stress, or as an adverse effect of certain drugs. An increased intake of dietary fibre (see fibre, dietary) can alleviate constipation. Laxatives may be used to relieve temporary constipation but they should not be used routinely.

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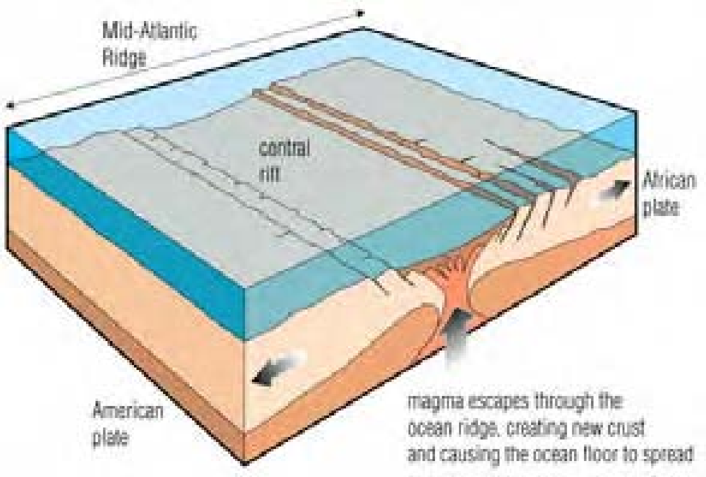
construction

in geometry, an addition to a figure, which is drawn to help solve a problem or produce a proof. The term is also applied to the accurate drawing of shapes.

constructive margin

in plate tectonics, a boundary between two lithospheric plates, along which new crust is being created. The term usually refers to divergent margins, where two oceanic plates are moving away from each other. As they diverge, magma (molten rock) wells up to fill the open space, and solidifies, forming new oceanic crust. Similar processes occur where a continent plate is beginning to split apart.

constructive margin


Mid-Atlantic Ridge
central rift
African plate
American plate
magma escapes through the ocean ridge, creating new crust and causing the ocean floor to spread

(Image © Research Machines plc)

A rift in the crustal plates where new material is being formed causes the plates to be pushed apart. This usually occurs as a result of volcanic action.

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consumption

(Latin consumptio 'wasting')

in medicine, former popular name for the disease tuberculosis.

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contact lens

lens, made of soft or hard plastic, that is worn in contact with the cornea and conjunctiva of the eye, beneath the eyelid, to correct defective vision. In special circumstances, contact lenses may be used as protective shells or for cosmetic purposes, such as changing eye colour.

The earliest use of contact lenses in the late 19th century was protective, or in the correction of corneal malformation. It was not until the 1930s that simplification of fitting technique by taking eye impressions made general use possible. Recent developments are a type of soft lens that can be worn for lengthy periods without removal, and a disposable soft lens that needs no cleaning but should be discarded after a week of constant wear.

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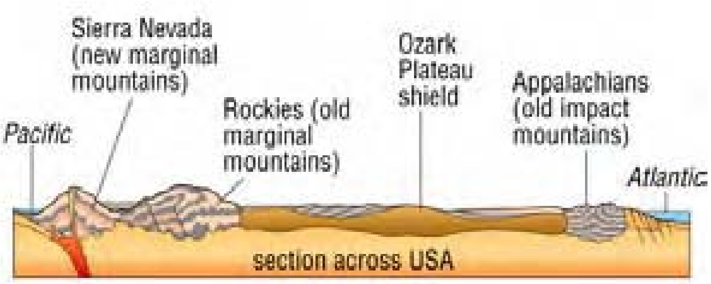
continent

any one of the seven large land masses of the Earth, as distinct from the oceans. They are Asia, Africa, North America, South America, Europe, Australia, and Antarctica. Continents are constantly moving and evolving (see plate tectonics). A continent does not end at the coastline; its boundary is the edge of the shallow continental shelf, which may extend several hundred kilometres out to sea.

Continental crust, as opposed to the crust that underlies the deep oceans, is composed of a wide variety of igneous, sedimentary, and metamorphic rocks. The rocks vary in age from recent (currently forming) to almost 4,000 million years old. Unlike the ocean crust, the continents are not only high standing, but extend to depths as great at 70 km/45 mi under high mountain ranges. Continents, as high, dry masses of rock, are present on Earth because of the density contrast between them and the rock that underlies the oceans. Continental crust is both thick and light, whereas ocean crust is thin and dense. If the crust were the same thickness and density everywhere, the entire Earth would be covered in water.

At the centre of each continental mass lies a shield or craton, a deformed mass of old metamorphic rocks dating from Precambrian times. The shield is thick, compact, and solid (the Canadian Shield is an example), and is usually worn flat. Around the shield is a concentric pattern of fold mountains, with older ranges, such as the Rockies, closest to the shield, and younger ranges, such as the coastal ranges of North America, farther away. This general concentric pattern is modified when two continental masses have drifted together and they become welded with a great mountain range along the join, the way Europe and northern Asia are joined along the Urals. If a continent is torn apart, the new continental edges have no mountains; for instance, South America has mountains (the Andes) along its western flank, but none along the east where it tore away from Africa 200 million years ago.

continent


Sierra Nevada (new marginal mountains)
Ozark Plateau shield
Appalachians (old impact mountains)
Pacific
Rockies (old marginal mountains)
Atlantic
section across USA

(Image © Research Machines plc)

The North American continent is growing in the west as a result of collision with the Pacific plate. On the east of the wide area of the Ozark Plateau shield lie the Appalachian Mountains, showing where the continent once collided with another continent. The eastern coastal rifting formed when the continents broke apart. On the western edge, new impact mountains have formed.

continents

To remember the seven continents:

Eat **an as**pirin **af**ter **a n**ight-time **s**nack

Europe, **An**tarctica, **As**ia, **Af**rica, **A**ustralia, **N**orth America, **S**outh America

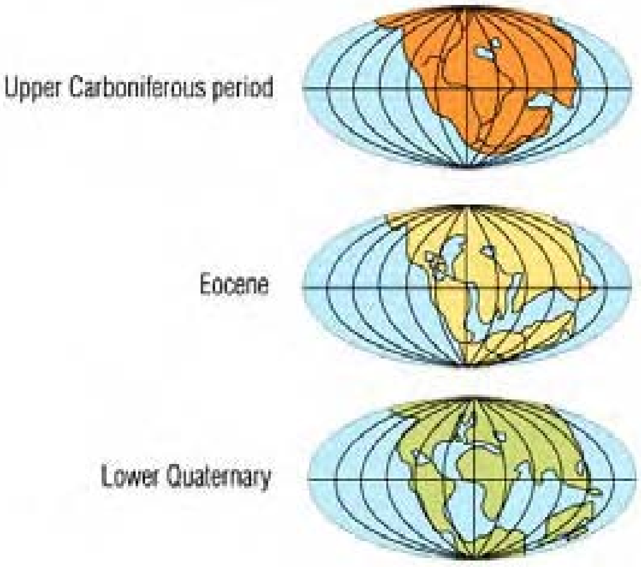
---

continental drift

in geology, the theory that, about 250-200 million years ago, the Earth consisted of a single large continent (Pangaea), which subsequently broke apart to form the continents known today. The theory was first proposed in 1912 by German meteorologist Alfred Wegener, but such vast continental movements could not be satisfactorily explained or even accepted by geologists until the 1960s.

The theory of continental drift gave way to the theory of plate tectonics. Whereas Wegener proposed that continents pushed their way through underlying mantle and ocean floor, plate tectonics states that continents are just part of larger lithospheric plates (which include ocean crust as well) that move laterally over the Earth's surface.

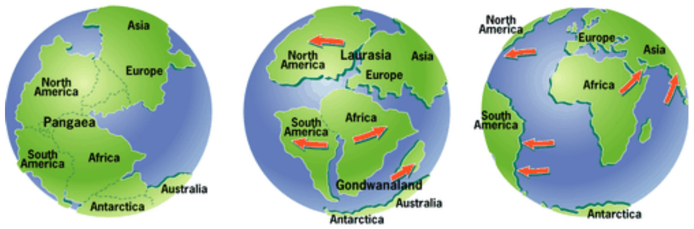
continental drift


Upper Carboniferous period
Eocene
Lower Quaternary

(Image © Research Machines plc)

The continents are slowly shifting their positions, driven by fluid motion beneath the Earth's crust. Over 200 million years ago, there was a single large continent called Pangaea. By 200 million years ago, the continents had started to move apart. By 50 million years ago, the continents were approaching their present positions.

continental drift



(Image © Research Machines plc)

The changing positions of the Earth's continents. Millions of years ago, there was a single large continent, Pangaea. This split 200 million years ago: the continents had started to move apart, to form Gondwanaland in the south and Laurasia in the north. By 50 million years ago the continents were almost in their present positions.

continental rise

portion of the ocean floor rising gently from the abyssal plain toward the steeper continental slope. The continental rise is a depositional feature formed from sediments transported down the slope mainly by turbidity currents. Much of the continental rise consists of coalescing submarine alluvial fans bordering the continental slope.

continental shelf

submerged edge of a continent, a gently sloping plain that extends into the ocean. It typically has a gradient of less than 1°. When the angle of the sea bed increases to 1°-5° (usually several hundred kilometres away from land), it becomes known as the continental slope.

continental slope

sloping, submarine portion of a continent. It extends downward from the edge of the continental shelf. In some places, such as south of the Aleutian Islands of Alaska, continental slopes extend directly to the ocean deeps or abyssal plain. In others, such as the east coast of North America, they grade into the gentler continental rises that in turn grade into the abyssal plains.

continuous data

in mathematics, data that can take any of an infinite number of values between whole numbers and so may not be measured completely accurately. This type of data contrasts with discrete data, in which the variable can only take one of a finite set of values. For example, the sizes of apples on a tree form continuous data, whereas the numbers of apples form discrete data.

continuum

in mathematics, a set that is infinite and everywhere continuous, such as the set of points on a line.

contour

on a map, a line drawn to join points of equal height. Contours are drawn at regular height intervals; for example, every 10 m. The closer together the lines are, the steeper the slope. Contour patterns can be used to interpret the relief of an area and to identify land forms.

contraceptive

any drug, device, or technique that prevents pregnancy. The contraceptive pill (the Pill) contains female hormones that interfere with egg production or the first stage of pregnancy. The 'morning-after' pill can be taken up to 72 hours after unprotected intercourse. Barrier contraceptives include condoms (sheaths), diaphragms, and sponges; they prevent the sperm entering the cervix (neck of the womb).

Intrauterine devices, also known as IUDs or coils, cause a slight inflammation of the lining of the womb; this prevents the fertilized egg from becoming implanted. See also family planning.

Other contraceptive methods include sterilization (women) and vasectomy (men); these are usually nonreversible. 'Natural' methods include withdrawal of the penis before ejaculation (coitus interruptus), and avoidance of intercourse at the time of ovulation (rhythm method). These methods are unreliable and normally only used on religious grounds. The use of any contraceptive (birth control) is part of family planning. The effectiveness of a contraceptive method is often given as a percentage. To say that a method has 95% effectiveness means that, on average, out of 100 healthy couples using that method for a year, 95 will not conceive.

contractile root

in botany, a thickened root at the base of a corm, bulb, or other organ that helps position it at an appropriate level in the ground. Contractile roots are found, for example, on the corms of plants of the genus *Crocus*. After they have become anchored in the soil, the upper portion contracts, pulling the plant deeper into the ground.

control experiment

essential part of a scientifically valid experiment, designed to show that the factor being tested is actually responsible for the effect observed. In the control experiment all factors, apart from the one under test, are exactly the same as in the test experiments, and all the same measurements are carried out. In drug trials, a placebo (a harmless substance) is given alongside the substance being tested in order to compare effects.

control unit

component of the central processing unit (CPU) that decodes, synchronizes, and executes program instructions.

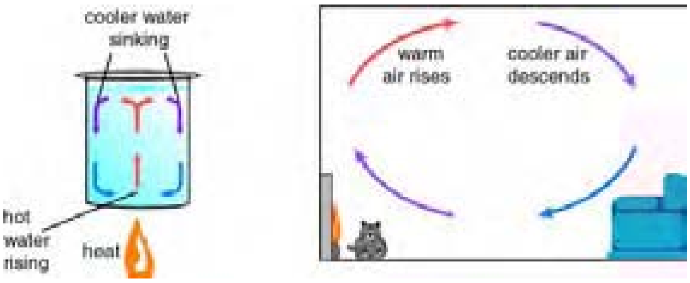
convection

transfer of heat energy that involves the movement of a fluid (gas or liquid). Fluid in contact with the source of heat expands and tends to rise within the bulk of the fluid. Cooler fluid sinks to take its place, setting up a convection current. This is the principle of natural convection in many domestic hot-water systems and space heaters.

Hot-air balloons use convection currents in order to rise into the air. The air inside the balloon is heated. As the hot air rises, so does the balloon. For the balloon to descend, the air in the balloon is cooled or allowed to escape.

Gravity and air currents allow gliders to fly. The glider falls by the force of gravity acting on it. It gains height in the air from rising, warm currents of air known as thermals. These currents are formed by air being heated by the ground; the heated air becomes less dense and rises.

convection



(Image © Research Machines plc)

Convection is the transfer of heat energy in a liquid or a gas. The fluid near the heat source is heated, becomes less dense, and rises upwards. Once away from the heat source, the fluid starts to cool, becomes denser, and starts to sink. A kettle uses the principle of convection currents. As the water at the bottom is heated by the element, it rises and brings cool water closer to the element.

convectional rainfall

rainfall associated with hot climates, resulting from the uprising of convection currents of warm air. Air that has been warmed by the extreme heating of the ground surface rises to great heights and is abruptly cooled. The water vapour carried by the air condenses and rain falls heavily. Convectional rainfall is often associated with a thunderstorm.

convection current

current caused by the expansion of a liquid, solid, or gas as its temperature rises. The expanded material, being less dense, rises, while colder, denser material sinks. Material of neutral buoyancy moves laterally. Convection currents arise in the atmosphere above warm land masses or seas, giving rise to sea breezes and land breezes, respectively. In some heating systems, convection currents are used to carry hot water upwards in pipes.

Convection currents in the hot, solid rock of the Earth's mantle help to drive the movement of the rigid plates making up the Earth's surface (see plate tectonics).

conventional current

direction in which an electric current is considered to flow in a circuit. By convention, the direction is that in which positive-charge carriers would flow - from the positive terminal of a cell to its negative terminal. It is opposite in direction to the flow of electrons. In circuit diagrams, the arrows shown on symbols for components such as diodes and transistors point in the direction of conventional current flow.

In the 19th century, with the early applications of electricity such as starter motors and light bulbs, there was not an exact understanding of the nature of current flow. It was assumed at the time that electricity flowed from the positive terminal to the negative.

convergence

in mathematics, the property of a series of numbers in which the difference between consecutive terms gradually decreases. The sum of a converging series approaches a limit as the number of terms tends to infinity.

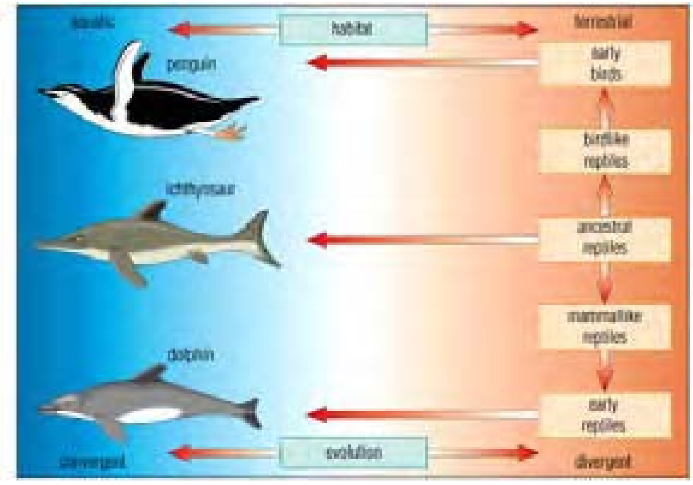
convergent evolution

or convergence

in biology, the independent evolution of similar structures in species (or other taxonomic groups) that are not closely related, as a result of living in a similar way. Thus, birds and bees have wings, not because they are descended from a common winged ancestor, but because their respective ancestors independently evolved flight.

In such cases, the structures often differ in their anatomical origins and are only superficially similar. Such structures are said to be 'analogous', in contrast to the homologous organs of related groups.

convergent evolution



(Image © Research Machines plc)

Convergent evolution produced the superficially similar streamlined bodies of the dolphin and penguin. Despite their very different evolutionary paths - one as a mammal, the other as a bird - both have evolved and adapted to the aquatic environment they now inhabit.

converging lens

lens that converges or brings to a focus those light rays that have been refracted by it. It is a convex lens, with at least one surface that curves outwards, and is thicker towards the centre than at the edge. Converging lenses are used to form real images in many optical instruments, such as cameras and projectors. A converging lens that forms a virtual, magnified image may be used as a magnifying glass or to correct long-sightedness (hypermetropia).

converse

in mathematics, the reversed order of a conditional statement; the converse of the statement 'if *a*, then *b* ' is 'if *b*, then *a* '. The converse does not always hold true; for example, the converse of 'if $x = 3$, then $x^2 = 9$' is 'if $x^2 = 9$, then $x = 3$', which is not true, as *x* could also be -3.

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conversion graph

graph for changing values from one unit to another, for example from Celsius to Fahrenheit.

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conversion table

a table for changing values from one unit to another, for example from imperial to metric.

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convertiplane

vertical takeoff and landing craft (VTOL) with rotors on its wings that spin horizontally for takeoff, but tilt to spin in a vertical plane for forward flight.

At takeoff it looks like a two-rotor helicopter, with both rotors facing skywards. As forward speed is gained, the rotors tilt slowly forward until they are facing directly ahead. There are several different forms of convertiplane. The LTV-Hillier-Ryan XC-142, designed in the USA, had wings, carrying the four engines and propellers, that rotated. The German VC-400 had two rotors on each of its wingtips. Neither of these designs went into production. A Bell/Boeing design, the V-22 Osprey, uses a pair of tilting engines, with propellers 11.5 m/38 ft across, mounted at the end of the wings. It was originally intended to carry about 50 passengers direct to city centres. Crashes of two prototypes led to design changes 1994, but the project continues.

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convex

of a surface, curving outwards, or towards the eye. For example, the outer surface of a ball appears convex. In geometry, the term is used to describe any polygon possessing no interior angle greater than 180°. Convex is the opposite of concave.

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convex lens

lens that possesses at least one surface that curves outwards. It causes light to deviate inward, bringing the rays of light to a focus, and is thus called a converging lens. A convex lens is thicker at its centre than at its edges, and is used to correct long-sightedness (hypermetropism).

The distance between the lens and the point at which all the rays of light converge (the focal point) is called the focal length. The centre of the lens is known as the optical centre.

At close distance a convex lens forms a magnified virtual image of an object. At further distances the image formed is real, and it can be focused and projected onto a screen behind the lens. The real image formed is upside down, and it can be smaller than, the same size as, or larger than the object depending upon how far the object is from the lens.

Ray diagrams are used to show the position (distance from the lens), size (enlarged or diminished), and nature (real, virtual, inverted, or upright) of an image formed. The lens formula is used to work out the position and nature of an image formed by a lens: $1/u + 1/v = 1/f$, where *u* and *v* are the distances of the object and image from the lens, respectively, and *f* is the focal length of the lens.

---

convex mirror

curved mirror that reflects light from its outer surface, the curve being outward. Rays of light are caused to diverge outward on reflection. It forms a reduced, upright, virtual image. Convex mirrors give a wide field of view and are therefore particularly suitable for car wing mirrors and surveillance purposes in shops.

---

conveyor

device used for transporting materials. Widely used throughout industry is the **conveyor belt**, usually a rubber or fabric belt running on rollers. Trough-shaped belts are used, for example in mines, for transporting ores and coal.
Chain conveyors are also used in coal mines to remove coal from the cutting machines. Crossbars attached to an endless chain drag the coal along a trough. Overhead endless chain conveyors are used to carry components and bodies in car-assembly works. Other types include **bucket conveyors** and **screw conveyors**, powered versions of the Archimedes screw.

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convolvulus

or bindweed

any of a group of plants belonging to the morning-glory family. They are characterized by their twining stems and by their petals, which are joined into a funnel-shaped tube. (Genus *Convolvulus*, family Convolvulaceae.)

Convolvulus, Field

Go to site

Informative resource relating to field convolvulus, or field bindweed. It contains a detailed description of the plant, including information about its blooming pattern, its habitat, and its propagation methods. Also included here are links to information about related plants, including the jalap bindweed.

convulsion

series of violent contractions of the muscles over which the patient has no control. It may be associated with loss of consciousness. Convulsions may arise from any one of a number of causes, including brain disease (such as epilepsy), injury, high fever, poisoning, and electrocution.

Cooley's anaemia

alternative name for thalassaemia.

Cooper, Leon Niels (1930-)

US physicist who in 1955 began work on the phenomenon of superconductivity. He proposed that at low temperatures electrons would be bound in pairs (since known as **Cooper pairs**) and in this state electrical resistance to their flow through solids would disappear. He was awarded the Nobel Prize for Physics in 1972 for his work on the theory of superconductivity. He shared the award with John Bardeen and J Robert Schrieffer.

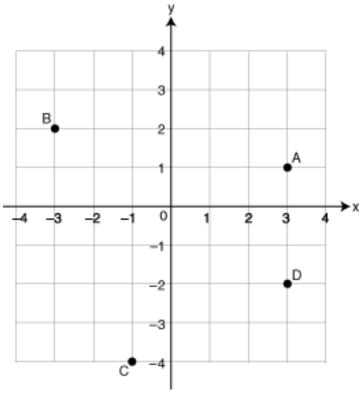
cooperative farming

system in which individual farmers pool their resources (excluding land) to buy commodities such as seeds and fertilizers, and services such as marketing. It is a system of farming found throughout the world and is particularly widespread in Denmark and the ex-Soviet republics. In a collective farm, land is also held in common.

coordinate

in geometry, a number that defines the position of a point relative to a point or axis (reference line). Cartesian coordinates define a point by its perpendicular distances from two or more axes drawn through a fixed point mutually at right angles to each other. Polar coordinates define a point in a plane by its distance from a fixed point and direction from a fixed line.

When working on the two-dimensional plane the coordinates can be plotted on a graph.

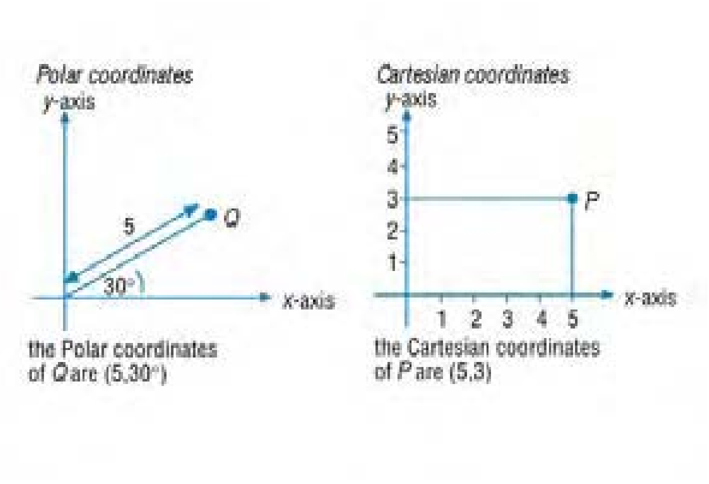


The coordinates of the points A, B, C, and D are: A (3, 1), B (-3, 2), C (-1, -4), D (3, -2). Coordinates can, therefore, be both positive numbers, both negative numbers, or a positive and a negative number. The *x*- and *y*-axes intersect to create four quadrants.

Once plotted, coordinates can be joined up to obtain straight-line graphs from linear equations or curves from quadratic equations and cubic equations. The intercept and gradient can be calculated.

Distance-time graphs and conversion graphs are both obtained by plotting coordinates.

coordinate



(Image © Research Machines plc)

Coordinates are numbers that define the position of points in a plane or in space. In the Cartesian coordinate system, a point in a plane is charted based upon its location along intersecting horizontal and vertical axes. In the polar coordinate system, a point in a plane is defined by its distance from a fixed point and direction from a fixed line.

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coordinate geometry

or analytical geometry

system of geometry in which points, lines, shapes, and surfaces are represented by algebraic expressions. In plane (two-dimensional) coordinate geometry, the plane is usually defined by two axes at right angles to each other, the horizontal *x*-axis and the vertical *y*-axis, meeting at O, the origin. A point on the plane can be represented by a pair of Cartesian coordinates, which define its position in terms of its distance along the *x*-axis and along the *y*-axis from O. These distances are, respectively, the *x* and *y* coordinates of the point.

Lines are represented as equations; for example, $y = 2x + 1$ gives a straight line, and $y = 3x^2 + 2x$ gives a parabola (a curve). The graphs of varying equations can be drawn by plotting the coordinates of points that satisfy their equations, and joining up the points. One of the advantages of coordinate geometry is that geometrical solutions can be obtained without drawing but by manipulating algebraic expressions. For example, the coordinates of the point of intersection of two straight lines can be determined by finding the unique values of *x* and *y* that satisfy both of the equations for the lines, that is, by solving them as a pair of simultaneous equations. The curves studied in simple coordinate geometry are the conic sections (circle, ellipse, parabola, and hyperbola), each of which has a characteristic equation.

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coot

freshwater bird of the genus *Fulica* in the rail family, order Gruiformes. Coots are about 38 cm/1.2 ft long, and mainly black. They have a white bill, extending up the forehead in a plate, and big feet with four lobed toes. Coots are omnivores, but feed mainly on water weed, except as chicks, when they feed on insects and other invertebrates.

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copepod

crustacean of the subclass Copepoda, mainly microscopic and found in plankton.

Copernicus, Nicolaus (1473-1543)

Polish Mikolaj Kopernik

Polish astronomer who believed that the Sun, not the Earth, is at the centre of the Solar System, thus defying the Christian church doctrine of the time. For 30 years, he worked on the hypothesis that the rotation and the orbital motion of the Earth are responsible for the apparent movement of the heavenly bodies. His great work *De Revolutionibus Orbium Coelestium/On the Revolutions of the Heavenly Spheres* was the important first step to the more accurate picture of the Solar System built up by Tycho Brahe, Kepler, Galileo, and later astronomers.

Copernicus proposed replacing Ptolemy's ideas with a model in which the planets (including the Earth) orbited a centrally situated Sun. He proposed that the Earth described one full orbit of the Sun in a year, whereas the Moon orbited the Earth. The Earth rotated daily about its axis (which was inclined at 23.5° to the plane of orbit), thus accounting for the apparent daily rotation of the sphere of the fixed stars.

This model was a distinct improvement on the Ptolemaic system for a number of reasons. It explained why the planets Mercury and Venus displayed only 'limited motion'; their orbits were inside that of the Earth's. Similarly, it explained that the planets Mars, Jupiter, and Saturn displayed such curious patterns in their movements ('retrograde motion', loops, and kinks) because they travel in outer orbits at a slower pace than the Earth. The movement of the Earth on its axis accounted for the precession of the equinoxes, previously discovered by Hipparchus.

Copernicus's model represents a complete reformation of astronomy by replacing the **anthropocentric** view of the universe with the **heliocentric** viewpoint. Unable to free himself from the constraints of classical thinking, however, Copernicus was able to imagine only circular planetary orbits. This forced him to retain the system of epicycles, with the Earth revolving around a centre that revolved around another centre, which in turn orbited the Sun. Kepler rescued the model by introducing the concept of elliptical orbits. Copernicus also held to the notion of spheres, in which the planets were supposed to travel. It was Brahe who finally rid astronomy of that concept.

Copernican System

Go to site

Good introduction to Copernicus's work. There are several portraits and pages from early manuscripts showing his concept of the Solar System. Embedded in the text are links to a number of other important astronomers.

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coplanar

in geometry, describing lines or points that all lie in the same plane.

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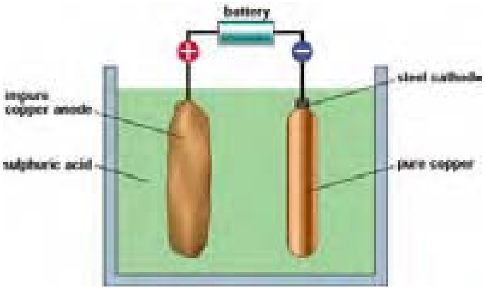
copper

chemical symbol Cu

red-brown, very malleable and ductile, metallic element, atomic number 29, relative atomic mass 63.546. Its symbol comes from the Latin *cuprum*. It is one of the transition metals in the periodic table. Copper is used for its durability, pliability, high thermal and electrical conductivity, and resistance to corrosion. It is used in electrical wires and cables, and water pipes and tanks.

Copper was the first metal used systematically for tools by humans; when mined and worked into utensils it formed the technological basis for the Copper Age in prehistory. When alloyed with tin it forms bronze, which is stronger than pure copper and may hold a sharp edge; the systematic production and use of this alloy was the basis for the prehistoric Bronze Age. Brass, another hard copper alloy, includes zinc. The element's name comes from the Latin *cyprium* ('Cyprus metal'), due to Cyprus being a major source of copper.

copper



(Image © Research Machines plc)

Copper purification by electrolysis. Pure copper dissolves from the impure copper anode, which decreases in size. The copper is deposited at the cathode, which increases in size. When the purification process is complete the cathode is melted down and cast into bars to be sold to manufacturers, such as producers of electrical wiring.

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copper ore

any mineral from which copper is extracted, including native copper, Cu; chalcocite, Cu_2S; chalcopyrite, $CuFeS_2$; bornite, Cu_5FeS_4; azurite, $Cu_3(CO_3)_2(OH)_2$; malachite, $Cu_2CO_3(OH)_2$; and chrysocolla, $CuSiO_3.2H_2O$.

Native copper and the copper sulphides are usually found in veins associated with igneous intrusions. Chrysocolla and the carbonates are products of the weathering of copper-bearing rocks. Copper was one of the first metals to be worked, because it occurred in native form and needed little refining. Today the main producers are the USA, Russia, Kazakhstan, Georgia, Uzbekistan, Armenia, Zambia, Chile, Peru, Canada, and the Democratic Republic of Congo (formerly Zaire).

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coppicing

woodland management practice of severe pruning where trees are cut down to near ground level at regular intervals, typically every 3-20 years, to promote the growth of numerous shoots from the base.

This form of forestry was once commonly practised in Europe, principally on hazel and chestnut, to produce large quantities of thin branches for firewood, fencing, and so on; alder, eucalyptus, maple, poplar, and willow were also coppiced. The resulting thicket was known as a coppice or copse. See also pollarding.

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copra

dried meat from the kernel of the coconut, used to make coconut oil.

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copulation

act of mating in animals with internal fertilization. Male mammals have a penis or other organ that is used to introduce spermatozoa into the reproductive tract of the female. Most birds transfer sperm by pressing their cloacas (the openings of their reproductive tracts) together.

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coral

marine invertebrate of the class Anthozoa in the phylum Cnidaria, which also includes sea anemones and jellyfish. It has a skeleton of lime (calcium carbonate) extracted from the surrounding water. Corals exist in warm seas, at moderate depths with sufficient light. Some coral is valued for decoration or jewellery, for example, Mediterranean red coral *Corallum rubrum*.

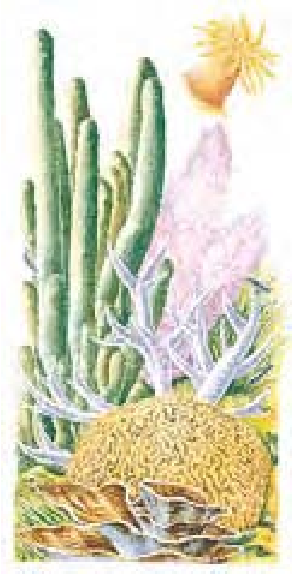
Corals live in a symbiotic relationship with microscopic algae (zooxanthellae), which are incorporated into the soft tissue. The algae obtain carbon dioxide from the coral polyps, and the polyps receive nutrients from the algae. Corals also have a relationship to the fish that rest or take refuge within their branches, and which excrete nutrients that make the corals grow faster. The majority of corals form large colonies although there are species that live singly. Their accumulated skeletons make up large coral reefs and atolls. The Great Barrier Reef, to the northeast of Australia, is about 1,600 km/1,000 mi long, has a total area of 20,000 sq km/7,700 sq mi, and adds 50 million tonnes of calcium to the reef each year. The world's reefs cover an estimated 620,000 sq km/240,000 sq mi.

Coral reefs provide a habitat for a diversity of living organisms. In 1997 some 93,000 species were identified. One third of the world's marine fishes live in reefs. The world's first global survey of coral reefs, carried out in 1997, found around 95% of reefs had experienced some damage from overfishing, pollution, dynamiting, poisoning, and the dragging of ships' anchors. A 1998 research showed that nearly two-thirds of the world's coral reefs were at risk, including 80% of the reefs in the Philippines and Indonesia, 66% of those in the Caribbean, and over 50% of those in the Indian Ocean, the Red Sea, and the Gulf of Arabia.

diseases

Since the 1990s, coral reefs have been destroyed by previously unknown diseases. The **white plague** attacked 17 species of coral in the Florida Keys, USA, in 1995. The **rapid wasting disease**, discovered in 1997, affects coral reefs from Mexico to Trinidad. In the Caribbean, the fungus *Aspergillus* attacks sea fans, a soft coral. It was estimated in 1997 that around 90% of the coral around the Galapagos islands had been destroyed as a result of 'bleaching', a whitening of coral reefs which occurs when the coloured algae evacuate the coral. This happens either because the corals produce toxins that are harmful to the algae or because they do not produce sufficient nutrients. Without the algae, the coral crumbles and dies away. Bleaching is widespread all over the Caribbean and the Indo-Pacific. A report published in November 1998 by Reef Check, an international organization, claimed that coral reefs are dying at a record rate throughout the world, and reefs which had existed for hundreds of years had suddenly died in 1998. Worldwide warming has caused bleaching of coral reefs in 50 or more countries in that year.

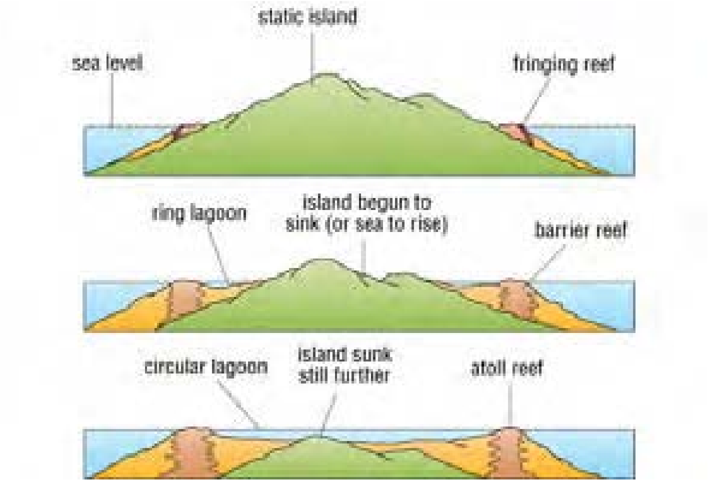
coral



(Image © Research Machines plc)

Corals are marine animals related to jellyfishes and sea anemones. Most hard or stony corals live as colonies of polyps that secrete a rigid external skeleton of lime. But there are also those that live as solitary individuals. Corals grow in a wide variety of forms as the types here demonstrate. Sea fans, for example, have an internal skeleton linking the polyps, while the polyps of the brain coral are arranged in rows.
The stagshorn coral gets its name from the resemblance of the colony to a male deer's antlers. The names of the plate and pillar corals also reflect their appearance.

coral atoll


static island
sea level
fringing reef
ring lagoon
island begun to sink (or sea to rise)
barrier reef
circular lagoon
island sunk still further
atoll reef

(Image © Research Machines plc)

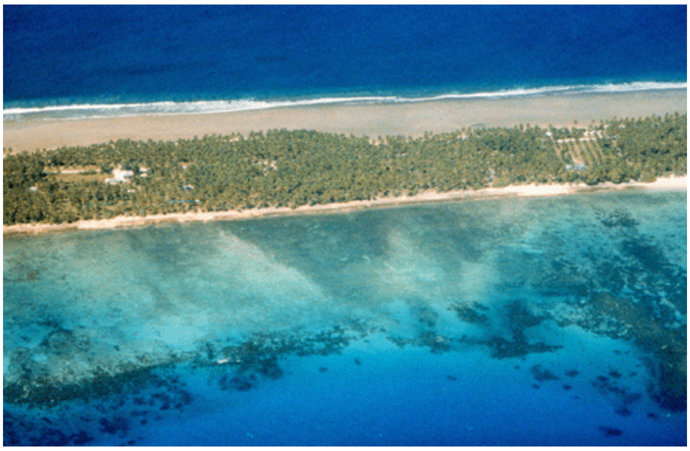
The formation of a coral atoll by the gradual sinking of a volcanic island. The reefs fringing the island build up as the island sinks, eventually producing a ring of coral around the spot where the island sank.

coral

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

A view of a classic coral atoll in the western Pacific. In effect it represents a frame for something that is no longer there: a volcanic peak that once protruded through the water surface in the middle, but has since eroded away. What is left is a circular island based upon coral that for the most part remains beneath the surface.

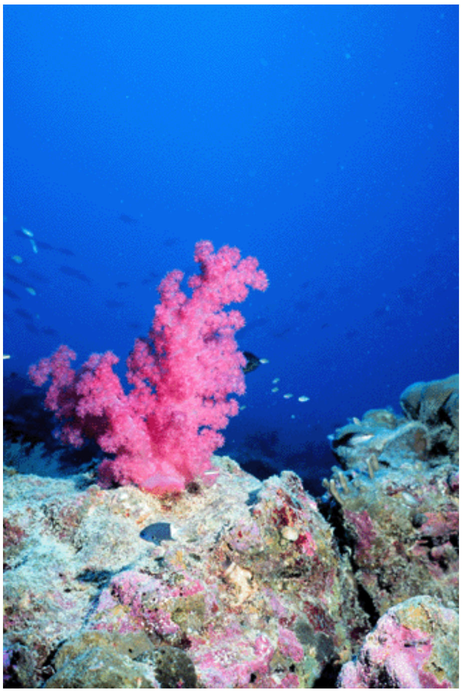
coral



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Many coral atolls are surrounded by a barrier reef enclosing a lagoon. This is a secondary phase of development, during which the atoll has taken on the mantle of the volcanic peak that once existed in the middle, and the reef is another atoll that is in turn forming around it.

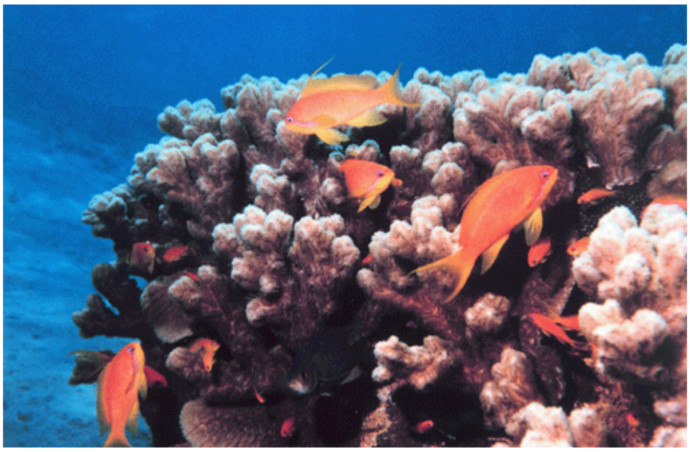
coral



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

A coral reef off Tarawa, northern Kiribati, in the Pacific. Pacific coral is renowned for its coloration - and yet the natural colour of coral (primarily composed of calcium carbonate) is matt white. The colours of coral (and 'coral' is itself generally counted as a colour that is not white) are caused by mineral impurities in the water absorbed by the coral organisms. Absorption of iron, for example, contributes to shades between pink and brown.

coral



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Coral in the Red Sea is under threat. The sea is a major shipping lane and has several popular tourist centres along its shores. Potentially, the pollution emitted could do serious damage to the coral that lines the coasts. This is particularly disturbing, since one theory regarding the origin of the name 'Red Sea' suggests the existence of an important symbiotic relationship between algae and the endangered coral.

coral

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

A shoal of carp around a coral reef in the Pacific Ocean. This familiar scene is under threat. Surveys during the 1990s proved that reefs were becoming subject to dangerous levels of pollution and physical damage. They are also experiencing new and pernicious diseases, affecting both the coral and the fish, algae, and other creatures that live in frequently symbiotic proximity.

Corals and Coral Reefs

Go to site

Extensive educational resource about coral, covering everything from classification and anatomy to diet and reproduction. There is also a section on the importance of coral and the measures being taken to conserve it.

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coral snake

venomous snake. *Elaps corallinus* is a typical specimen; it occurs in the tropical forests of South America, and its small body, less than 1 m/3.3 ft in length, is ringed with coral-red. It is highly poisonous.

classification

Coral snakes are in the family Elapidae, suborder Serpentes, order Squamata, class Reptilia.

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coral tree

any of several tropical trees with bright red or orange flowers and producing a very lightweight wood. (Genus *Erythrina*, family Fabaceae.)

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cord

unit for measuring the volume of wood cut for fuel. One cord equals 128 cubic feet (3.456 cubic metres), or a stack 8 feet (2.4 m) long, 4 feet (1.2 m) wide, and 4 feet high.

---

cordierite

silicate mineral, $(Mg,Fe)_2Al_4Si_5O_{18}$, blue to purplish in colour. It is characteristic of metamorphic rocks formed from clay sediments under conditions of low pressure but moderate temperature; it is the mineral that forms the spots in spotted slate and spotted hornfels.

---

cordillera

group of mountain ranges and their valleys, all running in a specific direction, formed by the continued convergence of two tectonic plates (see plate tectonics) along a line. The term is applied especially to the principal mountain belt of a continent. The Andes of South America are an example.

---

core

in archaeology, a solid cylinder of sediment or soil collected with a coring device and used to evaluate the geological context and stratigraphy of archaeological material or to obtain palaeobotanical samples. Core can also mean the tool used to extract a core sample from the ground, or a stone blank from which flakes or blades are removed.

---

core

in earth science, the innermost part of the Earth. It is divided into an outer core, which begins at a depth of 2,900 km/1,800 mi, and an inner core, which begins at a depth of 4,980 km/3,100 mi. Both parts are thought to consist of iron-nickel alloy. The outer core is liquid and the inner core is solid.

The fact that seismic shear waves disappear at the mantle-outer core boundary indicates that the outer core is molten, since shear waves cannot travel through fluid. Scientists infer the iron-nickel rich composition of the core from the Earth's density and its moment of inertia, and the composition of iron meteorites, which are thought to be pieces of cores of small planets. The temperature of the core, as estimated from the melting point of iron at high pressure, is thought to be at least 4,000°C/7,232°F, but remains controversial. The Earth's magnetic field is believed to be the result of the movement of liquid metal in the outer core.

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corgi

breed of dog. See Welsh corgi.

Cori

Carl Ferdinand (1896-1984) and Gerty (Theresa, born Radnitz) (1896-1957)

Austro-Hungarian-born US biochemists who were awarded a Nobel Prize for Physiology and Medicine in 1947 for their work on the production and breakdown of glycogen - a derivative of glucose - for use as a store and source of energy. They shared the prize with Argentine physiologist Bernardo Houssay.

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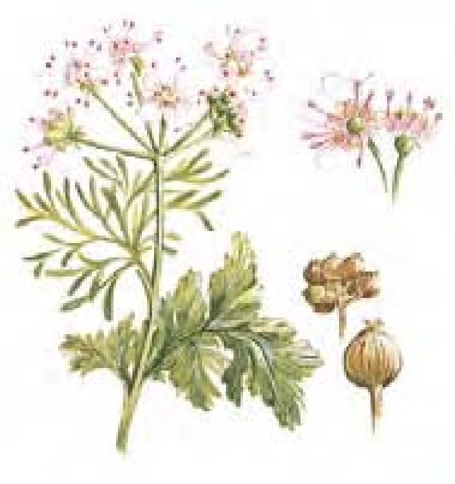
coriander

pungent fresh herb belonging to the parsley family, native to Europe and Asia; also a spice made from its dried ripe seeds. The spice is used commercially as a flavouring in meat products, bakery goods, tobacco, gin, liqueurs, chilli, and curry powder. Both are commonly used in cooking in the Middle East, India, Mexico, and China. (*Coriandrum sativum*, family Umbelliferae.)

coriander



(Image © Research Machines plc)

Coriander is a hardy annual growing to 45-60 cm/18-24 in. The fresh leaves are chopped and added to curries and other spiced dishes. Coriander originated on the eastern shores of the Mediterranean and has been cultivated for centuries.

Coriolis effect

effect of the Earth's rotation on the atmosphere, oceans, and theoretically all objects moving over the Earth's surface. In the northern hemisphere it causes moving objects and currents to be deflected to the right; in the southern hemisphere it causes deflection to the left. The effect is named after its discoverer, French mathematician Gaspard de Coriolis (1792-1843).

Coriolis Effect

Go to site

Subtitled 'a (fairly) simple explanation', this site contains a description of the principles involved, and is aimed at non-physicists.

---

cork

light, waterproof outer layers of the bark covering the branches and roots of almost all trees and shrubs. The cork oak (*Quercus suber*), a native of southern Europe and North Africa, is cultivated in Spain and Portugal; the exceptionally thick outer layers of its bark provide the cork that is used commercially.

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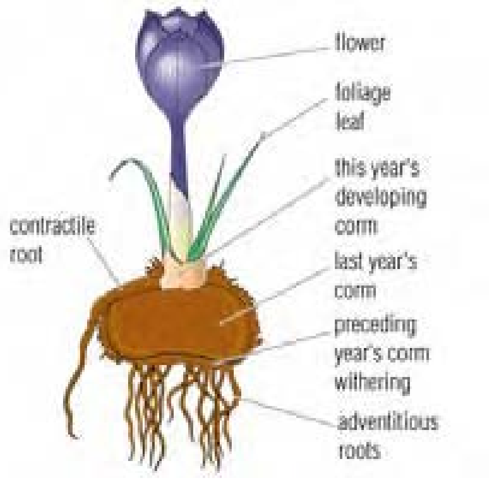
corm

short, swollen, underground plant stem, surrounded by protective scale leaves, as seen in the genus *Crocus*. It stores food, provides a means of vegetative reproduction, and acts as a perennating organ.

During the year, the corm gradually withers as the food reserves are used for the production of leafy, flowering shoots formed from axillary buds. Several new corms are formed at the base of these shoots, above the old corm.

corm



(Image © Research Machines plc)

Corms, found in plants such as the gladiolus and crocus, are underground storage organs. They provide the food for growth during adverse conditions such as cold or drought.

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cormorant

any of various diving seabirds, mainly of the genus *Phalacrocorax*, order Pelecaniformes, about 90 cm/3 ft long, with webbed feet, a long neck, hooked beak, and glossy black plumage. Cormorants generally feed on fish and shellfish, which they catch by swimming and diving under water, sometimes to a considerable depth. They collect the food in a pouch formed by the dilatable skin at the front of the throat. Some species breed on inland lakes and rivers.

P. carbo has a bright shiny head and neck, with bluish-black feathers, speckled with white. The general colour above is a greenish black, the throat white, and the bill and feet are dark grey. It is found in all parts of the world in coastal regions.

There are about 30 species of cormorant worldwide, including a flightless form *Nannopterum harrisi* in the Galapagos Islands; the **shag**, or **green cormorant**, *P. aristotelis*; and the **small European cormorant**, *Halietor pygmaeus*, which is a freshwater bird. The **guanay cormorant** *P. bougainvillei*, of the Peruvian coast, is the main producer of the guano of those regions.

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corn

UK maize

cultivated New World plant *Zea mays* of the grass family, with the grain borne on cobs enclosed in husks. It was domesticated by 6,500 BC in Mesoamerica, where it grew wild. It became the staple crop for the Neolithic farming villages and civilizations of Mexico and Peru. Today it is grown extensively in all subtropical and warm temperate regions, and its range has been extended to colder zones by hardy varieties developed in the 1960s.

Corn was cultivated throughout most of the New World by the time of European contact. It was brought to Europe, Asia, and Africa by the colonizing powers, but its use in those regions is mainly for animal feed. In the USA, a corn monoculture dominates the Midwest, where many hybrids have been developed for both human food and animal feed. Corn is eaten fresh (on the cob or creamed), canned (niblets), frozen, and in dried forms (cornmeal, popcorn), and is made into hominy, polenta, cornflour, and corn bread. It is pressed for corn oil and fermented into a mash, which, distilled, is corn liquor (whiskey). Most of the methods of storing, processing, and cooking corn can be traced to American Indian recipes. Popcorn has been found in archeological sites in the southwest dating from 4000 BC. Corn stalks are made into paper and hardboard.

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corncrake

or landrail

bird *Crex crex* of the rail family Rallidae, order Gruiformes. About 25 cm/10 in long, the bill and tail are short, the legs long and powerful, and the toes have sharp claws. It is drably coloured, shy, and has a persistent rasping call. The corncrake can swim and run easily, but its flight is heavy. It lives in meadows and crops in temperate regions, but has become rare where mechanical methods of cutting corn are used.

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cornea

transparent front section of the vertebrate eye. The cornea is curved and behaves as a fixed lens, so that light entering the eye is partly focused before it reaches the lens.

There are no blood vessels in the cornea and it relies on the fluid in the front chamber of the eye for nourishment. Further protection for the eye is provided by the conjunctiva. In humans, diseased or opaque parts may be replaced by grafts of corneal tissue from a donor.

---

cornflower

native European and Asian plant belonging to the same genus as the knapweeds but distinguished from them by its deep azure-blue flowers. Formerly a common weed in northern European wheat fields, it is now widely grown in gardens as a herbaceous plant with flower colours ranging from blue through shades of pink and purple to white. (*Centaurea cyanus*, family Compositae.)

Cornflower

Go to site

Detailed information about the cornflower, including a description of the plant and its habitat. There are also extensive notes on the possible uses of cornflower, which include making ink and potpourri and treating bruises.

Cornforth, John Warcup (1917-)

Australian chemist. Using radioisotopes as markers, he found out how cholesterol is manufactured in the living cell and how enzymes synthesize chemicals that are mirror images of each other (optical isomers).

He shared the Nobel Prize for Chemistry in 1975 with Swiss chemist Vladimir Prelog for his work in the stereochemistry of enzyme-catalysed reactions. He was knighted in 1977.

---

corolla

a collective name for the petals of a flower. In some plants the petal margins are partially or completely fused to form a **corolla tube**, for example in morning glories *Convolvulus*.

---

corona

faint halo of hot (about 2,000,000°C/3,600,000°F) and tenuous gas around the Sun, which boils from the surface. It is visible at solar eclipses or through a **coronagraph**, an instrument that blocks light from the Sun's brilliant disc. Gas flows away from the corona to form the solar wind. It is not certain why the corona is so much hotter than the surface of the Sun (about 6,700°C/12,100°F). The heating may be due to interactions with the Sun's magnetic field, or to pulses of sound waves from the Sun. NASA's Reuven Ramaty High-Energy Solar Spectroscopic Imager mission, launched in 2001, studies the evolution of energy in the corona.

Corona Australis

or Southern Crown

small constellation of the southern hemisphere, located near the constellation Sagittarius. It is similar in size and shape to Corona Borealis but is not as bright.

Corona Borealis

or Northern Crown

small but easily recognizable constellation of the northern hemisphere, between Hercules and Boötes, traditionally identified with the jewelled crown of Ariadne that was cast into the sky by Bacchus in Greek mythology. Its brightest star is Alphecca (or Gemma), which is 78 light years from Earth.

It contains several variable stars. R Coronae Borealis is normally fairly constant in brightness but fades at irregular intervals and stays faint for a variable length of time. T Coronae Borealis is normally faint, but very occasionally blazes up and for a few days may be visible to the naked eye. It is a recurrent nova.

---

coronary

in biology, describing any of several structures in the body that encircle an organ in the manner of a crown. For example, the coronary arteries arise from the aorta and deliver blood to the heart muscle.

---

coronary artery disease

(Latin corona 'crown', from the arteries encircling the heart)

condition in which the fatty deposits of atherosclerosis form in the coronary arteries that supply the heart muscle, narrowing them and restricting the blood flow.

These arteries may already be hardened (arteriosclerosis). If the heart's oxygen requirements are increased, as during exercise, the blood supply through the narrowed arteries may be inadequate, and the pain of angina results. A heart attack occurs if the blood supply to an area of the heart is cut off, for example because a blood clot (thrombus) has blocked one of the coronary arteries. The subsequent lack of oxygen damages the heart muscle (infarct), and if a large area of the heart is affected, the attack may be fatal. Coronary artery disease tends to run in families and is linked to smoking, lack of exercise, and a diet high in saturated (mostly animal) fats, which tends to increase the level of blood cholesterol. It is a common cause of death in many industrialized countries; older men are the most vulnerable group. The condition is treated with drugs or bypass surgery.

'Preventing Recurrent Coronary Heart Disease'

Go to site

Part of a collection of articles maintained by the *British Medical Journal*, this page features the full text of a 9 May 1998 editorial concerning coronary heart disease, in which the authors explain that lowering the heart rate may reduce mortality. In addition to the editorial, you will find a list of related articles from the *BMJ* 's collection and the extensive *PubMed* collection. You can also search the collections under which this article appears, search other articles written by the authors of this article, and submit or read responses to this article. There is also a list of references at the end of the article.

---

coronary thrombosis

in medicine, acute manifestation of coronary heart disease causing a heart attack.

---

corpus luteum

glandular tissue formed in the mammalian ovary after ovulation from the Graafian follicle, a group of cells associated with bringing the egg to maturity. It secretes the hormone progesterone in anticipation of pregnancy.

After the release of an egg the follicle enlarges under the action of luteinizing hormone, released from the pituitary. The corpus luteum secretes the hormone progesterone, which maintains the uterus wall ready for pregnancy. If pregnancy occurs, the corpus luteum continues to secrete progesterone until the fourth month; if pregnancy does not occur the corpus luteum breaks down.

---

corrasion

or abrasion

grinding away of solid rock surfaces by particles carried by water, ice, and wind. It is generally held to be the most significant form of erosion in rivers. As the eroding particles are carried along they are eroded themselves (becoming rounder and smaller) due to the process of attrition.

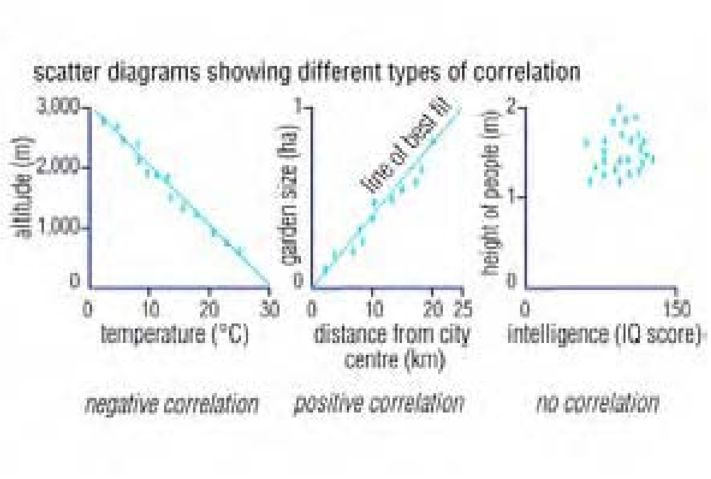
---

correlation

degree of relationship between two sets of information. If one set of data increases at the same time as the other, the relationship is said to be **positive** or direct. If one set of data increases as the other decreases, the relationship is **negative** or inverse. If there is no relationship between the two sets of data the relationship is said to be **zero linear correlation**. Correlation can be shown by plotting a line of best fit on a scatter diagram. The steeper the line drawn, whether positive or negative, the stronger the correlation.

In statistics, such relations are measured by the calculation of coefficients of correlation. These generally measure correlation on a scale with 1 indicating perfect positive correlation, 0 no correlation at all, and -1 perfect negative correlation. Correlation coefficients for assumed linear relations include the Pearson product moment correlation coefficient (known simply as the correlation coefficient), Kendall's tau correlation coefficient, or Spearman's rho correlation coefficient, which is used in nonparametric statistics (where the data are measured on ordinal rather than interval scales). A high correlation does not always indicate dependence between two variables; it may be that there is a third (unstated) variable upon which both depend.

correlation



(Image © Research Machines plc)

Scattergraphs showing different kinds of correlation. In this way, a causal relationship between two variables may be proved or disproved, provided there are no hidden factors.

---

correspondence

in mathematics, the relation between two sets where an operation on the members of one set maps some or all of them onto one or more members of the other. For example, if *A* is the set of members of a family and *B* is the set of months in the year, *A* and *B* are in correspondence if the operation is: '...has a birthday in the month of...'.

---

corresponding angles

a pair of equal angles lying on the same side of a transversal (a line that cuts through two or more lines in the same plane), and making an interior and exterior angle with the intersected lines.

---

corrosion

in earth science, an alternative name for solution, the process by which water dissolves rocks such as limestone.

---

corrosion

eating away and eventual destruction of metals and alloys by chemical attack. The rusting of ordinary iron and steel is the most common form of corrosion. Rusting takes place in moist air, when the iron combines with oxygen and water to form a brown-orange deposit of rust (hydrated iron oxide). The rate of corrosion is increased where the atmosphere is polluted with sulphur dioxide. Salty road and air conditions accelerate the rusting of car bodies.

Corrosion is largely an electrochemical process, and acidic and salty conditions favour the establishment of electrolytic cells on the metal, which cause it to be eaten away. Other examples of corrosion include the green deposit that forms on copper and bronze, called verdigris, a basic copper carbonate. The tarnish on silver is a corrosion product, a film of silver sulphide.

---

corruption of data

introduction or presence of errors in data. Most computers use a range of verification and validation routines to prevent corrupt data from entering the computer system or detect corrupt data that are already present.

---

cortex

in biology, the outer part of a structure such as the brain, kidney, or adrenal gland. In botany the cortex includes nonspecialized cells lying just beneath the surface cells of the root and stem.

---

corticosteroid

any of several steroid hormones secreted by the cortex of the adrenal glands; also synthetic forms with similar properties. Corticosteroids have anti-inflammatory and immunosuppressive effects and may be used to treat a number of conditions, including rheumatoid arthritis, severe allergies, asthma, some skin diseases, and some cancers. Side effects can be serious, and therapy must be withdrawn very gradually.

The two main groups of corticosteroids include **glucocorticoids** (cortisone, hydrocortisone, prednisone, and dexamethasone), which are essential to carbohydrate, fat, and protein metabolism, and to the body's response to stress; and **mineralocorticoids** (aldosterone, fluorocortisone), which control the balance of water and salt in the body.

---

cortisone

natural corticosteroid produced by the adrenal gland, now synthesized for its anti-inflammatory qualities and used in the treatment of rheumatoid arthritis.

Cortisone was discovered by Tadeus Reichstein of Basel, Switzerland, and put to practical clinical use for rheumatoid arthritis by Philip Hench and Edward Kendall in the USA (all three shared a Nobel prize in 1950).

A product of the adrenal gland, it was first synthesized from a constituent of ox bile, and is now produced commercially from a Mexican yam and from a by-product of the sisal plant. It is used for treating allergies and certain cancers, as well as rheumatoid arthritis. The side effects of cortisone steroids include muscle wasting, fat redistribution, diabetes, bone thinning, and high blood pressure.

---

corundum

Al_2O_3

native aluminium oxide and the hardest naturally occurring mineral known, apart from diamond (corundum rates 9 on the Mohs scale of hardness); lack of cleavage also increases its durability. Its crystals are barrel-shaped prisms of the trigonal system. Varieties of gem-quality corundum are **ruby** (red) and **sapphire** (any colour other than red, usually blue). Poorer-quality and synthetic corundum is used in industry, for example as an abrasive.

Corundum forms in silica-poor igneous and metamorphic rocks. It is a constituent of emery, which is metamorphosed bauxite.

---

cosecant

in trigonometry, a function of an angle in a right-angled triangle found by dividing the length of the hypotenuse (the longest side) by the length of the side opposite the angle. Thus the cosecant of an angle *A*, usually shortened to cosec *A*, is always greater than (or equal to) 1. It is the reciprocal of the sine of the angle, that is, cosec $A = 1/\sin A$.

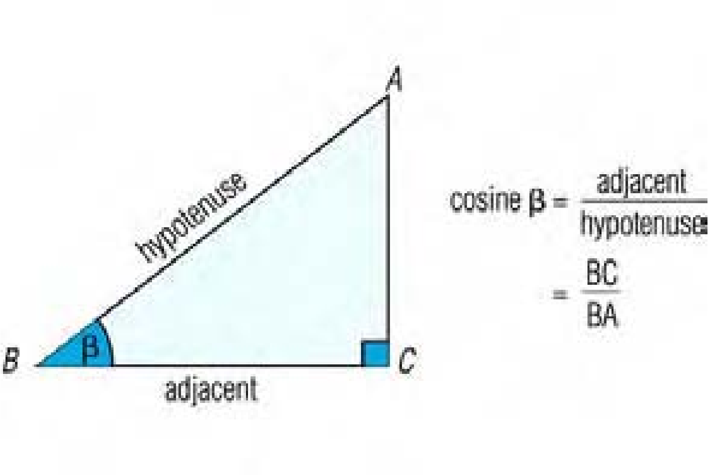
---

cosine

cos

in trigonometry, a function of an angle in a right-angled triangle found by dividing the length of the side adjacent to the angle by the length of the hypotenuse (the longest side). This function can be used to find either angles or sides in a right-angled triangle.

cosine



(Image © Research Machines plc)

The cosine of angle β is equal to the ratio of the length of the adjacent side to the length of the hypotenuse (the longest side, opposite to the right angle).

---

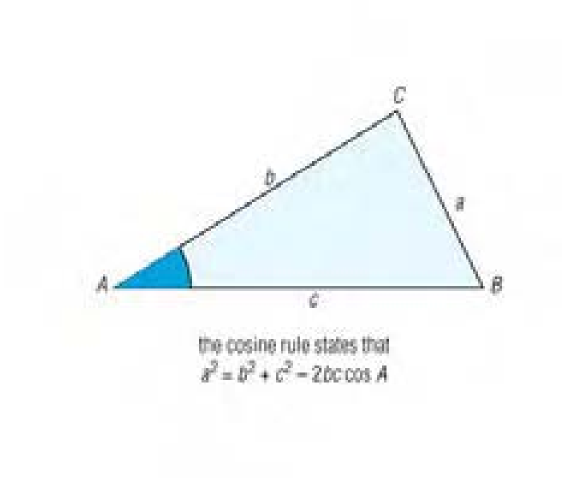
cosine rule

in trigonometry, a rule that relates the sides and angles of triangles. The rule has the formula:

$a^2 = b^2 + c^2 - 2bc \cos A$

where *a*, *b*, and *c* are the lenghts of the sides of the triangle, and *A* is the angle opposite *a*.

cosine rule



(Image © Research Machines plc)

The cosine rule is a rule of trigonometry that relates the sides and angles of triangles. It can be used to find an unknown length or angle in a triangle.

---

cosmic background radiation

or 3° radiation

electromagnetic radiation left over from the original formation of the universe in the Big Bang between 10 and 20 billion years ago. It corresponds to an overall background temperature of 2.73 K (-270.4°C/-454.8°F), or approximately 3°C above absolute zero.

Cosmic background radiation was first detected in 1965 by US physicists Arno Penzias and Robert Wilson, who in 1978 shared the Nobel Prize for Physics for their discovery. In 1992 the US Cosmic Background Explorer satellite detected slight 'ripples' in the strength of cosmic background radiation that are believed to mark the first stage in the formation of galaxies. On 30 June 2001, NASA launched the Wilkinson Microwave Anisotropy Probe, which has measured and mapped the temperature of the cosmic background radiation over the entire sky.

---

cosmic radiation

streams of high-energy particles and electromagnetic radiation from outer space, consisting of electrons, protons, alpha particles, light nuclei, and gamma rays, which collide with atomic nuclei in the Earth's atmosphere and produce secondary nuclear particles (chiefly mesons, such as pions and muons) that shower the Earth. Space shuttles carry dosimeter instruments to measure the levels of cosmic radiation.

Cosmic radiation of lower energy seems to be galactic in origin, while that of high energy is of extragalactic origin. The galactic particles may come from supernova explosions or pulsars. At higher energies, other sources must exist, possibly the giant jets of gas that are emitted from some galaxies.

---

cosmology

branch of astronomy that deals with the structure and evolution of the universe as an ordered whole. Cosmologists construct 'model universes' mathematically and compare their large-scale properties with those of the observed universe.

Modern cosmology began in the 1920s with the discovery that the universe is expanding, which suggested that it began in an explosion, the Big Bang. An alternative – now discarded – view, the steady-state theory, claimed that the universe has no origin, but is expanding because new matter is being continually created.

Brief History of Cosmology

Go to site

Based at St Andrews University, Scotland, a site chronicling the history of cosmology from the time of the Babylonians to the Hubble Space Telescope. It includes links to the biographies of the key historical figures responsible for the advancement of the subject and a brief list of references for further reading.

Unsolved Mysteries

Go to site

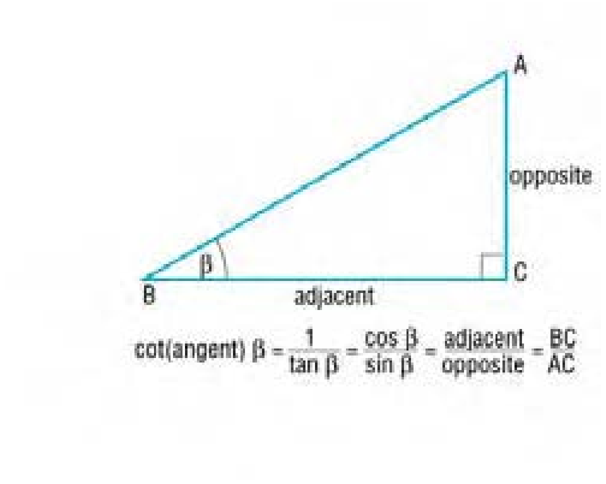
Part of a larger site on cosmology provided by PBS Online, this page features seven articles that address the most difficult questions regarding the mysteries of our universe. Some of the articles include 'Where does matter come from?', 'Is time travel possible?', 'Where is the missing matter?', 'An inhabited universe?', and 'Is there a theory for everything?' You can follow the link to the main site to explore other aspects of the cosmos.

---

cotangent

in trigonometry, a function of an angle in a right-angled triangle found by dividing the length of the side adjacent to the angle by the length of the side opposite it. It is usually written as cotan, or cot and it is the reciprocal of the tangent of the angle, so that cot $A = 1/\tan A$, where A is the angle in question.

cotangent


A
opposite
β
B
adjacent
C
cot(angent) β = 1/tan β = cos β/sin β = adjacent/opposite = BC/AC

(Image © Research Machines plc)

The cotangent of angle β is equal to the ratio of the length of the adjacent side to the length of the opposite side.

---

cot death

or sudden infant death syndrome (SIDS)

death of an apparently healthy baby, almost always during sleep. It is most common in the winter months, and strikes more boys than girls. The cause is not known but risk factors that have been identified include prematurity, respiratory infection, overheating, and sleeping position. In August 2001, it was announced that smoking during pregnancy can increase the risk of cot death by a factor of 15.

---

cotoneaster

any of a group of shrubs or trees found in Europe and Asia, belonging to the rose family and closely related to the hawthorn and medlar. The fruits, though small and unpalatable, are usually bright red and conspicuous, often surviving through the winter. Some of the shrubs are cultivated for their attractive appearance. (Genus *Cotoneaster*, family Rosaceae.)

---

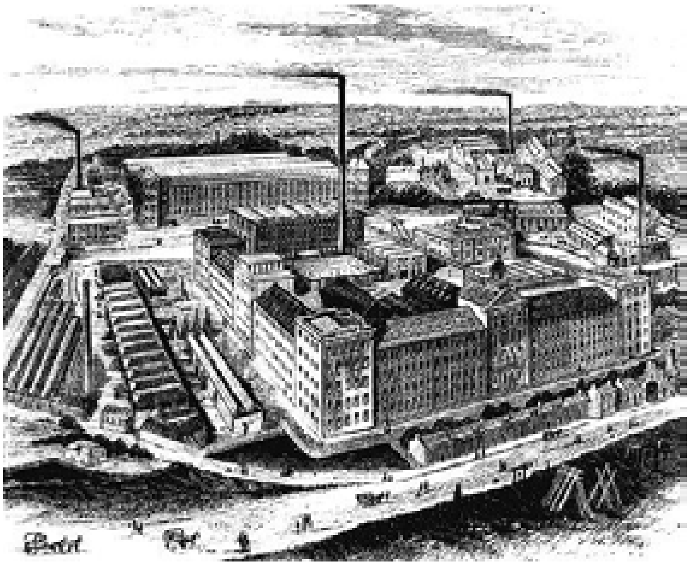
cotton

tropical and subtropical herbaceous plant belonging to the mallow family. (Genus *Gossypium*, family Malvaceae). Fibres surround the seeds inside the ripened fruits, or bolls, and these are spun into yarn for cloth. Cotton fabric is cool and comfortable to wear, resilient, absorbs moisture, is light, washes easily, and dyes well, but can crease quite badly.

The fibres are separated from the seeds in a machine called a cotton gin. Individual fibres can measure up to 6 cm/2.4 in long. The seeds are used to produce cooking oil and livestock feed, and the pigment gossypol may be useful as a male contraceptive in a modified form. Cotton disease (byssinosis), caused by cotton dust, can affect the lungs of those working in the industry. The cotton plant is very susceptible to disease and cotton production uses 50% of world pesticides while representing only 5% of world agricultural output. However, advances in genetic engineering led to the development and trial of a cotton plant genetically modified to contain the Bt gene, which produces an insecticidal toxin. Although controversial, the modified plants led to an 80% decrease in organophosphate pesticides.

Improvements in synthetic fibre mean that it is sometimes used instead of cotton. Different areas produce different qualities of cotton. Egyptian cotton fibres are usually very fine and long, whereas Asian cotton fibres are shorter and coarser. Very short fibres (cotton linters) are used in the production of regenerated synthetic fibres.

cotton



(Image © Billie Love)

A cotton mill, *c.*1850. Cotton was spun and woven into cloth by hand in England until textile machinery, developed in the late 1700s, revolutionized its manufacture and provided an impetus for the Industrial Revolution. By the mid-19th century, cotton manufacture was an entirely factory-based operation, notably in the Lancashire towns of Manchester and Oldham.

---

cotton grass

or bog cotton

any grasslike plant of a group belonging to the sedge family. White tufts cover the fruiting heads in midsummer; these break off and are carried long distances on the wind. Cotton grass is found in wet places throughout the Arctic and temperate regions of the northern hemisphere, most species growing in acid bogs. (Genus *Eriophorum*, family Cyperaceae.)

---

cottonwood

any of several North American poplar trees with seeds topped by a thick tuft of silky hairs. The eastern cottonwood (*Populus deltoides*), growing to 30 m/100 ft, is native to the eastern USA. The name 'cottonwood' is also given to the downy-leaved Australian tree *Bedfordia salaoina*. (True cottonwood genus *Populus*, family Salicaceae.)

---

cotyledon

structure in the embryo of a seed plant that may form a 'leaf' after germination and is commonly known as a seed leaf. The number of cotyledons present in an embryo is an important character in the classification of flowering plants (angiosperms).

Monocotyledons (such as grasses, palms, and lilies) have a single cotyledon, whereas dicotyledons (the majority of plant species) have two. In seeds that also contain endosperm (nutritive tissue), the cotyledons are thin, but where they are the primary food-storing tissue, as in peas and beans, they may be quite large. After germination the cotyledons either remain below ground (hypogeal) or, more commonly, spread out above soil level (epigeal) and become the first green leaves. In gymnosperms there may be up to a dozen cotyledons within each seed.

---

couch grass

European grass that spreads rapidly by underground stems. It is considered a troublesome weed in North America, where it has been introduced. (*Agropyron repens*, family Gramineae.)

Grasses

Go to site

Informative resource relating to various types of grass, such as couch grass and darnel. It contains detailed descriptions of the plants, including, where relevant, information about the plants' habitats, their constituents, and even their medicinal uses, which, in the case of couch grass, include treating rheumatism and acting as a diuretic.

---

cougar

another name for the puma, a large North American cat.

---

coulomb

symbol C

SI unit of electrical charge. One coulomb is the amount of charge transferred by a current of one ampere in one second. The unit is named after French scientist Charles Augustin de Coulomb.

---

courtship

behaviour exhibited by animals as a prelude to mating. The behaviour patterns vary considerably from one species to another, but are often ritualized forms of behaviour not obviously related to courtship or mating (for example, courtship feeding in birds).

Courtship ensures that copulation occurs with a member of the opposite sex of the right species. It also synchronizes the partners' readiness to mate and allows each partner to assess the suitability of the other.

courtship

Birds often use colour in courtship rituals. The kea uses red objects including artificial objects such as buttons; the male satin bower bird uses blue objects; the fairy wren uses a yellow flower.

Cousteau, Jacques-Yves (1910-1997)

French oceanographer. He pioneered the invention of the aqualung in 1943, as well as techniques in underwater filming. In 1951 he began the first of many research voyages in the ship *Calypso*. His film and television documentaries and books established him as a household name.

Cousteau was born in the Gironde. He joined the navy and worked for naval intelligence during the Nazi occupation. From 1936 he experimented with diving techniques. The compressed air cylinder had been invented in 1933 but restricted the diver to very short periods of time beneath the surface. Testing new breathing equipment, Cousteau was several times nearly killed.

In 1942 Cousteau met Emile Gagnan, an expert on industrial gas equipment. Gagnan had designed an experimental demand valve for feeding gas to car engines. Together, Gagnan and Cousteau developed a self-contained compressed air 'lung', the aqualung. In June 1943 Cousteau made his first dive with it, achieving a depth of 18 m/60 ft.

---

covalence

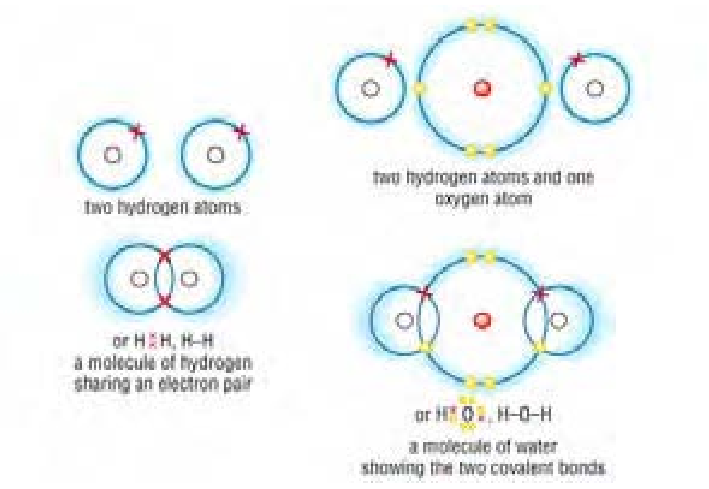
in chemistry, a form of valence in which two atoms unite by sharing electrons in pairs, so that each atom provides half the shared electrons (see also covalent bond).

---

covalent bond

chemical bond produced when two atoms share one or more pairs of electrons (usually each atom contributes an electron). The bond is often represented by a single line drawn between the two atoms. Covalently bonded substances include hydrogen (H_2), water (H_2O), and most organic substances.

covalent bond


two hydrogen atoms
two hydrogen atoms and one oxygen atom
or H:H, H–H
a molecule of hydrogen sharing an electron pair
or H:O:H, H–O–H
a molecule of water showing the two covalent bonds

(Image © Research Machines plc)

The formation of a covalent bond between two hydrogen atoms to form a hydrogen molecule (H_2), and between two hydrogen atoms and an oxygen atom to form a molecule of water (H_2O). The sharing means that each atom has a more stable arrangement of electrons (its outer electron shells are full).

cowboy

US cattle herder working on horseback; one of the great figures of American history and part of the folklore of the rugged adventurous West portrayed in books, films, and plays. Thousands of cowboys worked across the Great Plains in the heyday of the early US cattle industry 1866-87, initially on the long cattle drives, herding cattle from the ranches to the cow towns, and later on the open range, the vast unfenced grazing grounds belonging to the cattle barons. They represented the spirit of adventure and independence that was seen to epitomize the American spirit during the USA's push to take over the West in the 19th century.

The number of cowboys was severely reduced when the open range system collapsed between 1886 and 1887. Falling prices, drought, and unusually harsh winter conditions combined to bankrupt the cattle barons and, although the cowboy lived on, demand for their work declined.

cow parsley

or keck

tall perennial plant belonging to the carrot family, found in Europe, northern Asia, and North Africa. It grows up to 1 m/3 ft tall and has pinnate leaves (leaflets growing either side of a stem), hollow furrowed stems, and heads of delicate white flowers. (*Anthriscus sylvestris*, family Umbelliferae.)

cowrie

marine snail of the family Cypreidae, in which the interior spiral form is concealed by a double outer lip. The shells are hard, shiny, and often coloured. Most cowries are shallow-water forms, and are found in many parts of the world, particularly the tropical Indo-Pacific. Cowries have been used as ornaments and fertility charms, and also as currency, for example the Pacific money cowrie *Cypraea moneta*.

cowslip

European plant related to the primrose, with several small deep-yellow fragrant flowers growing from a single stem. It is native to temperate regions of the Old World. The oxlip (*Primula elatior*) is also closely related. (*Primula veris*, family Primulaceae.)

Cowslip

Go to site

Informative resource relating to this European plant. It contains a very detailed description of the plant, including information about its habitat, constituents, and even its medicinal uses, which include acting as a sedative or antispasmodic. There are also links to information about related plants, including the primrose.

coyote

wild dog *Canis latrans*, in appearance like a small wolf, living in North and Central America. Its head and body are about 90 cm/3 ft long and brown, flecked with grey or black. Coyotes live in open country and can run at 65 kph/40 mph. Their main foods are rabbits and rodents. Although persecuted by humans for over a century, the species is very successful.

---

coypu

another name for nutria.

CP/M

abbreviation for control program/monitor or control program for microcomputers

one of the earliest operating systems for microcomputers. It was written by Gary Kildall, who founded Digital Research. In the 1970s it became a standard for microcomputers based on the Intel 8080 and Zilog Z80 8-bit microprocessors. In the 1980s it was superseded by Microsoft's MS-DOS, written for Intel's 16-bit 8086/88 microprocessors.

CPU

in computing, abbreviation for central processing unit.

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crab

any decapod (ten-legged) crustacean of the division Brachyura, with a broad, rather round, upper body shell (carapace) and a small abdomen tucked beneath the body. Crabs are related to lobsters and crayfish. Mainly marine, some crabs live in fresh water or on land. They are alert carnivores and scavengers. They have a typical sideways walk, and strong pincers on the first pair of legs, the other four pairs being used for walking. Periodically, the outer shell is cast to allow for growth. The name 'crab' is sometimes used for similar arthropods, such as the horseshoe crab, which is neither a true crab nor a crustacean.

crab

Female crabs can only mate just after moulting, when their shells are still soft. This is a vulnerable time, particularly for female paddle crabs, as some large male paddle crabs are cannibalistic. Most males, however, are keener to mate than to eat. Having found a female that is about to moult, the male paddle crab carries her around until she is ready, then mates with her and protects her until her shell hardens again.

---

crab apple

any of 25 species of wild apple trees, native to temperate regions of the northern hemisphere. Numerous varieties of cultivated apples have been derived from *Malus pumila*, the common native crab apple of southeastern Europe and central Asia. The fruit of native species is smaller and more bitter than that of cultivated varieties and is used in crab-apple jelly. (Genus *Malus*, family Rosaceae.)

Crab Nebula

cloud of gas 6,000 light years from Earth, in the constellation Taurus. It is the remains of a star that, according to Chinese records, exploded as a supernova observed as a brilliant point of light on 4 July 1054. At its centre is a pulsar that flashes 30 times a second. It was named by Lord Rosse after its crablike shape.

---

crack

street name for a chemical derivative (bicarbonate) of cocaine in hard, crystalline lumps; it is heated and inhaled (smoked) as a stimulant. Crack was first used in San Francisco in the early 1980s, and is highly addictive.

Its use has led to numerous deaths, but it is the fastest-growing sector of the illegal drug trade, since it is less expensive than cocaine.

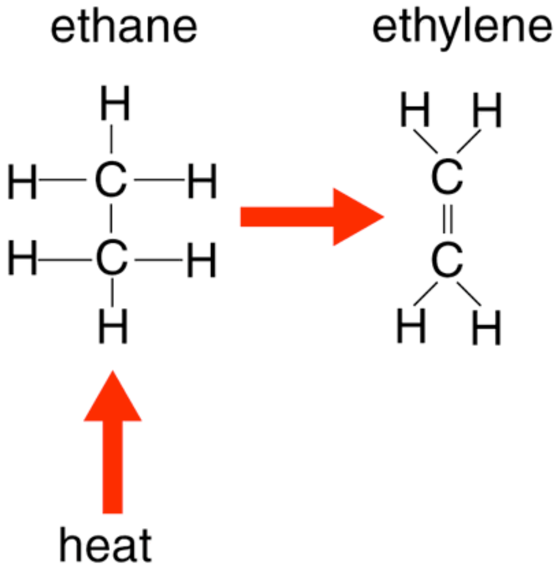
---

cracking

chemical reaction in which a large alkane molecule is broken down by heat into a smaller alkane and a small alkene molecule. The reaction is carried out at a high temperature (600°C/100°F or higher) and often in the presence of a catalyst. Cracking is a commonly used process in the petrochemical industry.

It is the main method of preparation of alkenes and is also used to manufacture petrol from the higher-boiling-point fractions that are obtained by the fractional distillation of crude oil (unrefined petroleum).

cracking



(Image © Research Machines plc)

Cracking occurs when a larger molecule is broken down into a smaller molecule by the heating or the addition of a catalyst. When ethane is heated ethylene is formed.

---

crag

in previously glaciated areas, a large lump of rock that a glacier has been unable to wear away. As the glacier passed up and over the crag, weaker rock on the far side was largely protected from erosion and formed a tapering ridge, or **tail**, of debris.

An example of a crag-and-tail feature is found in Edinburgh in Scotland; Edinburgh Castle was built on the crag (Castle Rock), which dominates the city beneath.

---

crake

any of several small birds of the family Rallidae, order Gruiformes, related to the corncrake.

---

cranberry

any of several trailing evergreen plants belonging to the heath family, related to bilberries and blueberries. They grow in marshy places and bear small, acid, crimson berries, high in vitamin C content, used for making sauce and jelly. (Genus *Vaccinium*, family Ericaceae.)

---

crane

in engineering, a machine for raising, lowering, or placing in position heavy loads. The three main types are the jib crane, the overhead travelling crane, and the tower crane. Most cranes have the machinery mounted on a revolving turntable. This may be mounted on trucks or be self-propelled, often being fitted with caterpillar tracks.

The main features of a **jib crane** are a power winch, a rope or cable, and a movable arm or jib. The cable, which carries a pulley block, hangs from the end of the jib and is wound up and down by the winch. The **overhead travelling crane**, chiefly used in workshops, consists of a fixed horizontal arm, along which runs a trolley carrying the pulley block.
Tower cranes, seen on large building sites, have a long horizontal arm able to revolve on top of a tall tower. The arm carries the trolley.

Cranes can also be mounted on barges or large semisubmersibles for marine construction work.

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crane

in zoology, a large, wading bird of the family Gruidae, order Gruiformes, with long legs and neck, short powerful wings, a naked or tufted head, and unwebbed feet. The hind toe is greatly elevated, and has a sharp claw. Cranes are marsh- and plains-dwelling birds, feeding on plants as well as insects and small animals. They fly well and are usually migratory. Their courtship includes frenzied, leaping dances. They are found in all parts of the world except South America.

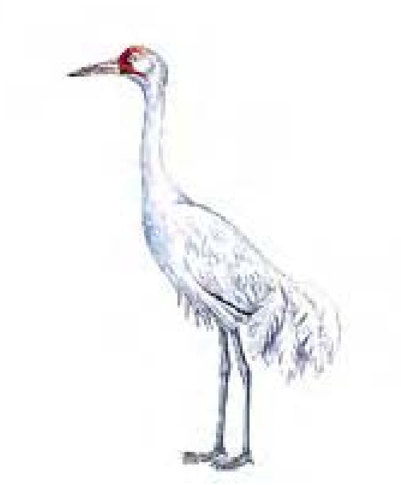
The **common crane** *Grus grus* is still numerous in many parts of Europe, and winters in Africa and India. It stands over 1 m/3ft high. The plumage of the adult bird is grey, varied with black and white, with a red patch of bare skin on the head and neck. All cranes have suffered through hunting and loss of wetlands; the population of the North American **whooping crane** *G. americana* fell to 21 wild birds in 1944. Through careful conservation, numbers have now risen to about 400.

red-headed crane

(Image © Corel)

The red-crowned crane *Grus japonensis*. Cranes inhabit plains and marsh regions, feeding on grain, plants, and small animals. This individual was photographed in Kenya.

crane



(Image © Research Machines plc)

The whooping crane *Grus americana* of North America is exceedingly rare in the wild. It breeds in Canada and migrates to the Texas coast in winter. Like all cranes, whooping cranes migrate in flocks, flying in V-formation or in lines, with necks forward and legs trailing.

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crane fly

or daddy-long-legs

any fly of the family Tipulidae, with long, slender, fragile legs. They look like giant mosquitoes, but the adults are quite harmless. The larvae live in soil or water. Females have a pointed abdomen; males have a club-shaped one.

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cranesbill

any of a group of plants containing about 400 species. The plants are named after the long beaklike protrusion attached to the seed vessels. When ripe, this splits into coiling spirals which jerk the seeds out, helping to scatter them. (Genus *Geranium*, family Geraniaceae.)

Cranesbill Root, American

Go to site

This Web site contains a detailed description of the American cranesbill root, including information about its habitat, constituents, and even its medicinal uses, which include acting as a styptic and treating piles. There is also information about related species.

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cranium

the dome-shaped area of the vertebrate skull that protects the brain. It consists of eight bony plates fused together by sutures (immovable joints). Fossil remains of the human cranium have aided the development of theories concerning human evolution.

The cranium has been studied as a possible indicator of intelligence or even of personality. The Victorian argument that a large cranium implies a large brain, which in turn implies a more profound intelligence, has been rejected.

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crankshaft

essential component of piston engines that converts the up-and-down (reciprocating) motion of the pistons into useful rotary motion. The car crankshaft carries a number of cranks. The pistons are connected to the cranks by connecting rods and bearings; when the pistons move up and down, the connecting rods force the offset crank pins to describe a circle, thereby rotating the crankshaft.

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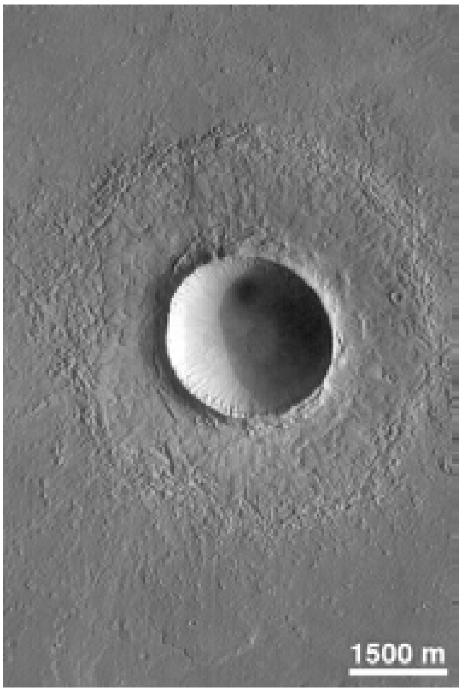
crater

bowl-shaped depression in the ground, usually round and with steep sides. Craters are formed by explosive events such as the eruption of a volcano or the impact of a meteorite.

The Moon has more than 300,000 craters over 1 km/0.6 mi in diameter, mostly formed by asteroid and meteorite bombardment; similar craters on Earth have mostly been worn away by erosion. Craters are found on all of the other rocky bodies in the Solar System.

Craters produced by impact or by volcanic activity have distinctive shapes, enabling geologists to distinguish likely methods of crater formation on planets in the Solar System. Unlike volcanic craters, impact craters have raised rims and central peaks and are circular, unless the meteorite has an extremely low angle of incidence or the crater has been affected by some later process.

crater



(Image © NASA)

Crater on the northern Elysium Planitia on Mars. It was formed by the impact and subsequent explosion of a meteorite and is a little more than twice the diameter of the Barringer Crater in Arizona, which has a diameter of 1.2 km/0.7 mi.

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craton

or continental shield

The relatively stable core of a continent that is not currently affected by tectonics along plate boundaries. Cratons generally consist of highly deformed metamorphic rock that formed during ancient orogenic explosions.

Cratons exist in the hearts of all the continents, a typical example being the Canadian Shield.

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crayfish

freshwater decapod (ten-limbed) crustacean belonging to several families structurally similar to, but smaller than, the lobster. Crayfish are brownish-green scavengers and are found in all parts of the world except Africa. They are edible, and some species are farmed. There are 300-400 species worldwide.

crayfish

(Image © Research Machines plc)

Large crayfish. The crayfish is a ten-limbed crustacean closely related to the lobster family. There are more than 500 species, nearly all of which live in fresh water. The *Austropotamobius* genus, the most common in Europe, is the only one native to Great Britain.

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creationism

theory concerned with the origins of matter and life, claiming, as does the Bible in Genesis, that the world and humanity were created by a supernatural Creator, not more than 6,000 years ago. It was developed in response to Darwin's theory of evolution; it is not recognized by most scientists as having a factual basis.

After a trial 1981-82, a US judge ruled as unconstitutional an attempt in Arkansas schools to enforce equal treatment of creationism and evolutionary theory. From 1996 in Alabama, all biology textbooks had to contain a statement that evolution is a controversial theory and not a proven fact. In 1999 the Kansas Board of Education added creationism to the school science curriculum, and removed evolution. However, evolution was restored to the curriculum in 2001.

Centre for Scientific Creation

Go to site

Dedicated to researching the case for creation, rather than evolution, as the origin of living species. Most of the evidence is gathered in a book which is heavily promoted on this page. However, the entire book is available online.

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creep

in civil and mechanical engineering, the property of a solid, typically a metal, under continuous stress that causes it to deform below its yield point (the point at which any elastic solid normally stretches without any increase in load or stress). Lead, tin, and zinc, for example, exhibit creep at ordinary temperatures, as seen in the movement of the lead sheeting on the roofs of old buildings.

Copper, iron, nickel, and their alloys also show creep at high temperatures.

creeper

any small, short-legged passerine bird of the family Certhidae. They spiral with a mouselike movement up tree trunks, searching for insects and larvae with their thin, down-curved beaks.

The brown creeper *Certhia familiaris* is 12 cm/5 in long, brown above, white below, and is found across North America and Eurasia.

creosote

black, oily liquid derived from coal tar, used as a wood preservative. Medicinal creosote, which is transparent and oily, is derived from wood tar.

crescent

curved shape of the Moon when it appears less than half illuminated. It also refers to any object or symbol resembling the crescent Moon. Often associated with Islam, it was first used by the Turks on their standards after the capture of Constantinople in 1453, and appears on the flags of many Muslim countries. The **Red Crescent** is the Muslim equivalent of the Red Cross.

cress

any of several plants of the cress family, characterized by a pungent taste. The common European garden cress (*Lepidium sativum*) is cultivated worldwide. (Genera include *Lepidium*, *Cardamine*, and *Arabis*; family Cruciferae.)

Cretaceous

period of geological time approximately 143-65 million years ago. It is the last period of the Mesozoic era, during which angiosperm (seed-bearing) plants evolved, and dinosaurs reached a peak. The end of the Cretaceous period is marked by a mass extinction of many lifeforms, most notably the dinosaurs. The north European chalk, which forms the white cliffs of Dover, was deposited during the latter half of the Cretaceous, hence the name Cretaceous, which comes from the Latin *creta*, 'chalk'.

crevasse

deep crack in the surface of a glacier; it can reach several metres in depth. Crevasses often occur where a glacier flows over the break of a slope, because the upper layers of ice are unable to stretch and cracks result. Crevasses may also form at the edges of glaciers owing to friction with the bedrock.

Crick, Francis Harry Compton (1916-2004)

English molecular biologist who was awarded a Nobel Prize for Physiology or Medicine in 1962, together with Maurice Wilkins and James Watson, for the discovery of the double-helical structure of DNA and of the significance of this structure in the replication and transfer of genetic information.

Using Wilkins's and others' discoveries, Crick and Watson postulated that DNA consists of a double helix consisting of two parallel chains of alternate sugar and phosphate groups linked by pairs of organic bases. They built molecular models which also explained how genetic information could be coded – in the sequence of organic bases. Crick and Watson published their work on the proposed structure of DNA in 1953. Their model is now generally accepted as correct.

DNA: Discovery of the Structure of DNA

the first announcement

'We wish to suggest a structure for the salt of deoxyribose nucleic acid (DNA). This structure has novel features which are of considerable biological interest.'

So began a 900-word article that was published in the journal *Nature* in April 1953. Its authors were British molecular biologist Francis Crick (1916-) and US biochemist James Watson (1928-). The article described the correct structure of DNA, a discovery that many scientists have called the most important since Austrian botanist and monk Gregor Mendel (1822-1884) laid the foundations of the science of genetics.

DNA is the molecule of heredity, and by knowing its structure, scientists can see exactly how forms of life are transmitted from one generation to the next.

the problem of inheritance

The story of DNA really begins with British naturalist Charles Darwin (1809–1882). When, in November 1859, he published 'On the Origin of Species by Means of Natural Selection' outlining his theory of evolution, he was unable to explain exactly how inheritance came about. For at that time it was believed that offspring inherited an average of the features of their parents. If this were so, as Darwin's critics pointed out, any remarkable features produced in a living organism by evolutionary processes would, in the natural course of events, soon disappear.

The work of Gregor Mendel, only rediscovered 18 years after Darwin's death, provided a clear demonstration that inheritance was not a 'blending' process at all. His description of the mathematical basis to genetics followed years of careful plant-breeding experiments. He concluded that each of the features he studied, such as colour or stem length, was determined by two 'factors' of inheritance, one coming from each parent. Each egg or sperm cell contained only one factor of each pair. In this way a particular factor, say for the colour red, would be preserved through subsequent generations.

genes

Today, we call Mendel's factors **genes**. Through the work of many scientists, it came to be realized that genes are part of the chromosomes located in the nucleus of living cells and that DNA, rather than protein as was first thought, was a hereditary material.

the double helix

In the early 1950s, scientists realized that X-ray crystallography, a method of using X-rays to obtain an exact picture of the atoms in a molecule, could be successfully applied to the large and complex molecules found in living cells.

It had been known since 1946 that genes consist of DNA. At King's College, London, New Zealand-British biophysicist Maurice Wilkins (1916–) had been using X-ray crystallography to examine the structure of DNA, together with his colleague, British X-ray crystallographer Rosalind Franklin (1920–1958), and had made considerable progress.

While in Copenhagen, US scientist James Watson had realized that one of the major unresolved problems of biology was the precise structure of DNA. In 1952, he came as a young postdoctoral student to join the Medical Research Council Unit at the Cavendish Laboratory, Cambridge, where Francis Crick was already working. Convinced that a gene must be some kind of molecule, the two scientists set to work on DNA.

Helped by the work of Wilkins, they were able to build an accurate model of DNA. They showed that DNA had a double helical structure, rather like a spiral staircase. Because the molecule of DNA was made from two strands, they envisaged that as a cell divides, the strands unravel, and each could serve as a template as new DNA was formed in the resulting daughter cells. Their model also explained how genetic information might be coded in the sequence of the simpler molecules of which DNA is comprised. Here for the first time was a complete insight into the basis of heredity. James Watson commented that this result was 'too pretty not to be true!'

cracking the code

Later, working with South African-British molecular biologist Sidney Brenner (1927–), Crick went on to work out the genetic code, and so ascribe a precise function to each specific region of the molecule of DNA. These triumphant results created a tremendous flurry of scientific activity around the world. The pioneering work of Crick, Wilkins, and Watson was recognized in the award of the Nobel Prize for Physiology or Medicine in 1962.

The unravelling of the structure of DNA led to a new scientific discipline, molecular biology, and laid the foundation stones for genetic engineering – a powerful new technique that is revolutionizing biology, medicine, and food production through the purposeful adaptation of living organisms.

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cricket

in zoology, an insect belonging to any of various families, especially the Gryllidae, of the order Orthoptera. Crickets are related to grasshoppers. They have somewhat flattened bodies and long antennae. The males make a chirping noise by rubbing together special areas on the forewings. The females have a long needlelike egglaying organ (ovipositor). There are around 900 species known worldwide.

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crith

unit of mass used for weighing gases. One crith is the mass of one litre of hydrogen gas (H_2) at standard temperature and pressure.

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critical density

in cosmology, the minimum average density that the universe must have in order for it to stop expanding at some point in the future.

The precise value depends on Hubble's constant and so is not fixed, but it is between approximately 10^{-29} and

2×10^{-29}g/cm^3, equivalent to a few hydrogen atoms per cubic metre. The density parameter (symbol Ω) is the ratio of the actual density to the critical density. If $\Omega < 1$, the universe is open and will expand forever. If $\Omega > 1$, the universe is closed and the expansion will eventually halt, to be followed by a contraction (Big Crunch). Current estimates from visible matter in the universe indicate that Ω is about 0.01, well below critical density, but unseen dark matter may be sufficient to raise Ω to somewhere between 0.1 and 2.

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critical mass

in nuclear physics, the minimum mass of fissile material that can undergo a continuous chain reaction. Below this mass, too many neutrons escape from the surface for a chain reaction to carry on; above the critical mass, the reaction may accelerate into a nuclear explosion.

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critical path analysis

procedure used in the management of complex projects to minimize the amount of time taken. The analysis shows which subprojects can run in parallel with each other, and which have to be completed before other subprojects can follow on.

By identifying the time required for each separate subproject and the relationship between the subprojects, it is possible to produce a planning schedule showing when each subproject should be started and finished in order to complete the whole project most efficiently. Complex projects may involve hundreds of subprojects, and computer applications packages for critical path analysis are widely used to help reduce the time and effort involved in their analysis. The critical path is the sequence of project elements with the longest overall duration.

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crocodile

large scaly-skinned reptile with a long, low body and short legs. Crocodiles can grow up to 7 m/23 ft in length, and have long, powerful tails that propel them when swimming. They are found near swamps, lakes, and rivers in Asia, Africa, Australia, and Central America. They are fierce hunters and active mainly at night. Young crocodiles eat worms and insects, but as they mature they add frogs and small fish to their diet. Adult crocodiles will attack animals the size of antelopes and, occasionally, people. They can live up to 100 years and are related to the alligator and the smaller cayman.

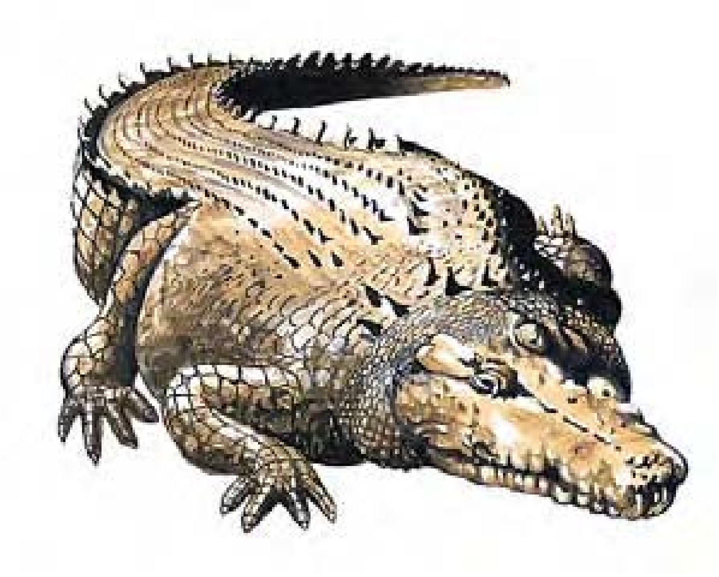
types of crocodile

There are 15 species of crocodile, all of them endangered, found in tropical parts of Africa, Asia, Australia, and Central America. The largest is the saltwater (indopacific) crocodile *Crocodylus porosus*, which can grow to 7 m/23 ft or more, and is found in eastern India, Australia, and the western Pacific, in both freshwater and saltwater habitats. The Nile crocodile *C. niloticus* is found in Africa and reaches 6 m/20 ft. The American crocodile *C. acutus*, about 4.6 m/15 ft long, is found from southern Florida to Ecuador. The gavial, or gharial, *Gavialis gangeticus* is sometimes placed in a family of its own. It is an Indian species that grows to 6.5 m/21 ft or more, and has a very long narrow snout specialized for capturing and eating fish. The Cuban crocodile *C. rhombifer* has a short snout, grows up to 3.5 m/11.5 ft, and lives in freshwater swamps in Cuba. Morelet's crocodile *C. moreletti* is found in Central America, where it is overhunted, and grows up to 3.5 m/11.5 ft. Johnston's crocodile *C. johnstoni* is an Australian crocodile that feeds mainly on fish and reaches up to 3 m/9.75 ft in length. The Siamese crocodile *C. siamensis* is found in the wild in Cambodia and Laos. These populations consist of only a few hundred crocodile, making the Siamese one of the most endangered crocodile species. The Philippine crocodile *C. mindorensis* is found in the Philippine Islands and grows to just under 3 m/9.75 ft. *C. palustris* is an Indian crocodile resembling the Nile crocodile but smaller, reaching up to 4 m/13 ft. The Orinoco crocodile *C. intermedius* grows up to 6 m/19.5 ft. *Tomistoma schlegelli* is found in rivers in India and Indochina and grows up to 4 m/13 ft. The African slender-snouted crocodile *C. cataphractus* grows up to 4 m/13 ft and is found in western and central Africa. *Osteolaemus tetraspis*, the dwarf crocodile, reaches only 2 m/6.6 ft in length and is found in the tropical forests of west and central Africa. The New Guinea crocodile *C. novaguineae* reaches 7 m/23 ft in length.

crocodile

Over short distances on land, the crocodile can move at 48 kmph/30 mph, lifting itself up on its legs like a lizard. In the water, it can move at 32 kmph/20 mph.

crocodile



(Image © Research Machines plc)

The estuarine or saltwater crocodile, of India, SE Asia, and Australasia, is one of the largest and most dangerous of its family. It has been known to develop a taste for human flesh. Hunted near to extinction for its leather, it is now protected by restrictions and the trade in skins is controlled.

crocodile

(Image © Corel)

The female crocodile lays her eggs in nests of mud or vegetation and guards them until hatched, she then carries them to the water in her jaws.

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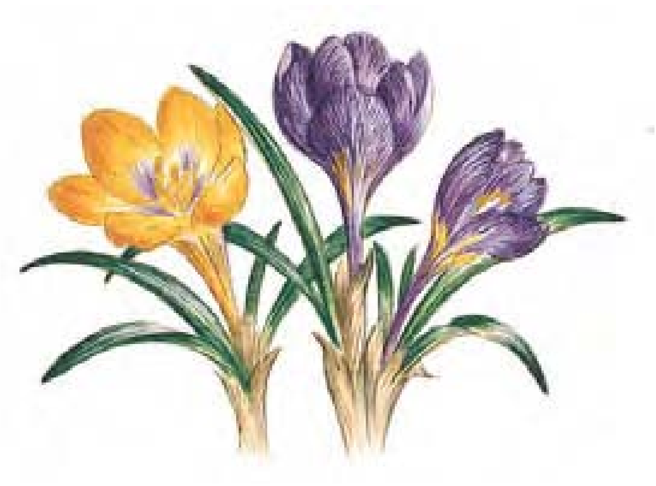
crocus

any of a group of plants belonging to the iris family, with single yellow, purple, or white flowers and narrow, pointed leaves. They are native to northern parts of the Old World, especially southern Europe and Asia Minor. (Genus *Crocus*, family Iridaceae.)

During the dry season of the year crocuses remain underground in the form of a corm (underground storage organ), and produce fresh shoots and flowers in spring or autumn. At the end of the season of growth new corms are produced. Several species are cultivated as garden plants, the familiar mauve, white, and orange forms being varieties of *Crocus vernus*, *C. versicolor*, and *C. aureus*. The saffron crocus *C. sativus* belongs to the same genus. The so-called autumn crocus or meadow saffron (*Colchicum autumnale*) is not a true crocus but belongs to the lily family.

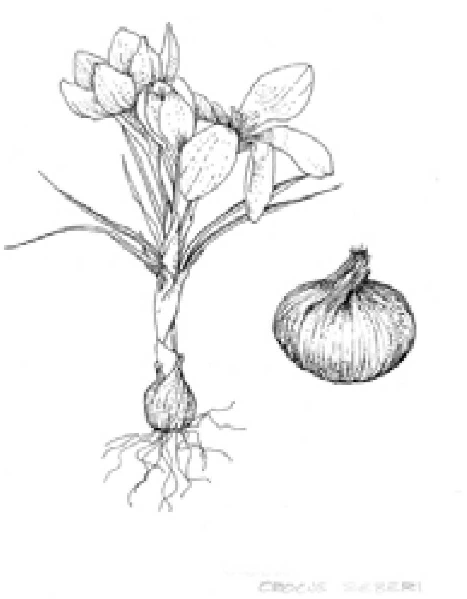
crocus



(Image © Research Machines plc)

Crocuses open when the temperature is exactly 23°C/73.4°F. When the temperature drops, they close. They are very accurate, reacting to temperature differences as slight as 0.5°C/1°F.

crocus



(Image © Research Machines plc)

Sieber's crocus (*Crocus sieberi*). Native to the Balkans, Sieber's crocus is one of 75 species of crocus, low-growing perennials which generally flower in the early spring. Crocuses are native to the Alps, southern Europe, and the Mediterranean. Sieber's crocus is characterized by white to pale mauve flowers and a yellow throat.

wild crocus

(Image © Corel)

Wild crocuses growing in the Austrian Alps.

Crohn's disease

or regional ileitis

chronic inflammatory bowel disease. It tends to flare up for a few days at a time, causing diarrhoea, abdominal cramps, loss of appetite, weight loss, and mild fever. The cause of Crohn's disease is unknown. However, research teams in Europe and the USA found that a number of cases of Crohn's disease can be attributed to a fault in the gene *Nod2*, which partly controls the way the immune system responds to gut microbes. Stress may also be a factor.

Crohn's disease may occur in any part of the digestive system but usually affects the small intestine. It is characterized by ulceration, abscess formation, small perforations, and the development of adhesions binding the loops of the small intestine. Affected segments of intestine may constrict, causing obstruction, or may perforate. It is treated by surgical removal of badly affected segments, and by corticosteroids. Mild cases respond to rest, bland diet, and drug treatment. Crohn's disease first occurs most often in adults aged 20-40.

In these cases ulceration is believed to be caused by the immune system attacking the healthy gut lining.

Crookes, William (1832-1919)

English scientist whose many chemical and physical discoveries include the metallic element thallium (1861), the radiometer (1875), and the Crookes high-vacuum tube used in X-ray techniques. He was knighted in 1897.

The radiometer consists of a four-bladed paddle wheel mounted horizontally on a pinpoint bearing inside an evacuated glass globe. Each vane of the wheel is black on one side (making it a good absorber of heat) and silvered on the other side (making it a good reflector). When the radiometer is put in strong sunlight, the paddle wheel spins round.

crop

in birds, the thin-walled enlargement of the digestive tract between the oesophagus and stomach. It is an effective storage organ especially in seed-eating birds; a pigeon's crop can hold about 500 cereal grains. Digestion begins in the crop, by the moisturizing of food. A crop also occurs in insects and annelid worms.

crop circle

circular area of flattened grain found in fields especially in southeast England, with increasing frequency every summer since 1980. More than 1,000 such formations were reported in the UK in 1991. The cause is unknown, but they are thought to be made by people.

Most of the research into crop circles has been conducted by dedicated amateur investigators rather than scientists. Physicists who have studied the phenomenon have suggested that an electromagnetic whirlwind, or 'plasma vortex', can explain both the crop circles and some UFO sightings, but this does not account for the increasing geometrical complexity of crop circles, nor for the fact that until 1990 they were unknown outside the UK. Crop circles began to appear in the USA only after a US magazine published an article about them. A few people have confessed publicly to having made crop circles that were accepted as genuine by investigators.

crop rotation

system of regularly changing the crops grown on a piece of land. The crops are grown in a particular order to utilize and add to the nutrients in the soil and to prevent the build-up of insect and fungal pests. Including a legume crop, such as peas or beans, in the rotation helps build up nitrate in the soil, because the roots contain bacteria capable of fixing nitrogen from the air.

A simple seven-year rotation, for example, might include a three-year ley (grassland) followed by two years of wheat and then two years of barley, before returning the land to temporary grass once more. In this way, the cereal crops can take advantage of the build-up of soil fertility which occurs during the period under grass. In the 18th century a four-field rotation was widely adopted; over four years a field might be planted with autumn-sown cereal, followed by a root crop, then spring cereal, and finally a leguminous crop. Innovative farmers such as Charles 'Turnip' Townshend improved cultivation techniques.

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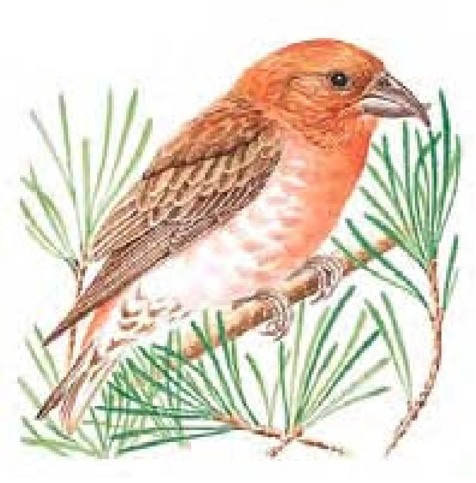
crossbill

species of finch, genus *Loxia*, family Fringillidae, order Passeriformes, in which the hooked tips of the upper and lower beak cross one another, an adaptation for extracting the seeds from conifer cones. The red or common crossbill *Loxia curvirostra* is found in parts of Eurasia and North America, living chiefly in pine forests.

The parrot crossbill *L. pytopsittacus* of Europe, and the white-winged crossbill *L. leucoptera* of northern Asia and North America, feed on pine and larch respectively.

crossbill



(Image © Research Machines plc)

The crossbill *Loxia curvirostra* feeds almost exclusively on the seeds of coniferous trees. The crossed beak is more pronounced in birds that feed on the tougher seeds of trees such as Scots pine. Crossbills' beaks are not crossed when they first hatch, but become crossed a few weeks after the young leave the nest. Male and female crossbills are not alike – males are orange-red (pictured here), while females are green.

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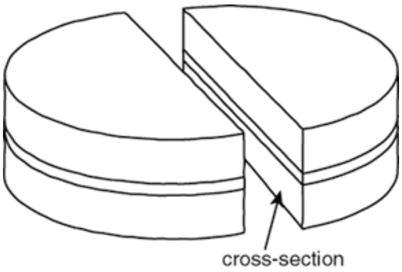
cross-section

the surface formed when a solid is cut through by a plane perpendicular to its axis.



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croup

inflammation of the larynx in small children, with harsh, difficult breathing and hoarse coughing. Croup is most often associated with viral infection of the respiratory tract.

Childhood Infections – Croup

Go to site

Useful information about croup. There is a detailed description of the infection, its symptoms, and its duration. A sound file is included to demonstrate the cough of sufferers of the infection. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

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crow

any of 35 species of omnivorous birds in the genus *Corvus*, family Corvidae, order Passeriformes, which also includes choughs, jays, and magpies. Crows are usually about 45 cm/1.5 ft long, black, with a strong bill feathered at the base. The tail is long and graduated, and the wings are long and pointed, except in the jays and magpies, where they are shorter. Crows are considered to be very intelligent. The family is distributed throughout the world, though there are very few species in eastern Australia or South America. The common crows are *C. brachyrhynchos* in North America, and *C. corone* in Europe and Asia.

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crowfoot

any of several white-flowered aquatic plants belonging to the buttercup family, with a touch of yellow at the base of the petals. The divided leaves are said to resemble the feet of a crow. (Genus *Ranunculus*, family Ranunculaceae.)

Crowfoot, Upright Meadow

Go to site

Informative resource relating to this plant. It contains a very detailed description of the upright meadow crowfoot, including information about its habitat. There are also notes on its medicinal uses, which include treating gout and warts. This page forms part of a larger site that also includes information about celery-leaved crowfoot.

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crude oil

unrefined form of petroleum.

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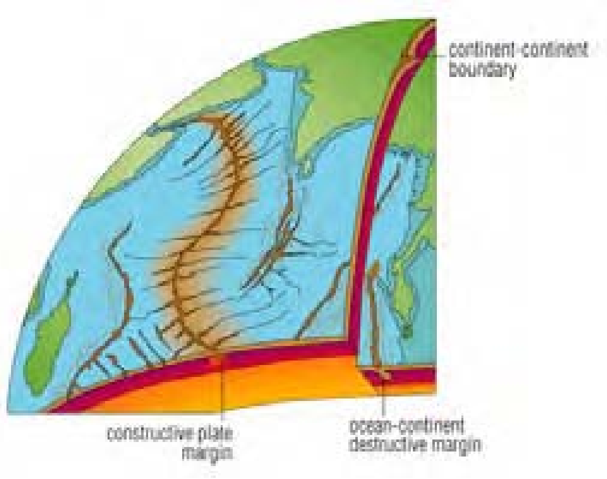
crust

rocky outer layer of the Earth, consisting of two distinct parts – the oceanic crust and the continental crust. The **oceanic** crust is on average about 10 km/6 mi thick and consists mostly of basaltic rock overlain by muddy sediments. By contrast, the **continental** crust is largely of granitic composition and has a more complex structure. Because it is continually recycled back into the mantle by the process of subduction, the oceanic crust is in no place older than about 200 million years. However, parts of the continental crust are over 3.5 billion years old.

Beneath a layer of surface sediment, the oceanic crust is made up of a layer of basalt, followed by a layer of gabbro. The continental crust varies in thickness from about 40 km/25 mi to 70 km/45 mi, being deepest beneath mountain ranges, and thinnest above continental rift valleys. Whereas the oceanic crust is composed almost exclusively of basaltic igneous rocks and sediments, the continental crust is made of a wide variety of sedimentary rocks, igneous rocks, and metamorphic rocks.

crust


continent-continent boundary
constructive plate margin
ocean-continent destructive margin

(Image © Research Machines plc)

The crust of the Earth is made up of plates with different kinds of margins. In mid-ocean, there are constructive plate margins, where magma wells up from the Earth's interior, forming new crust. On continent-continent margins, mountain ranges are flung up by the collision of two continents. At an ocean-continent destructive margin, ocean crust is forced under the denser continental crust, forming an area of volcanic instability.

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crustacean

one of the class of arthropods that includes crabs, lobsters, shrimps, woodlice, and barnacles. The external skeleton is made of protein and chitin hardened with lime. Each segment bears a pair of appendages that may be modified as sensory feelers (antennae), as mouthparts, or as swimming, walking, or grasping structures.

Crux

constellation of the southern hemisphere, popularly known as the Southern Cross, the smallest of the 88 constellations but one of the brightest, and one of the best known as it is represented on the flags of Australia and New Zealand. Its brightest stars are Alpha Crucis (or Acrux), a double star about 360 light years from the Sun, and Beta Crucis (or Mimosa).

Near Beta Crucis lies a glittering star cluster known as the Jewel Box, named by John Herschel. The constellation also contains the Coalsack, a dark nebula silhouetted against the bright starry background of the Milky Way.

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cryogenics

science of very low temperatures (sometimes approaching absolute zero), including the production of very low temperatures and the exploitation of special properties associated with them, such as the disappearance of electrical resistance (superconductivity).

Low temperatures can be produced by the Joule-Thomson effect (cooling a gas by making it do work as it expands). Gases such as oxygen, hydrogen, and helium may be liquefied in this way, and temperatures of 0.3 K can be reached. Further cooling requires magnetic methods; a magnetic material, in contact with the substance to be cooled and with liquid helium, is magnetized by a strong magnetic field. The heat generated by the process is carried away by the helium. When the material is then demagnetized, its temperature falls; temperatures of around 10^{-3} K have been achieved in this way. Much lower temperatures, of a few billionths of a kelvin above absolute zero, have been obtained by trapping gas atoms in an 'optical molasses' of crossed laser beams, which slow them down. At temperatures near absolute zero, materials can display unusual properties. Some metals, such as mercury and lead, exhibit superconductivity. Liquid helium loses its viscosity and becomes a 'superfluid' when cooled to below 2 K; in this state it flows up the sides of its container. Cryogenics has several practical applications. **Cryotherapy** is a process used in eye surgery, in which a freezing probe is briefly applied to repair a break in the retina. Electronic components called Josephson junctions, which could be used in very fast computers, need low temperatures to function. Magnetic levitation (maglev) systems must be maintained at low temperatures. Food can be frozen for years, and freezing eggs, sperm, and pre-embryos is now routine.

Cryogenics

Go to site

Information site of the Cryogenic Society of America (CSA), a non-profit technical society serving all those interested in any phase of cryogenics. This site provides online access to publications, supported by details of meetings and events.

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cryolite

rare granular crystalline mineral (sodium aluminium fluoride), Na_3AlF_6, used in the electrolytic reduction of bauxite to aluminium. It is chiefly found in Greenland.

In the extraction of aluminium from the ore bauxite (impure aluminium oxide), the alumina (pure aluminium oxide) has to be molten for electrolysis to take place. Alumina has a very high melting point (2,047°C/13,717°F), which would require a lot of energy to keep it as a liquid, so the alumina is dissolved in molten cryolite instead. Far less energy is required and a temperature of 950°C/1,750°F can be used.

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cryonics

practice of freezing a body at the moment of clinical death with the aim of enabling eventual resuscitation. The body, drained of blood, is indefinitely preserved in a thermos-type container filled with liquid nitrogen at -196°C/-321°F.

The first human treated was James H Bedford, a lung-cancer patient of 74, in the USA in 1967.

Cryonics Frequently Asked Question List

Go to site

Answers to all the questions you could possibly ask about the controversial practice of cryonics. If, after reading this, you are tempted to give it a go, be warned. Of the sixty people who have been suspended, forty have been thawed out and buried, as the cryonics companies they had paid went bankrupt.

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cryptography

science of creating and reading codes, for example, those produced by the German Enigma machine used in World War II, those used in the secure transmission of credit card details over the Internet, and those used to ensure the privacy of e-mail messages. Unencoded text (known as plaintext) is converted to an unreadable form (known as cyphertext) by the process of encryption. The recipient must then decrypt the message before it can be read. The breaking of such codes is known as cryptanalysis. No encryption method is completely unbreakable, but cryptanalysis of a strongly encrypted message can be so time-consuming and complex as to be almost impossible.

The growth of the Internet and online commerce has brought an increasing demand for good cryptography. Most Internet cryptography systems involve the use of digital 'keys' to encrypt and decrypt messages. In symmetric-key cryptography, both sender and recipient use the same key. An example of this is the Data Encryption Standard (DES), used by the US government. In public-key cryptography, each party has both a freely-available public key (used by anyone to encrypt messages) and a private key (used to decrypt received messages). The program Pretty Good Privacy (PGP) is a popular and effective (and free for non-commercial use) implementation of public-key cryptography. Encrypted messages may be further protected by concealing them within large graphics, audio, or video files – a technique known as steganography.

Cryptography

Go to site

Introduction to the science of encrypting messages. The author introduces various common encrypting systems and explains their relative weaknesses. The site also includes links to other pages that deal more comprehensively with cryptography in the computer age.

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cryptorchism

or cryptorchidism

condition marked by undescended testicles; failure of the testes to complete their descent into the scrotum before birth. When only one testicle has descended, the condition is known as monorchism.

About 10% of boys are born with one or both testes undescended. Usually the condition resolves within a few weeks of birth. Otherwise, an operation is needed to bring the testes down and ensure normal sexual development.

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cryptosporidium

waterborne parasite that causes disease in humans and other animals. It has been found in drinking water in the UK and USA, causing diarrhoea, abdominal cramps, vomiting, and fever, and can be fatal in people with damaged immune systems, such as AIDS sufferers or those with leukaemia. Just 30 cryptosporidia are enough to cause prolonged diarrhoea.

Conventional filtration and chlorine disinfection are ineffective at removing the parasite. Slow sand filtration is the best method of removal, but the existing systems were dismantled in the 1970s because of their slowness.

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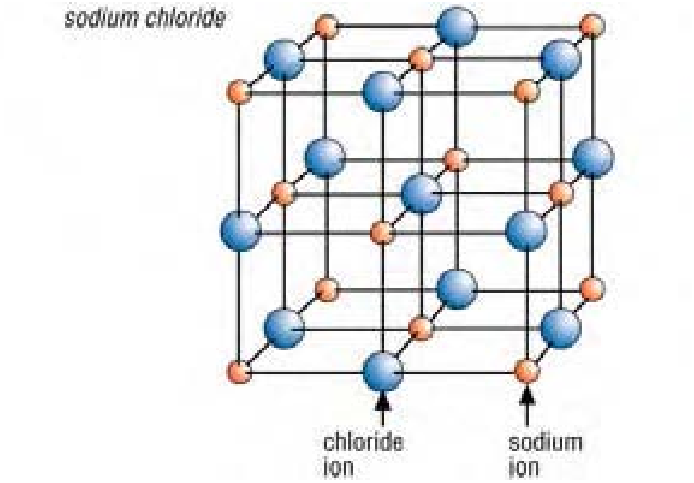
crystal

regular-shaped solid that reflects light. Examples include diamonds, grains of salt, and sugar. Particles forming a crystal are packed in an exact and ordered pattern. When this pattern is repeated many millions of times, the crystal is formed. Such an arrangement of particles, that is regular and repeating, is called a giant molecular structure.

In ionic compounds, such as sodium chloride (NaCl), the ions are arranged in a giant ionic lattice, with alternate positive and negative ions in a three-dimensional arrangement. The natural shape of the crystal is the same as the arrangement of ions in the lattice. In sodium chloride the ions form a cubic lattice. Hence sodium chloride crystals are cubic. In diamond there is a giant atomic structure made up of carbon atoms covalently bonded to each other in a regular, repeating arrangement throughout the whole of the structure. In metals the atoms are also packed tightly together in a regular pattern. This gives metals like copper a crystalline structure. Metal crystals are called grains.

A mineral can often be identified by the shape of its crystals and the system of crystallization determined. For example, extrusive igneous rock such as basalt contains very small crystals compared with an intrusive igneous rock such as granite. A single crystal can vary in size from a submicroscopic particle to a structure some 30 m/100 ft in length. Crystals fall into seven crystal systems or groups, classified on the basis of the relationship of three or four imaginary axes that intersect at the centre of any perfect, undistorted crystal.

crystal



(Image © Research Machines plc)

The sodium chloride, or common salt, crystal is a regular cubic array of charged atoms (ions) - positive sodium ions and negative chloride ions. Repetition of this structure builds up into cubic salt crystals.

crystallography

scientific study of crystals. In 1912 it was found that the shape and size of the repeating atomic patterns (unit cells) in a crystal could be determined by passing X-rays through a sample. This method, known as X-ray diffraction, opened up an entirely new way of 'seeing' atoms. It has been found that many substances have a unit cell that exhibits all the symmetry of the whole crystal; in table salt (sodium chloride, NaCl), for instance, the unit cell is an exact cube.

Many materials were not even suspected of being crystals until they were examined by X-ray crystallography. It has been shown that purified biomolecules, such as proteins and DNA, can form crystals, and such compounds may now be studied by this method. Since the first protein structure (myoglobin) was revealed by X-ray crystallography in 1959, this technique has become the most important tool of structural biology.

Other applications include the study of metals and their alloys, and of rocks and soils.

crystal system

any of the seven crystal systems defined by symmetry, into which all known crystalline susbtances crystallize. The elements of symmetry used for this purpose are: (1) planes of **mirror symmetry**, across which a mirror image is seen, and (2) axes of **rotational symmetry**, about which, in a 360° rotation of the crystal, equivalent faces are seen two, three, four, or six times. To be assigned to a particular crystal system, a mineral must possess a certain minimum symmetry, but it may also possess additional symmetry elements. Since crystal symmetry is related to internal structure, a given mineral will always crystallize in the same system, although the crystals may not always grow into precisely the same shape. In cases where two minerals have the same chemical composition but different internal structures (for example graphite and diamond, or quartz and cristobalite), they will generally have different crystal systems.

Crystal systems

crystal system	minimum symmetry	possible shape	mineral examples
cubic	4 threefold axes	cube, octahedron, dodecahedron	diamond, garnet, pyrite
tetragonal	1 fourfold axis	square-based prism	zircon
orthorhombic	3 twofold axes or mirror planes	matchbox shape	baryte
monoclinic	1 twofold axis or mirror plane	matchbox distorted in one plane	gypsum
triclinic	no axes or mirror planes	matchbox distorted in three planes	plagioclase feldspar
trigonal	1 threefold axis	triangular prism, rhombohedron	calcite, quartz
hexagonal	1 sixfold axis	hexagonal prism	beryl

CT scanner

medical device used to obtain detailed X-ray pictures of the inside of a patient's body. See CAT scan.

cu

abbreviation for **cubic** (measure).

cube

in geometry, a solid shape whose faces are all squares. It has 6 equal-area faces and 12 equal-length edges.

If the length of one edge is l, the volume (V) of the cube is given by:

$V = l^3$

Its surface area (A) is calculated by finding the area of one square:

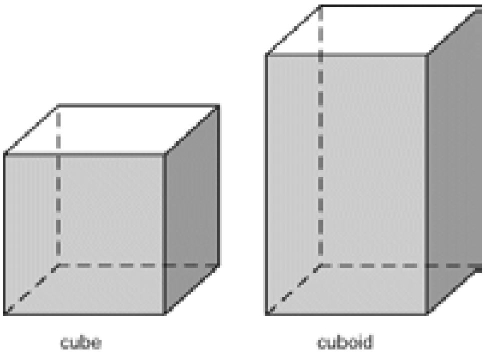
$l \times l = l^2$;

and multiplying it by 6:

$6 \times l^2$

$A = 6l^2$

cube



(Image © Research Machines plc)

Cubes and cuboids are both six-faced solid shapes. The faces on a cube are all squares while the faces on a cuboid are all rectangles.

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cube

in arithmetic, to multiply a number by itself and then by itself again. For example, 5 cubed = $5^3 = 5 \times 5 \times 5 = 125$. Alternatively, the cube root of 125 is 5. The term also refers to a number formed by cubing; for example, 1, 8, 27, 64 are the first four cubes.

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cube root

number that, multiplied by itself, and then by the product, produces the cube. For example, 3 × 3 × 3 = 27, 3 being the cube root of 27, which is the cube of 3.

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cubic equation

any equation in which the largest power of x is x^3. For example, $x^3 + 3x^2y + 4y^2 = 0$ is a cubic equation.

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cubit

earliest known unit of length, which originated between 2800 and 2300 BC. It is approximately 50.5 cm/20.6 in long, which is about the length of the human forearm measured from the tip of the middle finger to the elbow.

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cuboid

six-sided three-dimensional prism whose faces are all rectangles. A brick is a cuboid.

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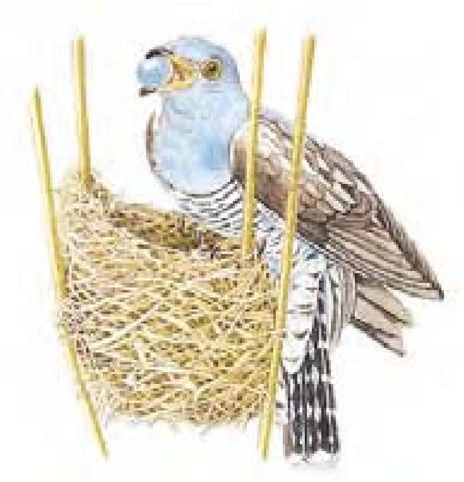
cuckoo

species of bird, any of about 200 members of the family Cuculidae, order Cuculiformes, especially the Eurasian cuckoo *Cuculus canorus*, whose name derives from its characteristic call. Somewhat hawklike, it is about 33 cm/1.1 ft long, bluish-grey and barred beneath (females are sometimes reddish), and typically has a long, rounded tail. Cuckoos feed on insects, including hairy caterpillars that are distasteful to most birds. It is a 'brood parasite', laying its eggs singly, at intervals of about 48 hours, in the nests of small insectivorous birds. As soon as the young cuckoo hatches, it ejects all other young birds or eggs from the nest and is tended by its 'foster parents' until fledging. American species of cuckoo hatch and rear their own young.

The North American **roadrunner** *Geococcyx californianus* is a member of the cuckoo family, and the yellow-billed cuckoo, *Coccysus americanus*, incubates its own eggs.

cuckoo



(Image © Research Machines plc)

The cuckoo *Cuculus canorus* migrates northwards in spring to breed, and in April the characteristic call of the male can be heard in Britain. During May the female begins searching for suitable nests in which to lay her eggs. The host she chooses must be an insect-eater, and a female cuckoo always chooses nests belonging to one species to lay in, probably the same species that reared her. Before laying an egg, she removes one of the host's own eggs from the nest. She may lay up to 12 eggs in this way, each in a separate nest.

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cuckoo spit

the frothy liquid surrounding and exuded by the larvae of the froghopper.

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cuckoo-spit insect

another name for froghopper.

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cucumber

trailing annual plant belonging to the gourd family, producing long, green-skinned fruit with crisp, translucent, edible flesh. Small cucumbers, called gherkins, usually the fruit of *Cucumis anguria*, are often pickled. (*Cucumis sativus*, family Cucurbitaceae.)

There are about 735 species belonging to the cucumber family.

Cugnot, Nicolas-Joseph (1725-1804)

French engineer who produced the first high-pressure steam engine and, in 1769, the first self-propelled road vehicle. Although it proved the viability of steam-powered traction, the problems of water supply and pressure maintenance severely handicapped the vehicle.

While serving in the army, Cugnot was asked to design a steam-operated gun carriage. After several years, he produced a three-wheeled, high-pressure carriage capable of carrying 1,800 litres/400 gallons of water and four passengers at a speed of 5 kph/3 mph. Although he worked further on the carriage, the political upheavals of the French revolutionary era obstructed progress and his invention was ignored.

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cultivar

variety of a plant developed by horticultural or agricultural techniques. The term derives from '**culti**vated **var**iety'.

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culture

in biology, the growing of living cells and tissues in laboratory conditions.

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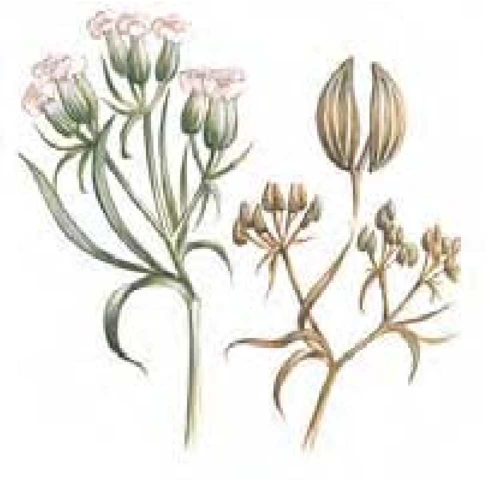
cumin

seedlike fruit of the herb cumin, which belongs to the carrot family. It has a bitter flavour and is used as a spice in cooking. (*Cuminum cyminum*, family Umbelliferae.)

cumin



(Image © Research Machines plc)

The cumin seed comes from a plant of the parsley family. A small, delicate annual, it grows to a height of about 25 cm/10 in. The spicy seeds are boat-shaped, ridged, and brownish green in colour.

Cumin

Go to site

Informative resource relating to this herb. It contains a detailed description of the plant, its habitat, and even its place in history. There are also notes on the cultivation, constituents, and possible medicinal uses of cumin, which include acting as an antispasmodic and carminative.

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cumulative frequency

in statistics, the total frequency of a given value up to and including a certain point in a set of data. It is calculated by adding together the frequencies to give a running total and used to draw the cumulative frequency curve, the ogive.

To plot a cumulative frequency diagram, the cumulative frequency is always plotted along the vertical axis and data are always plotted at the top range of the interval: for example, frequency for weekly salary ranges £100–150 and £151–200 would be plotted at 150 and 200.

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cuprite

copper(I) oxide; Cu_2O

ore found in crystalline form or in earthy masses. It is red to black in colour, and is often called ruby copper.

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cupronickel

copper alloy (75% copper and 25% nickel), used in hardware products and for coinage.

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curare

black, resinous poison extracted from the bark and juices of various South American trees and plants. Originally used on arrowheads by Amazonian hunters to paralyse prey, it blocks nerve stimulation of the muscles. Alkaloid derivatives (called curarines) are used in medicine as muscle relaxants during surgery.

Curie, Marie (1867–1934)

born Maria Sklodowska

Polish scientist who, with husband Pierre Curie, discovered in 1898 two new radioactive elements in pitchblende ores: polonium and radium. They isolated the pure elements in 1902. Both scientists refused to take out a patent on their discovery and were jointly awarded the Nobel Prize for Physics in 1903, with Henri Becquerel, for their research on radiation phenomena. Marie Curie was also awarded the Nobel Prize for Chemistry in 1911 for the discovery of radium and polonium, and the isolation and study of radium.

From 1896 the Curies worked together on radioactivity, building on the results of Wilhelm Röntgen (who had discovered X-rays) and Becquerel (who had discovered that similar rays are emitted by uranium salts). Marie Curie discovered that thorium emits radiation and found that the mineral pitchblende was even more radioactive than could be accounted for by any uranium and thorium content. In July 1898, the Curies announced the discovery of polonium, followed by the discovery of radium five months later. They eventually prepared 1 g/0.04 oz of pure radium chloride – from 8 tonnes of waste pitchblende from Austria.

They also established that beta rays (now known to consist of electrons) are negatively charged particles. In 1910 with André Debierne (1874–1949), who had discovered actinium in pitchblende in 1899, Marie Curie isolated pure radium metal in 1911.

Essay about Marie and Pierre Curie

Go to site

Extended essay on the life and deeds of Pierre and Marie Curie. The site spans the entirety of the couple's astonishing career and their contribution to the promotion of the understanding of radioactivity. It includes sections on Pierre's and Marie's joint research on radiation phenomena as well as Marie's own work after Pierre's untimely death in 1906: her discovery of the elements radium and polonium, her second Nobel prize, this time in chemistry, her difficulties with the press, and her family life.

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curing

method of preserving meat by soaking it in salt (sodium chloride) solution, with saltpetre (sodium nitrate) added to give the meat its pink colour and characteristic taste. The nitrates in cured meats are converted to nitrites and nitrosamines by bacteria, and these are potentially carcinogenic to humans.

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curium

chemical symbol Cm

synthesized, radioactive, metallic element of the actinide series, atomic number 96, relative atomic mass 247. It is produced by bombarding plutonium or americium with neutrons. Its longest-lived isotope has a half-life of 1.7×10^7 years.

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curlew

wading bird of the genus *Numenius* of the sandpiper family, Scolopacidae, order Charadriiformes. The curlew is between 36 cm/14 in and 55 cm/1.8 ft long, and has pale brown plumage with dark bars and mainly white underparts, long legs, and a long, thin, downcurved bill. It feeds on a variety of insects and other invertebrates. Several species live in northern Europe, Asia, and North America. The name derives from its haunting flutelike call.

One species, the Eskimo curlew, is almost extinct, never having recovered from relentless hunting in the late 19th century.

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currant

berry of a small seedless variety of cultivated grape (*Vitis vinifera*). Currants are grown on a large scale in Greece and California and are dried for use in cooking and baking. Because of the similarity of the fruit, the name 'currant' is also given to several species of shrubs (genus *Ribes*, family Grossulariaceae).

Currant, Red

Go to site

Complete resource of information about the redcurrant. Contained here are an informative description of the plant and its habitat. This site also features notes on the uses of the plant, which include the preparation of an antiseptic and the treatment of fevers.

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current

in earth science, flow of a body of water or air, or of heat, moving in a definite direction. Ocean currents are fast-flowing bodies of seawater moved by the wind or by variations in water density between two areas. They are partly responsible for transferring heat from the Equator to the poles and thereby evening out the global heat imbalance. There are three basic types of ocean current: **drift currents** are broad and slow-moving; **stream currents** are narrow and swift-moving; and **upwelling currents** bring cold, nutrient-rich water from the ocean bottom.

Stream currents include the Gulf Stream and the Japan (or Kuroshio) Current. Upwelling currents, such as the Gulf of Guinea Current and the Peru (Humboldt) Current, provide food for plankton, which in turn supports fish and sea birds. At approximate five-to-eight-year intervals, the Peru Current that runs from the Antarctic up the west coast of South America, turns warm, with heavy rain and rough seas, and has disastrous results (as in 1982-83) for Peruvian wildlife and for the anchovy industry. The phenomenon is called **El Niño** (Spanish 'the Child') because it occurs towards Christmas.

current, electric

see electric current.

curve

in geometry, the locus of a point moving according to specified conditions. The circle is the locus of all points equidistant from a given point (the centre). Other common geometrical curves are the ellipse, parabola, and hyperbola, which are also produced when a cone is cut by a plane at different angles.

Many curves have been invented for the solution of special problems in geometry and mechanics – for example, the cissoid (the inverse of a parabola) and the cycloid.

cuscus

tree-dwelling marsupial found in Australia, New Guinea, and Sulawesi. There are five species, all about the size of a cat. They have a prehensile tail and an opposable big toe.

Phalanger spilocuscus is known as the spotted cuscus or tiger cat; *P. ursinus* and *P. celebensis* are natives of the Celebes.

classification

Cuscuses are in genus *Phalanger*, in the family Phalangeridae (possums), order Marsupialia, class Mammalia.

Cushing, Harvey Williams (1869-1939)

US neurologist who pioneered neurosurgery. He developed a range of techniques for the surgical treatment of brain tumours, and also studied the link between the pituitary gland and conditions such as dwarfism. He first described the chronic wasting disease now known as **Cushing's syndrome**.

Cushing's syndrome

condition in which the body chemistry is upset by excessive production of steroid hormones from the adrenal cortex.

Symptoms include weight gain in the face and trunk, raised blood pressure, excessive growth of facial and body hair (hirsutism), demineralization of bone, and, sometimes, diabeteslike effects. The underlying cause may be an adrenal or pituitary tumour, or prolonged high-dose therapy with corticosteroid drugs.

cusp

point where two branches of a curve meet and the tangents to each branch coincide.

custard apple

any of numerous, primarily tropical trees and shrubs of the family Annonaceae. Several are cultivated for their large, edible, heart-shaped fruits. The pawpaw *Annona simina triloba* of the eastern USA, and the pond-apple *A. glabra* of the West Indies are representatives.

cuticle

the horny noncellular surface layer of many invertebrates such as insects; in botany, the waxy surface layer on those parts of plants that are exposed to the air, continuous except for stomata and lenticels. All types are secreted by the cells of the epidermis. A cuticle reduces water loss and, in arthropods, acts as an exoskeleton.

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cutting

technique of vegetative propagation involving taking a section of root, stem, or leaf and treating it so that it develops into a new plant.

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cuttlefish

any of a family, Sepiidae, of squidlike cephalopods with an internal calcareous shell (cuttlebone). The common cuttle *Sepia officinalis* of the Atlantic and Mediterranean is up to 30 cm/1 ft long. It swims actively by means of the fins into which the sides of its oval, flattened body are expanded, and jerks itself backwards by shooting a jet of water from its 'siphon'.

It is capable of rapid changes of colour and pattern. The large head has conspicuous eyes, and the ten arms are provided with suckers. Two arms are very much elongated, and with them the cuttlefish seizes its prey. It has an ink sac from which a dark fluid can be discharged into the water, distracting predators from the cuttle itself. The dark brown pigment sepia is obtained from the ink sacs of cuttlefish.

Cuvier, Georges (Léopold Chrêtien Frédéric Dagobert) (1769-1832)

Baron Cuvier

French comparative anatomist, the founder of palaeontology. In 1799 he showed that some species have become extinct by reconstructing extinct giant animals that he believed were destroyed in a series of giant deluges. These ideas are expressed in *Recherches sur les ossiments fossiles de quadrupèdes/Researches on the Fossil Bones of Quadrupeds* (1812) and *Discours sur les révolutions de la surface du globe/Discourse on the Revolutions of the Surface of the Globe* (1825).

In 1798 Cuvier produced *Tableau élémentaire de l'histoire naturelle des animaux*, in which his scheme of classification is outlined. He was the first to relate the structure of fossil animals to that of their living relatives. His great work *Le Règne animal/The Animal Kingdom* (1817) is a systematic survey.

Georges Cuvier - Discourse on the Revolutionary Upheavals on the Surface of the Earth

Go to site

Complete original text and English translation of Cuvier's celebrated *Discours sur les révolutions de la surface du globe*. This public domain version has translator's comments and explanatory footnotes to help illustrate Cuvier's argument.

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cwt

symbol for **hundredweight**, a unit of weight equal to 100 lb (45.36 kg) in the USA and 112 lb (50.8 kg) in the UK and Canada.

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cyanide

CN^-

ion derived from hydrogen cyanide (HCN), and any salt containing this ion (produced when hydrogen cyanide is neutralized by alkalis), such as potassium cyanide (KCN). The principal cyanides are potassium, sodium, calcium, mercury, gold, and copper. Most cyanides are poisons.

Organic compounds containing a CN group are sometimes called cyanides but are more properly known as nitriles.

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cyanobacteria

or blue-green algae

single-celled, primitive organisms that resemble bacteria in their internal cell organization, sometimes joined together in colonies or filaments. Cyanobacteria are among the oldest known living organisms and, with bacteria, belong to the kingdom Monera; remains have been found in rocks up to 3.5 billion years old. They are widely distributed in aquatic habitats, on the damp surfaces of rocks and trees, and in the soil.

Cyanobacteria and bacteria are prokaryotic organisms. Some can fix nitrogen and thus are necessary to the nitrogen cycle, while others follow a symbiotic existence - for example, living in association with fungi to form lichens. Fresh water can become polluted by nitrates and phosphates from fertilizers and detergents. This eutrophication, or overenrichment, of the water causes multiplication of the cyanobacteria in the form of cyanobacterial blooms. The cyanobacteria multiply and cover the water's surface, remaining harmless until they give off toxins as they decay. These toxins kill fish and other wildlife and can be harmful to domestic animals, cattle, and people.

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cyanocobalamin

chemical name for vitamin B_{12}, which is normally produced by micro-organisms in the gut. The richest sources are liver, fish, and eggs. It is essential to the replacement of cells, the maintenance of the myelin sheath which insulates nerve fibres, and the efficient use of folic acid, another vitamin in the B complex. Deficiency can result in pernicious anaemia (defective production of red blood cells), and possible degeneration of the nervous system.

It has a complex chemical structure containing several rings arranged around a central cobalt ion. Production of cyanocobalamin is by a controlled fermentation.

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cybernetics

(Greek kubernan 'to steer')

science concerned with how systems organize, regulate, and reproduce themselves, and also how they evolve and learn. In the laboratory, inanimate objects are created that behave like living systems. Applications range from the creation of electronic artificial limbs to the running of the fully automated factory where decision-making machines operate up to managerial level.

Cybernetics was founded and named in 1947 by US mathematician Norbert Wiener. Originally, it was the study of control systems using feedback to produce automatic processes.

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cyberspace

imaginary, interactive 'worlds' created by networked computers; often used interchangeably with 'virtual world'. The invention of the word 'cyberspace' is generally credited to US science fiction writer William Gibson in his novel *Neuromancer* (1984).

As well as meaning the interactive environment encountered in a virtual reality system, cyberspace is 'where' the global community of computer-linked individuals and groups lives. From the mid-1980s, the development of computer networks and telecommunications, both international (such as the Internet) and local (such as the services known as 'bulletin board' or conferencing systems), made possible the instant exchange of messages using e-mail and electronic conferencing systems directly from the individual's own home.

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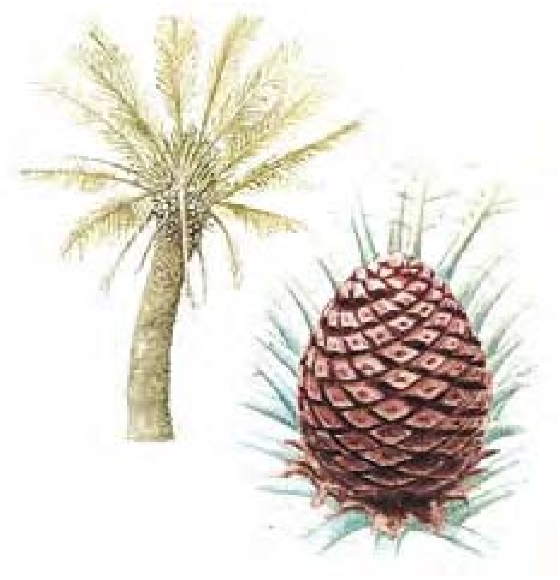
cycad

any of a group of plants belonging to the gymnosperms, whose seeds develop in cones. Some are superficially similar to palms, others to ferns. Their large cones (up to 0.5 m/1.6 ft in length) contain fleshy seeds. There are ten genera and about 80–100 species, native to tropical and subtropical countries. Cycads were widespread during the Mesozoic era (245–65 million years ago). (Order Cycadales.)

The stems of many species yield an edible starchy substance resembling sago. In 1993 cycads were discovered to be pollinated by insects, not by wind as had been previously thought; their cones produce heat that vaporizes a sweet minty odour to attract insects to a supply of nectarlike liquid.

cycad



(Image © Research Machines plc)

The palmlike gymnosperm plants known as cycads have existed more or less unchanged for at least 200 million years. They are often referred to as living fossils. Each plant consists of an array of fronds growing from a single, stout trunk. There are ten living genera found mainly in tropical and subtropical regions. Cycads bear separate, conelike male and female reproductive structures.

---

cyclamen

any of a group of perennial plants belonging to the primrose family, with heart-shaped leaves and petals that are twisted at the base and bent back, away from the centre of the downward-facing flower. The flowers are usually white or pink, and several species are cultivated. (Genus *Cyclamen*, family Primulaceae.)

Ivy-Leaved Cyclamen

Go to site

Informative resource relating to this plant. It contains a detailed description of the plant and its habitat. There are also notes on the constituents and possible medicinal uses of this type of cyclamen.

---

cycle

in physics, a sequence of changes in which a system moves away from, and then back to, its original state. An example is a vibration in which a particle moves first in one direction and then in the opposite direction, with the particle returning to its original position at the end of the each cycle.

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cyclic compound

any of a group of organic chemicals that have rings of atoms in their molecules, giving them a closed-chain structure.

---

cyclic patterns

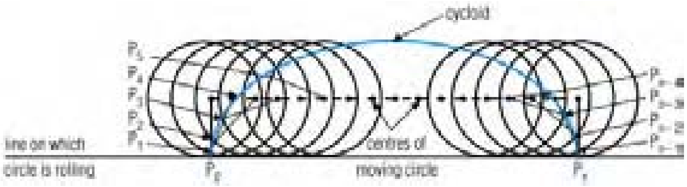
patterns in which simple ideas are repeated to form more complex designs. Some mathematical functions show cyclic patterns; for example, mapping round a circle.

---

cycloid

in geometry, a curve resembling a series of arches traced out by a point on the circumference of a circle that rolls along a straight line. Its applications include the study of the motion of wheeled vehicles along roads and tracks.

cycloid



(Image © Research Machines plc)

The cycloid is the curve traced out by a point on a circle as it rolls along a straight line. The teeth of gears are often cut with faces that are arcs of cycloids so that there is rolling contact when the gears are in use.

Cycloid

Go to site

Introduction to cycloids and links to associated curves. If you have a Java-enabled browser you can experiment interactively with this curve and its associates. There are also links to mathematicians who have studied the cycloid, including Galileo, who named the curve, and Cusa, who first studied it.

---

cyclone

alternative name for a depression, an area of low atmospheric pressure with winds blowing in an anticlockwise direction in the northern hemisphere and in a clockwise direction in the southern hemisphere. A severe cyclone that forms in the tropics is called a tropical cyclone or hurricane.

(Image © NASA)

Satellites provide invaluable information about the cloud and wind patterns of entire weather systems. This satellite picture, taken in 1969, shows a cyclonic storm, or hurricane, off Hawaii. Tropical cyclones begin in the hot, moist air over tropical oceans. As an area of very low pressure develops, air is sucked in, creating a violent storm of spiralling winds.

cyclosporin

immunosuppressive drug derived from a fungus (*Tolypocladium inflatum*). In use by 1978, it revolutionized transplant surgery by reducing the incidence and severity of rejection of donor organs.

It suppresses the T-cells (see lymphocyte) that reject foreign tissue without suppressing other cells that fight infection and cancer.

cyclotron

type of particle accelerator in which charged particles follow spiral paths inside hollow evacuated D-shaped chambers to which high-frequency alternating voltage is applied.

Cygnus

large prominent constellation of the northern hemisphere, represented as a swan. Its brightest star is first-magnitude Alpha Cygni or Deneb.

Beta Cygni (Albireo) is a yellow and blue double star, visible through small telescopes. The constellation contains the North America nebula (named after its shape), the Veil nebula (the remains of a supernova that exploded about 50,000 years ago), Cygnus A (apparently a double galaxy, a powerful radio source, and the first radio star to be discovered), and the X-ray source Cygnus X-1, thought to mark the position of a black hole. The area is rich in high-luminosity objects, nebulae, and clouds of obscuring matter. Deneb marks the tail of the swan, which is depicted as flying along the Milky Way. Some of the brighter stars form the Northern Cross, the upright being defined by Alpha, Gamma, Eta, and Beta, and the crosspiece by Delta, Gamma, and Epsilon Cygni.

cylinder

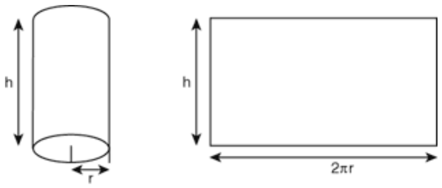
in geometry, a prism with a circular cross-section. In everyday use, the term applies to a **right cylinder**, in which the curved surface is perpendicular to the base.

As it is a prism, the volume (V) of a cylinder is area of cross-section (πr^2) × height (h), or

$$V = \pi r^2 h$$

where r is the radius of the base and h is the height of the cylinder.

Its total surface area (A) = the curved surface area + the area of both circular ends. To find the curved surface area, the hollow cylinder area should be imagined stretched flat to form a rectangle:



Curved surface area = circumference × h, or $2\pi r \times h$

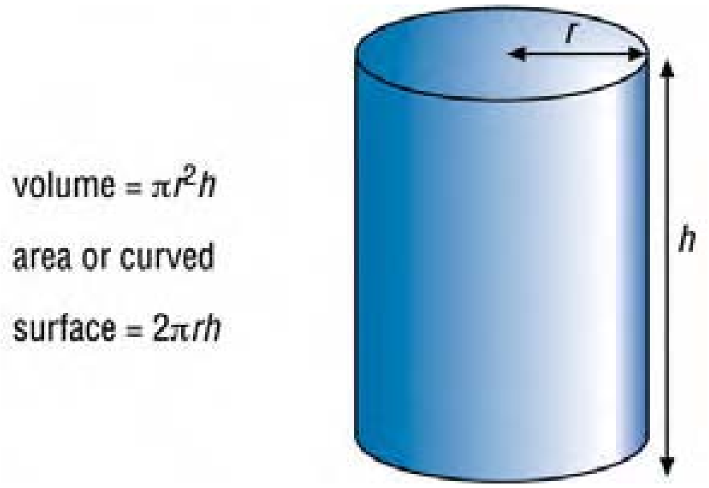
Area both circular ends = $2 \times \pi r^2$

So $A = 2\pi r^2 + 2\pi rh$

and by factorizing:

$A = 2\pi r(h + r)$

cylinder



(Image © Research Machines plc)

The volume and area of a cylinder are given by simple formulae relating the dimensions of the cylinder.

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cylindrical

having the shape of a cylinder. For example, tins of food, toilet rolls, pipes, and poles are all cylindrical objects.

---

cypress

any of a group of coniferous trees or shrubs containing about 20 species, originating from temperate regions of the northern hemisphere. They have tiny scalelike leaves and cones made up of woody, wedge-shaped scales containing an aromatic resin. (Genera *Cupressus* and *Chamaecyparis*, family Cupressaceae.)

---

cystic fibrosis

hereditary disease involving defects of various tissues, including the sweat glands, the mucous glands of the bronchi (air passages), and the pancreas. The sufferer experiences repeated chest infections and digestive disorders and generally fails to thrive. In 1989 a gene for cystic fibrosis was identified by teams of researchers in Michigan, USA, and Toronto, Canada. This discovery enabled the development of a screening test for carriers; the disease can also be detected in the unborn child.

inheriting the disease

One person in 22 is a carrier of the disease. If two carriers have children, each child has a one-in-four chance of having the disease, so that it occurs in about one in 2,000 pregnancies. Around 10% of newborns with cystic fibrosis develop an intestinal blockage (meconium ileus) which requires surgery. It is the commonest fatal hereditary disease amongst white people.

treatment

Cystic fibrosis was once universally fatal at an early age; now, although there is no definitive cure, treatments have raised both the quality and expectancy of life. Results in 1995 from a four-year US study showed that the painkiller ibuprofen, available over the counter, slowed lung deterioration in children by almost 90% when taken in large doses.

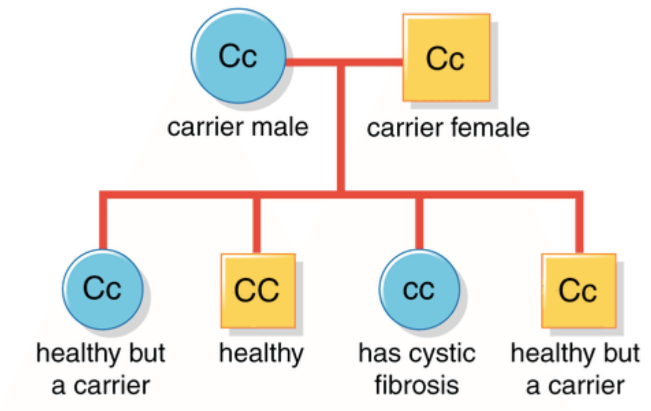
Management of cystic fibrosis is by diet and drugs, physiotherapy to keep the chest clear, and use of antibiotics to combat infection and minimize damage to the lungs. Some sufferers have benefited from heart-lung transplants.

gene therapy

In 1993, UK researchers (at the Imperial Cancer Research Fund, Oxford, and the Wellcome Trust, Cambridge) successfully introduced a corrective version of the gene for cystic fibrosis into the lungs of mice with induced cystic fibrosis, restoring normal function. Trials in human subjects began in 1993, and the cystic fibrosis defect in the nasal cavities of three patients in the USA was successfully corrected, though a later trial was halted after a patient became ill following a dose of the genetically altered virus. Patients treated by gene therapy administered in the form of a nasal spray showed signs of improvement following a preliminary trial in 1996.

In 1997, US researchers successful cured mice with cystic fibrosis by administering gene therapy in utero. The fetus breathes in the corrective gene attached to an adenovirus and it becomes incorporated in the developing cells. All the mice were born healthy and survived to old age. Cystic fibrosis is seen as a promising test case for gene therapy.

cystic fibrosis



(Image © Research Machines plc)

Family tree to show the likelihood of two people conceiving a child with cystic fibrosis when both are carriers of the recessive allele. If only one parent was a carrier then no children would be born with cystic fibrosis, though there would be a 50% chance of a child being a carrier.

cystitis

inflammation of the bladder, usually caused by bacterial infection, and resulting in frequent and painful urination. It is more common in women. Treatment is by antibiotics and copious fluids with vitamin C.

Cystitis is more common after sexual intercourse, and it is thought that intercourse encourages bacteria, especially *Escherichia coli*, which are normally present on the skin around the anus and vagina, to enter the urethra and ascend to the bladder. By drinking water before intercourse, and passing urine afterwards, the incidence of cystitis can be reduced, because the bacteria are driven back down the urethra.

cytochrome

protein responsible for part of the process of respiration by which food molecules are broken down in aerobic organisms. Cytochromes are part of the electron transport chain, which uses energized electrons to reduce molecular oxygen (O_2) to oxygen ions (O^{2-}). These combine with hydrogen ions (H^+) to form water (H_2O), the end product of aerobic respiration. As electrons are passed from one cytochrome to another, energy is released and used to make ATP.

cytokine

in biology, chemical messenger that carries information from one cell to another, for example the lymphokines.

cytokinin

plant hormone that stimulates cell division. Cytokinins affect several different aspects of plant growth and development, but only if auxin is also present. They may delay the process of senescence, or ageing, break the dormancy of certain seeds and buds, and induce flowering.

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cytology

study of the structure of cells and their functions. Major advances have been made possible in this field by the development of electron microscopes.

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cytoplasm

part of plant and animal cells outside the nucleus (and outside the large vacuole of plant cells). Strictly speaking, this includes all the organelles (mitochondria, chloroplasts, and so on) and is the area in which most cell activities take place. However, cytoplasm is often used to refer to the jellylike matter in which the organelles are embedded (correctly termed the cytosol). Most of the activities in the cytoplasm are chemical reactions (metabolism), for example, protein synthesis.

In many cells, the cytoplasm is made up of two parts: the **ectoplasm** (or plasmagel), a dense gelatinous outer layer concerned with cell movement, and the **endoplasm** (or plasmasol), a more fluid inner part where most of the organelles are found.

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cytoskeleton

in a living cell, a matrix of protein filaments and tubules that occurs within the cytosol (the liquid part of the cytoplasm). It gives the cell a definite shape, transports vital substances around the cell, and may also be involved in cell movement.

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cytotoxic drug

any drug used to kill the cells of a malignant tumour; it may also damage healthy cells. Side effects include nausea, vomiting, hair loss, and bone-marrow damage. Some cytotoxic drugs are also used to treat other diseases and to suppress rejection in transplant patients.

---

dab

small marine flatfish of the flounder family, especially the genus *Limanda*. Dabs live in the North Atlantic and around the coasts of Britain and Scandinavia.

Species include *L. limanda* which grows to about 40 cm/16 in, and the American dab *L. proboscida*, which grows to 30 cm/12 in. Both have both eyes on the right side of their bodies. The left, or blind, side is white, while the rough-scaled right side is light-brown or grey, with dark-brown spots.

DAC

abbreviation for digital-to-analogue converter.

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dachshund

(German 'badger-dog')

small dog of German origin, bred originally for digging out badgers. It has a long body and short legs. Several varieties are bred: standard size (up to 10 kg/22 lb), miniature (5 kg/11 lb or less), long-haired, smooth-haired, and wire-haired.

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daddy-long-legs

popular name for a crane fly.

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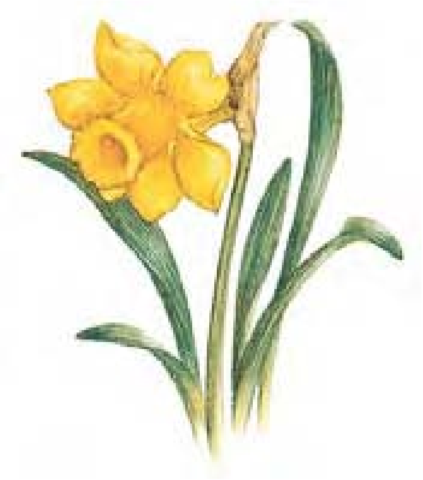
daffodil

any of several Old World species of bulbous plants belonging to the amaryllis family, characterized by their trumpet-shaped yellow flowers which appear in spring. The common daffodil of northern Europe (*Narcissus pseudonarcissus*) has large yellow flowers and grows from a large bulb. There are numerous cultivated forms in which the colours range from white to deep orange. (Genus *Narcissus*, family Amaryllidaceae.)

daffodil



(Image © Research Machines plc)

The common daffodil was the flower loved by the English poet William Wordsworth. Selective breeding has developed many different varieties with a range of colours and shapes.

Daffodil

Go to site

Detailed resource relating to this popular plant, including a description of the plant and its habitat. There are also notes on the constituents and possible medicinal uses of the daffodil, which include treating burns and stiff joints.

Daguerre, Louis Jacques Mandé (1787-1851)

French pioneer of photography. Together with Joseph Niépce, he is credited with the invention of photography (though others were reaching the same point simultaneously). In 1837 he invented the daguerreotype, a single image process superseded by Fox Talbot's negative/positive process.

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daguerreotype

in photography, a single-image process using mercury vapour and an iodine-sensitized silvered plate; it was invented by Louis Daguerre in 1838.

Daguerreian Society

Go to site

Information about the process involved in this early form of photography, 19th- and 20th-century texts about it, an extensive bibliography of related literature, plenty of daguerreotypes to look at, and information about the society itself can be found here.

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dahlia

any of a group of perennial plants belonging to the daisy family, comprising 20 species and many cultivated forms. Dahlias are stocky plants with tuberous roots and showy flowers that come in a wide range of colours. They are native to Mexico and Central America. (Genus *Dahlia*, family Compositae.)

Dahlias

Go to site

Detailed description of the plant and its habitat. There are also helpful notes on the constituents and possible uses of dahlias.

Daimler, Gottlieb Wilhelm (1834-1900)

German engineer who pioneered the car and the internal-combustion engine together with Wilhelm Maybach. In 1885 he produced a motor bicycle and in 1889 his first four-wheeled motor vehicle. He combined the vaporization of fuel with the high-speed four-stroke petrol engine.

Daimler's work on the internal-combustion engine began in earnest in 1872 when he teamed up with Nikolaus Otto at a gas-engine works; Maybach was the chief designer. Daimler built his first petrol engines in 1883. The Daimler Motoren Gesellschaft was founded in 1890, and Daimler engines were also manufactured under licence; a Daimler-powered car won the first international car race: Paris to Rouen 1894.

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dairying

the business of producing milk and milk products.

In the UK and the USA, over 70% of the milk produced is consumed in its liquid form, whereas areas such as the French Alps and New Zealand rely on easily transportable milk products such as butter, cheese, and condensed and dried milk.

It is now usual for dairy farms to concentrate on the production of milk and for factories to take over the handling, processing, and distribution of milk as well as the manufacture of dairy products.

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daisy

any of numerous species of perennial plants belonging to the daisy family, especially the field daisy of Europe and North America (*Chrysanthemum leucanthemum*) and the English common daisy (*Bellis perennis*), with a single white or pink flower rising from a rosette of leaves. (Family Compositae.)

Daisy, Common

Go to site

Informative resource relating to the English common daisy. It contains a description of the plant as well as notes on its possible medicinal uses, which include treating fevers, wounds, and liver disorders.

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daisy bush

any of several Australian and New Zealand shrubs with flowers like daisies and felted or hollylike leaves. (Genus *Olearia*, family Compositae.)

Dale, Henry Hallett (1875-1968)

English physiologist who was awarded a Nobel Prize for Physiology or Medicine in 1936, with Otto Loewi, for their work on the chemical transmission of nerve impulses.

Dalmatian

breed of dog, about 60 cm/24 in tall, with a distinctive smooth white coat with spots that are black or brown. Dalmatians are born white; the spots appear later. They were formerly used as coach dogs, running beside horse-drawn carriages to fend off highwaymen.

dalmatian

Three out of ten dalmatian dogs suffer from some form of hearing disability, and 8% of all dalmations are entirely deaf. Their beautiful spotty coats are caused by intense inbreeding, which has the side-effect of increasing genetic disorders – such as deafness.

Dalton, John (1766-1844)

English chemist who proposed the theory of atoms, which he considered to be the smallest parts of matter. He produced the first list of relative atomic masses in 'Absorption of Gases' in 1805 and put forward the law of partial pressures of gases (**Dalton's law**).

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dam

or barrage

structure built across a river to hold back a body of water (called a reservoir) in order to prevent flooding, provide water for irrigation and storage, and provide hydroelectric power. The biggest dams are of the earth- and rock-fill type, also called embankment dams. Such dams are generally built on broad valley sites. Deep, narrow gorges dictate a concrete dam, where the strength of reinforced concrete can withstand the water pressures involved.

concrete dams

A valuable development in arid regions, as in parts of Brazil, is the **underground dam**, where water is stored on a solid rock base, with a wall to ground level, so avoiding rapid evaporation. Many concrete dams are triangular in cross section, with their vertical face pointing upstream. Their sheer weight holds them in position, and they are called **gravity dams**. They are no longer favoured for very large dams, however, because they are expensive and time-consuming to build. Other concrete dams are built in the shape of an arch, which transfers the horizontal force into the sides of the river valley: the **arch dam** derives its strength from the arch shape, just as an arch bridge does, and has been widely used in the 20th century. They require less construction material than other dams and are the strongest type.

buttress dams are used when economy of construction is important or foundation conditions preclude any other type. The upstream portion of a buttress dam may comprise a series of cantilevers, slabs, arches or domes supported from the back by a line of buttresses. They are usually made from reinforced and pre-stressed concrete.

earth dams

Earth dams have a watertight core wall, formerly made of puddle clay but nowadays constructed of concrete. Their construction is very economical even for very large structures.
Rock-fill dams are a variant of the earth dam in which dumped rock takes the place of compacted earth fill.

major dams

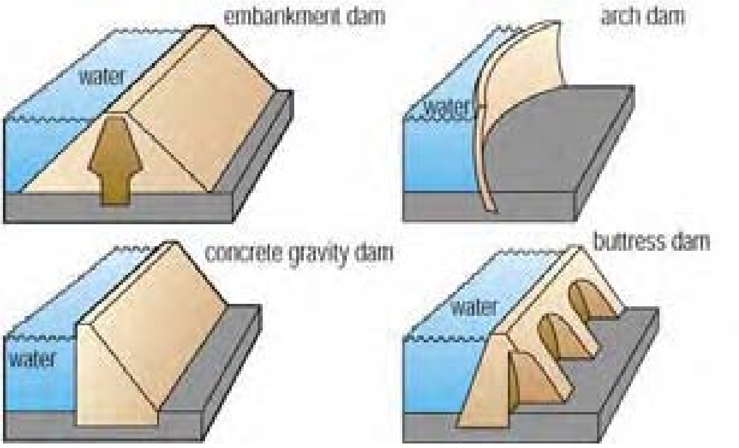
Rogun (Tajikistan) is the world's tallest at 335 m/1,099 ft. New Cornelia Tailings (USA) is the world's biggest in volume, 209 million cu m/7.4 billion cu ft. Owen Falls (Uganda) has the world's largest reservoir capacity, 204.8 billion cu m/7.2 trillion cu ft. Itaipu (Brazil/Paraguay) is the world's most powerful, producing 12,700 megawatts of electricity. The Three Gorges Dam on the Chang Jiang was officially inaugurated in 1994 and is due for completion 2009. A treaty between Nepal and India, ratified by Nepal in 1996, included plans to construct the 315-m/1,035-ft Pancheshwar dam across the River Mahakali, a tributary of the River Ganges.

In 1997 there were approximately 40,000 large dams (more than 15 m in height) and 800,000 small ones worldwide.

dam

If it were not for the world's dams holding back river water, sea levels would be 3 cm/1.2 in higher than they are.

dam



(Image © Research Machines plc)

There are two basic types of dam: the gravity dam and the arch dam. The gravity dam relies upon the weight of its material to resist the forces imposed upon it; the arch dam uses an arch shape to take the forces in a horizontal direction into the sides of the river valley. The largest dams are usually embankment dams. Buttress dams are used to hold back very wide rivers or lakes.

dam

(Image © Garret Nagle)

Dams, such as this one at Marmolada in the Dolomites, Italy, are a common sight in many upland areas. They trap and store water, making it available for use during periods of water shortage. Highland areas are favoured because of the higher rainfall there (known as orographic or relief rainfall). Hard rocks, which form the high ground, make a good base and building material for the reservoir, and the valleys in such areas provide narrow sites ideal for flooding, to become the reservoir basin.

Dams: Panoramic Photographs, 1851-1991

Go to site

Part of the Panoramic Photo Collection of the US Library of Congress, this page features more than 50 panoramic photographs of dams, mostly in the USA and mostly taken during the 1930s. To find a specific dam, click on New Search and try a word search. Many of the images include brief notes. Click on the images to increase their size.

Dam, Carl Peter Henrik (1895-1976)

Danish biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1943 for his discovery of vitamin K. He shared the prize with US biochemist Edward Doisy, who received the award for determining the chemical nature of vitamin K.

damask

textile of woven linen, cotton, wool, or silk, with a reversible figured pattern. It was first made in the city of Damascus, Syria.

daminozide

trade name Alar

chemical formerly used by fruit growers to make apples redder and crisper. In 1989 a report published in the USA found the consumption of daminozide to be linked with cancer, and the US Environment Protection Agency (EPA) called for an end to its use. The makers have now withdrawn it worldwide.

damper

any device that deadens or lessens vibrations or oscillations; for example, one used to check vibrations in the strings of a piano. The term is also used for the movable plate in the flue of a stove or furnace for controlling the draught.

damselfly

long, slender, colourful dragonfly of the suborder Zygoptera, with two pairs of similar wings that are generally held vertically over the body when at rest, unlike those of other dragonflies.

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damson

cultivated variety of plum tree, distinguished by its small oval edible fruits, which are dark purple or blue-black in colour. (*Prunus domestica* var. *institia*.)

Bullace

Go to site

Informative resource relating to this shrub or tree, which produces damsons. It contains a detailed description of the tree and its habitat. There are also notes on its constituents and possible medicinal uses, which include acting as a styptic and treating diarrhoea.

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dandelion

plant *Taraxacum officinale* belonging to the Compositae family. The stalk rises from a rosette of leaves that are deeply indented like a lion's teeth, hence the name (from French *dent de lion*). The flower heads are bright yellow. The fruit is surmounted by the hairs of the calyx which constitute the familiar dandelion 'puff'. Introduced from Europe, dandelions now grow throughout North America.

The milky juice of the dandelion has laxative properties, and the young leaves are sometimes eaten in salads. In the Russian species *Taraxacum koksaghyz*, the juice forms an industrially usable latex, relied upon especially during World War II.

Dandie Dinmont

breed of terrier that originated in the Scottish border country. It is about 25 cm/10 in tall, short-legged and long-bodied, with drooping ears and a long tail. Its hair, about 5 cm/2 in long, can be greyish or yellowish. It is named after the character Dandie Dinmont in Walter Scott's novel *Guy Mannering* (1815).

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darcy

symbol D

c.g.s. unit of permeability, used mainly in geology to describe the permeability of rock (for example, to oil, gas, or water).

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dark cloud

in astronomy, cloud of cold dust and gas seen in silhouette against background stars or an HII region (region of hot ionized hydrogen).

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darkling beetle

beetle in the family Tenebrionidae.

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dark matter

hypothetical matter that, according to certain modern theories of cosmology, is thought to make up over 90% of the mass of the universe but so far remains undetected. Measurements of the mass of galaxies using modern theories showed large discrepancies in the expected values, which led scientists to the conclusion that a theoretical substance that cannot be seen had to account for a significant proportion of the universe. Dark matter, if shown to exist, would account for many currently unexplained gravitational effects in the movement of galaxies.

Theories of the composition of dark matter include unknown atomic particles (cold dark matter) or fast-moving neutrinos (hot dark matter) or a combination of both. Other theories postulate that massively dense objects such as black holes form the majority of the 'missing' mass in the universe.

In 1993, astronomers identified part of the dark matter in the form of stray planets and brown dwarfs, and, possibly, stars that have failed to ignite. These objects are known as massive astrophysical compact halo objects (MACHOs) and may make up approximately half of the dark matter in the Milky Way's halo.

Darwin, Charles Robert (1809-1882)

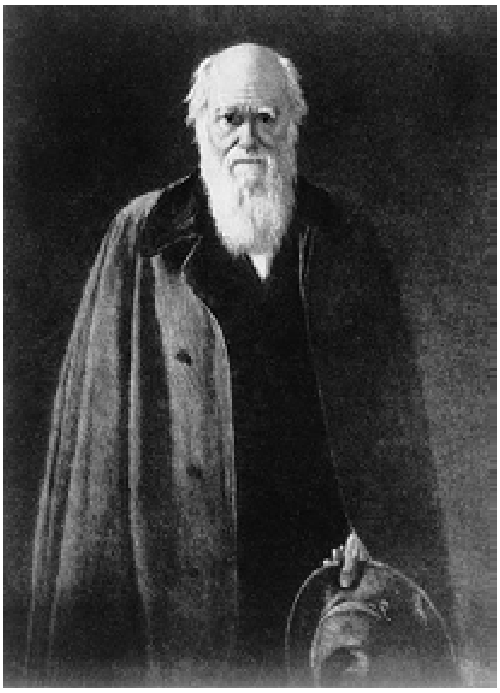
English naturalist who developed the modern theory of evolution and proposed, with Welsh naturalist Alfred Russel Wallace, the principle of natural selection. After research in South America and the Galapagos Islands as naturalist on HMS *Beagle* (1831-36), Darwin published *On the Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life* (1859). This book explained the evolutionary process through the principles of natural selection and aroused widespread argument and debate among scientists and religious leaders because it disagreed with the literal interpretation of the Book of Genesis in the Bible.

Darwin was born in Shrewsbury, the grandson of Erasmus Darwin, and studied medicine at Edinburgh and theology at Cambridge. His theory of natural selection concerned the differences existing between members of a sexually reproducing population. Those members with characteristics better fitted to the environment in which they lived would be more likely to survive and breed than other members, subsequently passing on these favourable characteristics to their young. He avoided the issue of human evolution, however, remarking at the end of *The Origin of Species* that 'much light will be thrown on the origin of man and his history'. It was not until his publication of *The Descent of Man and Selection in Relation to Sex* (1871), that Darwin argued that people evolved just like other living organisms. He did not seek the controversy he caused but his ideas soon caught the public imagination. The popular press soon published articles about the 'missing link' between humans and apes. Darwin's view was that when females or males choose to mate they are applying a form of natural selection that would result in evolution. Until fairly recently, this part of Darwin's theory was not widely supported by biologists, but now has some following.

Darwin, Charles Robert

The English naturalist Charles Darwin, who developed the theory of evolution, was once told by his father: 'You care for nothing but shooting, dogs, and rat-catching, and you will be a disgrace to yourself and all your family'.

Darwin



(Image © Billie Love)

A portrait of the English naturalist Charles Darwin, copy by John Collier (1850-1934) in the National Portrait Gallery, London. As the originator of the theory of evolution based on the concept of natural selection, Darwin's publication of his famous treatise *The Origin of Species* (1859) aroused considerable opposition, mainly from the church, and led to an historic debate at Oxford in 1860 on whether man was descended from 'apes or angels'.

Darwin, Charles

Go to site

Complete text of Darwin's seminal works *On the Origin of Species*.

Voyage of the Beagle

Go to site

Full text of Charles Darwin's account of his voyage to South America on board the *Beagle*.

Darwin, Erasmus (1731-1802)

British poet, physician, and naturalist; he was the grandfather of Charles Darwin. He anticipated aspects of evolutionary theory, but tended to the French naturalist J B de Lamarck's interpretation.

He wrote *The Botanic Garden* (1792), which included a versification of the Linnaean system entitled *The Loves of the Plants*, and *Zoonomia* (1794-96).

dasyure

any marsupial of the family Dasyuridae, also known as a 'native cat', found in Australia and New Guinea. Various species have body lengths from 25 cm/10 in to 75 cm/2.5 ft. Dasyures have long, bushy tails and dark coats with white spots. They are agile, nocturnal carnivores, able to move fast and climb.

DAT

abbreviation for digital audio tape.

data

singular datum

facts, figures, and symbols, especially as stored in computers. The term is often used to mean raw, unprocessed facts, as distinct from information, to which a meaning or interpretation has been applied.

Continuous data is data that can take any of an infinite number of values between whole numbers and so may not be measured completely accurately. This type of data contrasts with **discrete data**, in which the variable can only take one of a finite set of values. For example, the sizes of apples on a tree form continuous data, whereas the numbers of apples form discrete data.

Box Plots and Box and Whiskers Plots

Go to site

Comprehensive coverage of how to create and use box plots. A variety of sample data is given, along with worked examples of how to calculate plots from data. There are also some questions to attempt, using the data provided.

Click and Learn - About Data

Go to site

Part of a complete illustrated guide to computer hardware, logic, and architecture. It contains simple, easy-to-understand descriptions of different forms of data, and introduces the binary number system. There are also links to further modules and images of interest.

GCSE the EasyMaths Way: Data

Go to site

Continuous and discrete data are defined on this mainly text-based page, along with other types of data. It gives examples and an explanation of the types of data that different charts and diagrams, such as bar charts, represent.

database

in computing, a structured collection of data, which may be manipulated to select and sort desired items of information. For example, an accounting system might be built around a database containing details of customers and suppliers. In larger computers, the database makes data available to the various programs that need it, without the need for those programs to be aware of how the data are stored. The term is also sometimes used for simple record-keeping systems, such as mailing lists, in which there are facilities for searching, sorting, and producing records. Examples of database software include Oracle, Sybase, and Microsoft Access.

There are four main types (or 'models') of database: relational, object-oriented, hierarchical, and network, of which relational is the most widely used. Object-oriented databases have become more popular for certain types of application, and hybrids like object-relational are also available. In a **relational database** data are viewed as a collection of linked tables. A **free-text database** is one that holds the unstructured text of articles or books in a form that permits rapid searching. A telephone directory stored as a database might allow all the people whose names start with the letter B to be selected by one program, and all those living in Chicago by another.

data bus

in computing, the electrical pathway, or bus, used to carry data between the components of the computer.

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data communications

sending and receiving data via any communications medium, such as a telephone line. The term usually implies that the data consist of digital signals rather than analogue signals. In the ISDN (Integrated Services Digital Network) system, all data - including voices and video images - are transmitted digitally.

See also telecommunications.

---

data compression

in computing, techniques for reducing the amount of storage needed for a given amount of data. They include word tokenization (in which frequently used words are stored as shorter codes), variable bit lengths (in which common characters are represented by fewer bits than less common ones), and run-length encoding (in which a repeated value is stored once along with a count).

In **lossless compression** the original file is retrieved unchanged after decompression. Some types of data (sound and pictures) can be stored by **lossy compression** where some detail is lost during compression, but the loss is not noticeable. Lossy compression allows a greater level of compression. The most popular compression program is PKZIP, widely available as shareware.

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data flow chart

diagram illustrating the possible routes that data can take through a system or program; see flow chart.

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data mining

analysis of computer data to determine trends. It is used by retailers to find out those items often purchased together. For example, one supermarket chain found that purchases of nappies and beer were linked, and so increased sales by putting beer next to nappies. Store 'loyalty cards' enable retailers to profile customers' week-by-week shopping against their age, sex, and address.

---

data processing

DP; or electronic data processing (EDP)

use of computers for performing clerical tasks such as stock control, payroll, and dealing with orders. DP systems are typically batch systems, running on mainframe computers.

data processing cycle

For data to be processed the following cycle of operations must be undergone: data are collected, then input into a computer where they are processed to produce the output. As the output may also be the input of a subsequent process the process is deemed cyclical. While being processed, data may undergo other operations such as storage and validation.

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data protection

safeguarding of information about individuals stored in files and on computers, to protect privacy.

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data security

in computing, precautions taken to prevent the loss or misuse of data, whether accidental or deliberate. These include measures that ensure that only authorized personnel can gain entry to a computer system or file, and regular procedures for storing and 'backing up' data, which enable files to be retrieved or recreated in the event of loss, theft, or damage.

A number of verification and validation techniques may also be used to prevent data from being lost or corrupted by misprocessing.

Security

Go to site

Useful explanation of different security measures that all computer users should know. The topics include computer viruses and methods of protection against them, the UK Data Protection Act, and hacking. The terms are neatly summarized to help with revision.

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date

palm tree, also known as the date palm. The female tree produces the brown oblong fruit, dates, in bunches weighing 9-11 kg/20-25 lb. Dates are an important source of food in the Middle East, being rich in sugar; they are dried for export. The tree also supplies timber and materials for baskets, rope, and animal feed. (Genus *Phoenix*.)

The most important species is *Phoenix dactylifera*; native to northern Africa, soutwest Asia, and parts of India, it grows up to 25 m/80 ft high. A single bunch can contain as many as 1,000 dates. Their juice is made into a kind of wine.

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dating

in geology, the process of determining the age of minerals, rocks, fossils, and geological formations. There are two types of dating: relative and absolute.
Relative dating involves determining the relative ages of materials, that is determining the chronological order of formation of particular rocks, fossils, or formations, by means of careful field work.
Absolute dating is the process of determining the absolute age (that is the age in years) of a mineral, rock, or fossil. Absolute dating is accomplished using methods such as radiometric dating (measuring the abundances of particular isotopes in a mineral), fission track dating, and even counting annual layers of sediment.

Datura

genus of plants *Datura*, family Solanaceae, such as jimson weed, with handsome trumpet-shaped blooms. Species in this genus have narcotic properties.

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da Vinci

Italian painter, sculptor, architect, engineer, and scientist; see Leonardo da Vinci.

Davy, Humphry (1778-1829)

English chemist. He discovered, by electrolysis, the metallic elements sodium and potassium in 1807, and calcium, boron, magnesium, strontium, and barium in 1808. In addition, he established that chlorine is an element and proposed that hydrogen is present in all acids. He invented the safety lamp for use in mines where methane was present, enabling miners to work in previously unsafe conditions. He was knighted for his work in 1812 and made baronet in 1818.

Davy's experiments on electrolysis of aqueous (water-based) solutions from 1800 led him to suggest its large-scale use in the alkali industry. He proposed the theory that the mechanism of electrolysis could be explained in terms of substances that have opposite electric charges, which could be arranged on a scale of relative affinities - the foundation of the modern electrochemical series. His study of the alkali metals provided proof of French chemist Antoine Lavoisier's idea that all alkalis contain oxygen.

Humphry Davy's Discoveries

introduction

In 1793, the headmaster at Penzance Grammar School, Cornwall, England, told Humphry Davy that he was lazy. Yet Davy went on to become one of the best-known chemists of his time. He discovered six previously unknown elements, sodium, potassium, magnesium, calcium, barium, and strontium. He won many scientific honours, and was knighted in 1812 by Prince Regent - the King, George III, was insane and could not carry out the investiture. He was even awarded a prize established by Napoleon Bonaparte, at a time when England and France were at war. He became wealthy - in 1811 he was paid a very large sum of money for a course of lectures in Ireland. Not bad for a lazy schoolboy!

the safety lamp

Davy became a household name when he solved the problem of explosions in coal mines. The only illumination in the coal mines of the time was naked flames in lamps. The danger of explosions in some mines was very real, especially as mines were worked at deeper levels underground. The heat of the flame would ignite the mixture of air, coal dust, and fire damp (methane) found in the mines, causing an explosion. In 1815, within six months of being asked to devise a safe lamp, Davy had the solution. He discovered that the heat of a candle flame would not pass along a narrow metal tube, as the metal conducted the heat away. This meant that a mixture of air and coal dust at one end of the tube could not be ignited by a candle at the other end. Applying this discovery, Davy completely surrounded the flame of a lamp with a piece of metal gauze. The gauze acted as a huge number of short metal tubes and conducted the heat of the flame away from the explosive gas outside the lamp. The gas was not heated by the lamp and did not explode. The gauze did not block the light from the lamp. The new lamp was adopted widely and saved many lives. In appreciation, the mine owners of Tyne and Wear in Northeast England honoured Davy with a valuable gold plate. The Davy lamp meant that they could work coal seams previously thought too dangerous.

uses for nitrous oxide

Numerous other achievements can be attributed to this great scientist. He investigated the effect of breathing the gas nitrous oxide. It was thought at the time that the gas had the power to spread diseases. Davy decided to test the gas on himself and breathed two quarts from a silk bag. He found that the gas made him feel drunk, in a pleasant sort of way. When his friends breathed the gas, some laughed uncontrollably, so the gas became known as laughing gas. Davy also noticed that the gas eased the pain of a toothache he had been suffering. He commented: 'as nitrous oxide appears to destroy pain it may probably be used to advantage during surgical operations'. This suggestion was not taken up for another 45 years, when it was used by a US dentist, Horace Wells, as an anaesthetic.

other inventions

Davy also introduced a chemical approach to agriculture, the tanning industry and mineralogy; he designed an arc lamp for illumination, an electrolytic process for the desalination of sea water, and a method of cathodic protection for the copper-clad ships of the day by connecting them to zinc plates. But his genius has been described as flawed. At his best, he was a scientist of great perception, a painstaking laboratory worker, and a brilliant lecturer. At other times, he was disorganized, readily distracted, and prone to hasty decisions and arguments. He was snobbish, over-excitable, suspicious, and ungenerous to those he saw as scientific rivals. In 1824 he tried to block the election of his protégé Michael Faraday to the Royal Society, even after Faraday had demonstrated his genius by devising the first simple electric motor and discovering benzene. Ironically, many regard Faraday as Davy's finest discovery.

later success

In 1824, the people of Penzance decided to honour Davy. The local newspaper reported: 'At the general meeting in Penzance it was unanimously resolved that a public dinner be given to Sir Humphry Davy at the Union Hotel in Chapel Street, and that the Mayor be required to wait on him forthwith.' Later they wrote: 'Every heart, tongue, and eye were as one to do honour to him who had not only rendered the name of their town as famous and imperishable as science itself, but who had added lustre to the intellectual character of their country and ... who is one of the happy few who can claim to be permanent benefactors to the human race.' It is not recorded whether his old headmaster was present!

Davy

(Image © Billie Love)

A portrait of the English chemist Humphry Davy, *c.* 1810. Best known for his pioneering experiments in electrochemistry and for his invention of the miner's safety lamp, called the Davy lamp, he also discovered the anaesthetic properties of laughing gas.

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day

time taken for the Earth to rotate once on its axis. That part of the Earth's surface at any one time facing the Sun experiences day. As the Earth rotates, these parts move to face away from the Sun, receiving no direct sunlight, and experience night.

The **solar day** is the time that the Earth takes to rotate once relative to the Sun. It is divided into 24 hours, and is the basis of our civil day. The **sidereal day** is the time that the Earth takes to rotate once relative to the stars. It is 3 minutes 56 seconds shorter than the solar day, because the Sun's position against the background of stars as seen from Earth changes as the Earth orbits it.

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daylight saving time

legal time for a given zone that is one hour later than the standard time based on universal coordinated time (see time). It is used to provide additional daylight during the summer at the end of the usual working day.

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dBASE

family of microcomputer programs used for manipulating large quantities of data; also, a related fourth-generation language. The first version, dBASE II, was published by Ashton-Tate in 1981; it has since become the basis for a recognized standard for database applications, known as xBase.

DC

in physics, abbreviation for **direct current** (electricity).

DCC

abbreviation for digital compact cassette.

DDT

abbreviation for dichloro-diphenyl-trichloroethane; $(ClC_6H_5)_2CHC(HCl_3)$

insecticide discovered in 1939 by Swiss chemist Paul Müller. It is useful in the control of insects that spread malaria, but resistant strains develop. DDT is highly toxic and persists in the environment and in living tissue.

The Stockholm Convention, which came into force in 2004, calls for a complete ban on DDT and eleven other organic pollutants. However, public-health use of DDT in tropical countries (where the threats of mosquito-borne infections such as malaria far outweigh any concerns over DDT's toxicity) remains exempt from the ban until a viable alternative has been found.

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deadly nightshade

another name for belladonna, a poisonous plant.

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deafness

partial or total deficit of hearing in either ear. Of assistance are hearing aids, lip-reading, a cochlear implant in the ear in combination with a special electronic processor, sign language, and 'cued speech' (manual clarification of ambiguous lip movement during speech). Approximately 10% of people worldwide experience some hearing difficulties. This amounts to approximately 28 million people in the USA alone.

Conductive deafness is due to faulty conduction of sound inwards from the external ear, usually due to infection (see otitis), or a hereditary abnormality of the bones of the inner ear (see otosclerosis).

Perceptive deafness may be inborn or caused by injury or disease of the cochlea, auditory nerve, or the hearing centres in the brain. It becomes more common with age.

Information about Deafblindness

Go to site

Copious information on deaf-blindness written by James Gallager, who is himself deaf-blind. He explains how he communicates with other deaf-blind people and with the hearing-seeing world around him. There are links to UK deaf-blind organizations and groups, to the Deaf-blind Manual Alphabet, and to the Braille and Moon systems of embossed reading. The site also includes a biography of Dr William Moon.

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deamination

removal of the amino group ($—NH_2$) from an unwanted amino acid. This is the nitrogen-containing part, and it is converted into ammonia, uric acid, or urea (depending on the type of animal) to be excreted in the urine.

In vertebrates, deamination occurs in the liver.

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death

cessation of all life functions, so that the molecules and structures associated with living things become disorganized and indistinguishable from similar molecules found in nonliving things. In medicine, a person is pronounced dead when the brain ceases to control the vital functions, even if breathing and heartbeat are maintained artificially.

medical definition

Death used to be pronounced with the permanent cessation of heartbeat, but the advent of life-support equipment has made this point sometimes difficult to determine. For removal of vital organs in transplant surgery, the World Health Organization in 1968 set out that a potential donor should exhibit no brain-body connection, muscular activity, blood pressure, or ability to breathe spontaneously.

religious belief

In religious belief, death may be seen as the prelude to rebirth (as in Hinduism and Buddhism); under Islam and Christianity, there is the concept of a day of judgement and consignment to heaven or hell; Judaism concentrates not on an afterlife but on survival through descendants who honour tradition.

World infant mortality

Region	Infant deaths (thousands)	Deaths by age 5 (thousands)
Africa	88.5	148
Asia	53.2	71
Latin America and Caribbean	31.9	41
Oceania	25.9	35
Europe	8.9	11
North America	6.6	10
figures are based on 2003 estimates of population		

Approaching Death - Improving Care at the End of Life

Go to site

Comprehensive US report on attitudes to death and standards of medical care for the elderly. A huge range of social, medical, and ethical issues confronting ageing societies in advanced industrial countries is sensitively addressed.

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death cap

fungus of the amanita group, the most poisonous mushroom known. The fruiting body, or mushroom, has a scaly white cap and a collarlike structure (volva) near the base of the stalk. (*Amanita phalloides*, family Agaricaceae.)

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death rate

number of deaths per 1,000 of the population of an area over the period of a year. Death rate is a factor in demographic transition.

Death rate is linked to a number of social and economic factors such as standard of living, diet, and access to clean water and medical services. The death rate is therefore lower in wealthier countries; for example, in the USA it is 9/1,000; in Nigeria 18/1,000.

---

deathwatch beetle

any wood-boring beetle of the family Anobiidae, especially *Xestobium rufovillosum*. The larvae live in oaks and willows, and sometimes cause damage by boring in old furniture or structural timbers. To attract the female, the male beetle produces a ticking sound by striking his head on a wooden surface, and this is taken by the superstitious as a warning of approaching death.

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de Broglie

French physicists; see Broglie, Louis, and Broglie, Maurice.

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debt-for-environment swap

or debt-for-nature swap

agreement under which a proportion of a country's debts are written off in exchange for a commitment by the debtor country to undertake projects for environmental protection. Debt-for-environment swaps were set up by environment groups in the 1980s in an attempt to reduce the debt problem of poor countries, while simultaneously promoting conservation. From its introduction until 2001, over fifty countries had taken part in some sort of debt-for-environment scheme.

Most debt-for-environment swaps have concentrated on setting aside areas of land, especially tropical rainforest, for protection and have involved private conservation foundations. The first swap took place in 1987, when a US conservation group bought US$650,000 of Bolivia's national debt from a bank for US$100,000, and persuaded the Bolivian government to set aside a large area of rainforest as a nature reserve in exchange for never having to pay back the money owed. Other countries participating in debt-for-nature swaps are the Philippines, Costa Rica, Ecuador, and Poland.

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decagon

in geometry, a ten-sided polygon.

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decay, radioactive

see radioactive decay.

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decibel

symbol dB

unit of measure used originally to compare sound intensities and subsequently electrical or electronic power outputs; now also used to compare voltages. A whisper has a sound intensity of 20 dB; 140 dB (a jet aircraft taking off nearby) is the threshold of pain.

An increase of 10 dB is equivalent to a tenfold increase in intensity or power. The decibel scale is used for audibility measurements, as one decibel, representing an increase of about 25%, is about the smallest change the human ear can detect.

The decibel scale

The decibel (dB) scale is used primarily to measure relative sound intensities. It is used for audibility measurements because one decibel, representing an increase of about 25%, is about the smallest change the human ear can detect. An increase of 10 decibels is equivalent to a ten-fold increase in sound intensity or power. Decibels are also used to compare electric voltages or currents.

Decibels	Typical sound
0	threshold of human hearing
10	quiet whisper
20	average whisper
20-50	quiet conversation
40-45	light traffic
50-65	loud conversation
65-70	traffic on busy street
65-90	train
75-80	factory (light/medium work)
90	heavy traffic
90-100	thunder
110-140	jet aircraft at take-off
130	threshold of pain for humans
140-190	space rocket at take-off

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deciduous

describing trees and shrubs, that shed their leaves at the end of the growing season or during a dry season to reduce transpiration (the loss of water by evaporation).

Most deciduous trees belong to the angiosperms, plants in which the seeds are enclosed within an ovary, and the term 'deciduous tree' is sometimes used to mean 'angiosperm tree', despite the fact that many angiosperms are evergreen, especially in the tropics, and a few gymnosperms, plants in which the seeds are exposed, are deciduous (for example, larches). The term **broad-leaved** is now preferred to 'deciduous' for this reason.

deciduous

(Image © Garret Nagle)

Wytham Woods, near Oxford, England. In early spring the forest floor was covered in bluebells, but as new leaves grow and cast more shade, less sunlight reaches the flowers, and they die back. Deciduous woodlands thus have pronounced seasonal differences in flower and vegetation growth, to make use of the available light.

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decimal fraction

in mathematics, fraction in which the denominator is any higher power of 10. Thus 3/10, 51/100, and 23/1,000 are decimal fractions and are normally expressed as 0.3, 0.51, and 0.023. The use of decimals greatly simplifies addition and multiplication of fractions, though not all fractions can be expressed exactly as decimal fractions.

The regular use of the decimal point appears to have been introduced in about 1585, but the occasional use of decimal fractions can be traced back as far as the 12th century.

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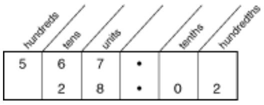
decimal number system

or denary number system

most commonly used number system, to the base ten. Decimal numbers do not necessarily contain a decimal point; 563, 5.63, and -563 are all decimal numbers. Other systems are mainly used in computing and include the binary number system, octal number system, and hexadecimal number system.

The decimals 0.3, 0.51, and 0.023 can be expressed as the decimal fractions 3/10, 51/100, and 23/1,000. They are all terminating decimals. These fractions can equally be expressed as the percentages 30%, 51%, and 2.3%.

Decimal numbers may be thought of as written under column headings based on the number 10. For example:



hundreds	tens	units		tenths	hundredths
5	6	7	•		
	2	8	•	0	2

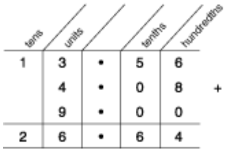
Using the table, 567 stands for 5 hundreds, 6 tens, and 7 units; 28.02 stands for 2 tens, 8 units, and 2 hundredths.

567 has no numbers after the decimal point, that is 0 **decimal places**. 28.02 has 2 numbers after the decimal point, that is 2 decimal places.

Large decimal numbers may also be expressed in floating-point notation.

addition and subtraction

When adding or subtracting decimals it is important to keep the decimal points underneath each other. For example, to work out 13.56 + 4.08 + 9:



tens	units		tenths	hundredths	
1	3	•	5	6	
	4	•	0	8	+
	9	•	0	0	
2	6	•	6	4	

Using the addition table, the answer is 26.64.

Decimals, Whole Numbers, and Exponents

Go to site

Plain but well laid out introduction to decimals. There are brief lessons covering areas such as adding and multiplying decimals, and square roots, with plenty of examples. The information would be useful as a resource to dip into to gain an overview rather than to read in its entirety.

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declination

in astronomy, coordinate on the celestial sphere that corresponds to latitude on the Earth's surface. Declination runs from 0° at the celestial equator to 90° at the north and south celestial poles.

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decoder

in computing, an electronic circuit used to select one of several possible data pathways. Decoders are, for example, used to direct data to individual memory locations within a computer's immediate access memory.

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decomposer

in biology, any organism that breaks down dead matter. Decomposers play a vital role in the ecosystem by freeing important chemical substances, such as nitrogen compounds, locked up in dead organisms or excrement. They feed on some of the released organic matter, but leave the rest to filter back into the soil as dissolved nutrients, or pass in gas form into the atmosphere, for example as nitrogen and carbon dioxide.

The principal decomposers are bacteria and fungi, but earthworms and many other invertebrates are often included in this group. The nitrogen cycle relies on the actions of decomposers.

---

decomposition

chemical change in which one substance is broken down into two or more simpler substances. In biology, decomposition is the result of the action of decomposer organisms, such as bacteria and fungi. The decomposer organisms obtain food from dead organisms, such as carbon compounds, which are energy-rich. These organisms have an important role in the cycling of carbon compounds as part of the carbon cycle. The respiration of the organisms releases carbon dioxide back into the atmosphere. Other organisms feed on the decomposers and they are part of the decomposer food chain. The decomposition of dead plants and animals allows chemicals to be washed out of the decaying remains into the soil. Many of these are important nutrients that plants can use.

In chemistry, there are three main types of decompositions – thermal, electrolytic, and catalysed.

Thermal decomposition occurs as a result of heating. For example, copper(II) carbonate decomposes on heating to give copper oxide and carbon dioxide:

$CuCO_3 \rightarrow CuO + CO_2$

Electrolytic decomposition may result when an electrical current is passed through a compound in the molten state or in aqueous solution. For example, molten sodium chloride breaks down into sodium and chlorine:

$2NaCl \rightarrow 2Na + Cl_2$

Catalysed decomposition describes the process by which decomposition is aided by the presence of a catalyst. For example, hydrogen peroxide decomposes more quickly with the use of manganese(IV) oxide:

$2H_2O_2 \rightarrow 2H_2O + O_2$

---

decompression sickness

illness brought about by a sudden and substantial change in hydrostatic pressure. It is caused by a too rapid release of nitrogen that has been dissolved into the bloodstream under pressure; when the nitrogen forms bubbles it causes the bends. The condition causes breathing difficulties, joint and muscle pain, and cramps, and is experienced mostly by divers who surface too quickly.

After a one-hour dive at 30 m/100 ft, 40 minutes of decompression are needed, according to US Navy tables.

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decontamination factor

in radiological protection, a measure of the effectiveness of a decontamination process. It is the ratio of the original contamination to the remaining radiation after decontamination: 1,000 and above is excellent; 10 and below is poor.

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dedicated computer

computer built into another device for the purpose of controlling or supplying information to it. Its use has increased dramatically since the advent of the microprocessor: washing machines, cars, and MP3 players all have their own processors.

A dedicated system is a general-purpose computer system confined to performing only one function for reasons of efficiency or convenience. A dedicated Web server is an example.

deep freezing

method of preserving food by lowering its temperature to -18°/0°F or below; see food technology. It stops almost all spoilage processes, although there may be some residual enzyme activity in uncooked vegetables, which is why these are blanched (dipped in hot water to destroy the enzymes) before freezing. Micro-organisms cannot grow or divide while frozen, but most remain alive and can resume activity once defrosted.

Commercial freezing is usually done by one of the following methods: blast, the circulation of air at -40°C/-40°F; contact, in which a refrigerant is circulated through hollow shelves; immersion, for example, fruit in a solution of sugar and glycerol; or cryogenic means, for example, by liquid nitrogen spray.

Accelerated freeze-drying (AFD) involves rapid freezing followed by heat drying in a vacuum, for example, prawns for later rehydration. The product does not have to be stored in frozen conditions.

Deep-Sea Drilling Project

research project initiated by the USA in 1968 to sample the rocks of the ocean crust. In 1985 it became known as the Ocean Drilling Program (ODP).

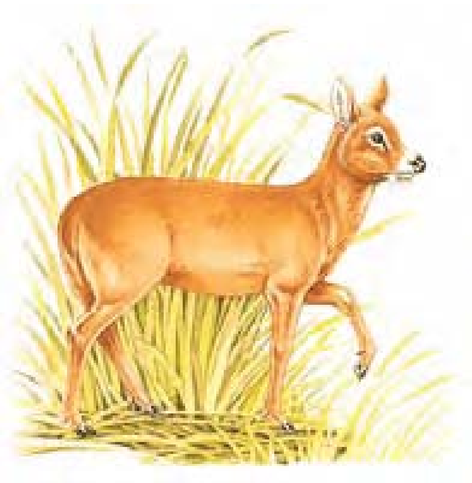
deep-sea trench

another term for ocean trench.

deer

any of various ruminant, even-toed, hoofed mammals belonging to the family Cervidae. The male typically has a pair of antlers, shed and regrown each year. Most species of deer are forest-dwellers and are distributed throughout Eurasia and North America, but are absent from Australia and Africa south of the Sahara.

deer



(Image © Research Machines plc)

Deer comprise a family of browsing and grazing mammals in which the males bear simple or complex antlers that are shed each year. Deer have four-toed feet. The Chinese water deer is the only true deer that does not have antlers but the male has enlarged upper canine teeth that grow as tusks.

deerhound

breed of large, rough-coated dog, formerly used in Scotland for hunting and killing deer. Slim and long-legged, it grows to 75 cm/30 in or more, usually with a bluish-grey coat.

defibrillation

use of electrical stimulation to restore a chaotic heartbeat to a rhythmical pattern. In fibrillation, which may occur in most kinds of heart disease, the heart muscle contracts irregularly; the heart is no longer working as an efficient pump. Paddles are applied to the chest wall, and one or more electric shocks are delivered to normalize the beat.

In patients suffering with arrhythmia, implantable defibrillators are inserted into the chest with leads threading through veins into the right side of the heart. The first was implanted in 1980 and by 1996 around 50,000-80,000 had been implanted worldwide.

definition

in mathematics, statement that describes a mathematical expression. If the definition is complete all the properties of the expression can be deduced from it.

deforestation

destruction of forest for timber, fuel, charcoal burning, and clearing for agriculture and extractive industries, such as mining, without planting new trees to replace those lost (reforestation) or working on a cycle that allows the natural forest to regenerate. The rate of deforestation is of major environmental concern as irreversible damage is being done to the habitats of plants and animals. Deforestation ultimately leads to famine, and is thought to be partially responsible for the flooding of lowland areas, since trees are needed to help slow down water movement.

Deforestation causes fertile soil to be blown away or washed into rivers, leading to soil erosion, drought, flooding, and loss of wildlife, and consequently affecting the biodiversity (biological variety) of ecosystems. It may also increase the carbon dioxide content of the atmosphere and intensify the greenhouse effect, because there are fewer trees absorbing carbon dioxide from the air for photosynthesis.

deforestation

(Image © Research Machines plc)

Timber extraction in a Russian forest. Large swathes of mixed and deciduous forest have been cleared to make way for agriculture, and to supply pulp and lumber mills.

deforestation

(Image © Research Machines plc)

Rainforest clearance and banana trees, Dominica. The destruction of rainforest for timber and fuel, its clearance for agricultural land, and the effects of extractive industries, cause soil erosion, drought, and the destruction of wildlife and their habitats.

deforestation

(Image © Research Machines plc)

Rainforest clearance and banana trees. During the period 1990–95, the process of deforestation in South America alone resulted in the loss of 24 million ha/59 million acres of tropical rainforest.

Tropical deforestation

The table shows the status of tropical moist forests in selected countries, 2000–2005.

Country	Area (sq km/sq mi)	Extent of forest cover 2000 (sq km/sq mi)	Extent of forest cover 2005 (sq km/sq mi)	Annual rate of change 2000-2005 (%)
Bolivia	1,098,581/424,162	600,910/232,012	587,400/226,796	-0.4
Brazil	8,511,960/3,286,468	4,932,130/1,904,306	4,776,980/1,844,402	-0.6
Myanmar	696,500/268,919	345,540/133,413	322,220/124,409	-1.4
Cameroon	475,442/183,568	223,450/86,274	212,450/82,027	-1.0
Colombia	1,138,891/439,726	609,630/235,379	607,280/234,472	-0.1
Congo	342,000/132,046	225,560/87,089	224,710/86,761	-0.1
Congo, Democratic Republic of the	2,344,886/905,360	1,352,070/522,037	1,336,100/515,871	-0.2
Ecuador	270,670/104,505	118,410/45,718	108,530/41,904	-1.7
Guyana	214,969/82,999	151,040/58,316	151,040/58,316	0
India	3,287,000/1,269,111	675,540/260,827	677,010/261,395	0
Indonesia	1,919,300/741,042	978,520/377,808	884,950/341,681	-2.0
Côte d'Ivoire	322,463/124,503	103,280/39,876	104,050/40,174	0.1
Cambodia	181,035/69,898	115,410/44,560	104,470/40,336	-0.2
Laos	236,800/91,428	165,320/63,830	161,420/62,324	-0.5
Madagascar	590,992/228,182	130,230/50,282	128,380/49,567	-0.3
Malaysia	329,079/127,057	215,910/83,363	208,900/80,656	-0.7
Mexico	1,967,180/759,528	655,400/253,051	642,380/248,024	-0.4
Nigeria	924,000/356,756	131,370/50,722	110,890/42,814	-3.3
Papua New Guinea	461,700/178,262	301,320/116,340	294,370/113,657	-0.5
Peru	1,285,220/496,223	692,130/267,232	687,420/265,414	-0.1
Philippines	299,400/115,598	79,490/30,691	71,620/27,652	-2.1
Thailand	513,517/198,269	148,140/57,197	145,200/56,062	-0.4
Venezuela	912,050/352,142	491,510/189,773	477,130/184,221	-0.6
Vietnam	334,331/129,085	117,250/45,270	129,310/49,926	2.0
World	130,639,000/50,439,979	39,886,100/15,400,109	39,520,025/15,258,767	-0.2

EO Library: Tropical Deforestation Fact Sheet

Go to site

NASA Earth Observatory pages looking at the deforestation of tropical rainforests. Articles examine the causes of deforestation, rates of clearance, and the effects it has. The site also has links to relevant remote-sensing data.

degaussing

removal of magnetism from a device. The term is usually used in reference to colour monitors and other display devices that use a cathode-ray tube (CRT). External magnetic forces, such as the Earth's natural magnetism or a magnet placed close to the monitor, can cause distorted images and colours.

In World War II, ships were degaussed to prevent them from detonating magnetic mines. This involved encircling each ship with a conductor, through which an electric current was maintained.

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degeneration

in biology, a change in the structure or chemical composition of a tissue or organ that interferes with its normal functioning. Examples of degeneration include fatty degeneration, fibroid degeneration (cirrhosis), and calcareous degeneration, all of which are part of natural changes that occur in old age.

The causes of degeneration are often unknown. Heredity often has a role in the degeneration of organs; for example, fibroid changes in the kidney can be seen in successive generations. Defective nutrition and continued stress on particular organs can cause degenerative changes. Alcoholism can result in cirrhosis of the liver and tuberculosis causes degeneration of the lungs.

---

degree

symbol °

in mathematics, a unit of measurement of an angle or arc. A circle or complete rotation is divided into 360°. A degree may be subdivided into 60 minutes (symbol '), and each minute may be subdivided in turn into 60 seconds (symbol ").

Temperature is also measured in degrees, which are divided on a decimal scale. See also Celsius, and Fahrenheit.

A degree of latitude is the length along a meridian such that the difference between its north and south ends subtend an angle of 1° at the centre of the Earth. A degree of longitude is the length between two meridians making an angle of 1° at the centre of the Earth.

De Havilland, Geoffrey (1882-1965)

English aircraft designer who designed and whose company produced the Moth biplane, the Mosquito fighter-bomber of World War II, and in 1949 the Comet, the world's first jet-driven airliner to enter commercial service. He was knighted in 1944.

After designing a fighter and a bomber for use in World War I, he founded the De Havilland Aircraft Company in 1920. This was eventually absorbed into the Hawker Siddeley conglomerate.

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dehydration

in chemistry, the removal of water from a substance to give a product with a new chemical formula; it is not the same as drying.

There are two types of dehydration. For substances such as hydrated copper sulphate ($CuSO_4.5H_2O$) that contain water of crystallization, dehydration means removing this water to leave the anhydrous substance. This may be achieved by heating, and is reversible.

Some substances, such as ethanol, contain the elements of water (hydrogen and oxygen) joined in a different form.
Dehydrating agents such as concentrated sulphuric acid will remove these elements in the ratio 2:1.

---

dehydration

process to preserve food. Moisture content is reduced to 10-20% in fresh produce, and this provides good protection against moulds. Bacteria are not inhibited by drying, so the quality of raw materials is vital.

The process was developed commercially in France about 1795 to preserve sliced vegetables, using a hot-air blast. The earliest large-scale application was to starch products such as pasta, but after 1945 it was extended to milk, potatoes, soups, instant coffee, and prepared baby and pet foods. A major benefit to food manufacturers is reduction of weight and volume of the food products, thus lowering distribution cost.

Deimos

one of the two moons of the planet Mars. It is irregularly shaped, 15 × 12 × 11 km/9 × 7.5 × 7 mi, orbits at a height of 24,000 km/15,000 mi every 1.26 days, and is not as heavily cratered as Mars's other moon, Phobos. Deimos was discovered in 1877 by US astronomer Asaph Hall, and is thought to be an asteroid captured by Mars's gravity.

NASA's Viking 2 probe visited Deimos in 1977, flying within 29 km/18 mi of the Moon's surface and taking detailed photographs of its pitted and boulder-strewn landscape.

Delbrück, Max (1906-1981)

German-born US biologist who was awarded the Nobel Prize for Physiology or Medicine in 1969 with Salvador Luria and Alfred Hershey for their work on the replication mechanism and genetic structure of viruses. He pioneered techniques in molecular biology, studying genetic changes occurring when viruses invade bacteria.

de Lesseps, Ferdinand, Vicomte

French engineer; see Lesseps, Ferdinand, Vicomte de Lesseps.

deliquescence

phenomenon of a substance absorbing so much moisture from the air that it ultimately dissolves in it to form a solution.

Deliquescent substances make very good drying agents and are used in the bottom chambers of desiccators. Calcium chloride ($CaCl_2$) is one of the commonest.

delirium

in medicine, a state of acute confusion in which the subject is incoherent, frenzied, and out of touch with reality. It is often accompanied by delusions or hallucinations.

Delirium may occur in feverish illness, some forms of mental illness, brain disease, and as a result of drug or alcohol intoxication. In chronic alcoholism, attacks of **delirium tremens** (DTs), marked by hallucinations, sweating, trembling, and anxiety, may persist for several days.

delphinium

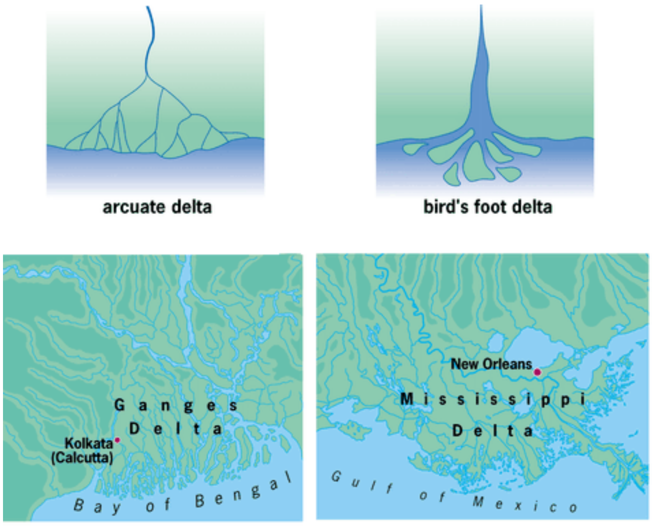
any plant of the genus *Delphinium* belonging to the buttercup family Ranunculaceae. There are some 250 species, including the great flowered larkspur *D. grandiflorum*, an Asian form and one of the ancestors of the garden delphinium. Most species have blue, purple, or white flowers in a long spike.

delta

river sediments deposited when a river flows into a standing body of water with no strong currents, such as a lake, lagoon, sea, or ocean. A delta is the result of fluvial and marine processes. Deposition is enhanced when water is saline because salty water causes small clay particles to adhere together. Other factors influencing deposition include the type of sediment, local geology, sea-level changes, plant growth, and human impact. Some examples of large deltas are those of the Mississippi, Ganges and Brahmaputra, Rhône, Po, Danube, and Nile rivers. The shape of the Nile delta is like the Greek letter *delta* or Δ, and gave rise to the name.

The **arcuate (arc-shaped) delta** of the Nile, found in areas where longshore drift keeps the seaward edge of the delta trimmed and relatively smooth, is only one form of delta. Others include **birdfoot (projecting) deltas**, where the river brings down enormous amounts of fine silt, as at the Mississippi delta; and **tidal (linear) deltas**, like that of the Mekong, China, where most of the material is swept to one side by sea currents. **Cuspate deltas** are pointed, and are shaped by regular opposing, gentle water movement, as seen at the Ebro and Tiber deltas in Italy.

delta



(Image © Research Machines plc)

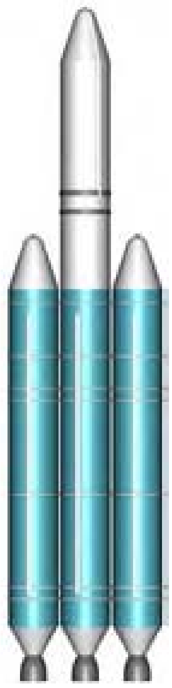
An arcuate delta and a bird's foot delta. The Mississippi delta is an example of a bird's foot delta and the Ganges delta is an example of an arcuate delta.

Delta rocket

US rocket used to launch many scientific and communications satellites since 1960. Its design is based on the Thor ballistic missile. Several increasingly powerful versions have been produced as satellites became larger and heavier. Solid-fuel boosters were attached to the first stage of the rocket in order to increase lifting power.

NASA's twin rovers were launched to Mars in June and July 2003 atop a Delta II rocket. Delta II, Delta III, and Delta IV series vehicles are all now in active use.

Delta rocket



(Image © Research Machines plc)

The Delta 4 Heavy (there are five configurations of Delta 4, of which this is the largest) can lift up to 13,130 kg/28,950 lb.

Delta

Go to site

Illustration of the design and capabilities of the modern Delta rocket family. The site includes information on the history of the Delta rocket and news of forthcoming launches. Via the Delta communications pages, visitors can access Boeing's impressive image gallery.

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delta wing

aircraft wing shaped like the Greek letter *delta* Δ. Its design enables an aircraft to pass through the sound barrier with little effect. The supersonic airliner Concorde and the US space shuttle have delta wings.

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delusion

in psychiatry, a false belief that is unshakeably held. Delusions are a prominent feature of schizophrenia and paranoia, but may also occur in other psychiatric states.

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dementia

mental deterioration as a result of physical changes in the brain. It may be due to degenerative change, circulatory disease, infection, injury, or chronic poisoning.
Senile dementia, a progressive loss of mental faculties such as memory and orientation, is typically a disease process of old age, and can be accompanied by depression.

Dementia is distinguished from amentia, or severe congenital (from birth) mental insufficiency.

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demodulation

in radio, the technique of separating a transmitted audio frequency signal from its modulated radio carrier wave. At the transmitter, the audio frequency signal (representing speech or music, for example) may be made to modulate the amplitude (AM broadcasting) or frequency (FM broadcasting) of a continuously transmitted radio-frequency carrier wave. At the receiver, the signal from the aerial is demodulated to extract the required speech or sound component. In early radio systems, this process was called detection. See modulation.

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dendrite

part of a nerve cell or neuron. The dendrites are slender filaments projecting from the cell body. They receive incoming messages from many other nerve cells and pass them on to the cell body.

If the combined effect of these messages is strong enough, the cell body will send an electrical impulse along the axon (the threadlike extension of a nerve cell). The tip of the axon passes its message to the dendrites of other nerve cells.

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dendrochronology

or tree-ring dating

analysis of the annual rings of trees to date past events by determining the age of timber. Since annual rings are formed by variations in the water-conducting cells produced by the plant during different seasons of the year, they also provide a means of establishing past climatic conditions in a given area.

Samples of wood are obtained by driving a narrow metal tube into a tree to remove a core extending from the bark to the centre. Samples taken from timbers at an archaeological site can be compared with a master core on file for that region or by taking cores from old living trees; the year when they were felled can be determined by locating the point where the rings of the two samples correspond and counting back from the present.

Deneb

or Alpha Cygni

brightest star in the constellation Cygnus, and the 20th-brightest star in the night sky. It is one of the greatest supergiant stars known, with a true luminosity of about 60,000 times that of the Sun. Deneb is 1,800 light years from the Sun.

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dengue

tropical viral fever transmitted by mosquitoes and accompanied by joint pains, headache, rash, and glandular swelling. The incubation time is a week and the fever also lasts about a week. A more virulent form, dengue haemorrhagic fever, is thought to be caused by a second infection on top of the first, and causes internal bleeding. It affects mainly children. There are an estimated 50-100 million cases annually in the tropics causing over 10,000 deaths(1998).

In 1998 an increase in dengue fever was observed in some areas where it is not normally a problem. The increase is believed to result from a growing spread of mosquitoes as global warming raises temperatures widening the geographical range of their habitats. In April 1998, there was a new case of dengue every ten minutes in the state of Rio de Janeiro, Brazil.

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denier

unit used in measuring the fineness of yarns, equal to the mass in grams of 9,000 metres of yarn. Thus 9,000 metres of 15 denier nylon, used in nylon stockings, weighs 15 g/0.5 oz, and in this case the thickness of thread would be 0.00425 mm/0.0017 in. The term is derived from the French silk industry; the *denier* was an old French silver coin.

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denitrification

process occurring naturally in soil, where bacteria break down nitrates to give nitrogen gas, which returns to the atmosphere.

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denominator

in mathematics, the bottom number of a fraction, so called because it names the family of the fraction. The top number, or numerator, specifies how many unit fractions are to be taken.

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density

measure of the compactness of a substance; it is equal to its mass per unit volume and is measured, for example, in kg per cubic metre or lb per cubic foot. Density is a scalar quantity. The average density D of a mass m occupying a volume V is given by the formula: $D = m/V$. Relative density is the ratio of the density of a substance to that of water at 4°C/39.2°F.

In photography, density refers to the degree of opacity of a negative; in electricity, current density is the amount of current passing through a cross-sectional area of a conductor (usually given in amperes per square in or per square cm).

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density wave

in astrophysics, concept proposed to account for the existence of spiral arms in galaxies. In the density wave theory, stars in a spiral galaxy move in elliptical orbits in such a way that they crowd together in waves of temporarily enhanced density that appear as spiral arms. The idea was first proposed by Swedish astronomer Bertil Lindblad in the 1920s and developed by US astronomers Chia Lin and Frank Shu in the 1960s.

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dental caries

in medicine, another name for caries.

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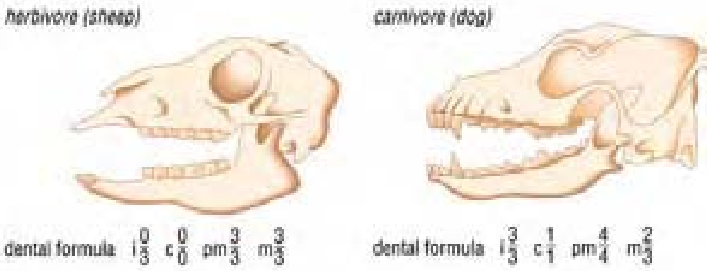
dental formula

way of showing the number of teeth in an animal's mouth. The dental formula consists of eight numbers separated by a line into two rows. The four above the line represent the teeth on one side of the upper jaw, starting at the front. If this reads 2 1 2 3 (as for humans) it means two incisors, one canine, two premolars, and three molars (see tooth). The numbers below the line represent the lower jaw. The total number of teeth can be calculated by adding up all the numbers and multiplying by two.

dentition


herbivore (sheep)
carnivore (dog)
dental formula $i\frac{0}{3}$ $c\frac{0}{0}$ $pm\frac{3}{3}$ $m\frac{3}{3}$
dental formula $i\frac{3}{3}$ $c\frac{1}{1}$ $pm\frac{4}{4}$ $m\frac{2}{3}$

(Image © Research Machines plc)

The dentition and dental formulae of a typical herbivore (sheep) and carnivore (dog). The dog has long pointed canines for puncturing and gripping its prey and has modified premolars and molars (carnassials) for shearing flesh. In the sheep, by contrast, there is a wide gap, or diastema, between the incisors, developed for cutting through blades of grass, and the grinding premolars and molars; the canines are absent.

dentistry

care and treatment of the teeth and gums.
Orthodontics deals with the straightening of the teeth for aesthetic and clinical reasons, and **periodontics** with care of the supporting tissue (bone and gums).

The bacteria that start the process of dental decay are normal, nonpathogenic members of a large and varied group of micro-organisms present in the mouth. They are strains of oral streptococci, and it is only in the presence of sucrose (from refined sugar) in the mouth that they become damaging to the teeth. Fluoride in the water supply has been one attempted solution to prevent decay, and several vaccines against it are under development.

dentition

type and number of teeth in a species. Different kinds of teeth have different functions; a grass-eating animal will have large molars for grinding its food, whereas a meat-eater will need powerful canines for catching and killing its prey. The teeth that are less useful to an animal's lifestyle may be reduced in size or missing altogether. An animal's dentition is represented diagramatically by a dental formula.

Young children have **deciduous dentition**, popularly known as 'milk teeth', the first ones erupting at about six months of age.
Mixed dentition is present from the ages of about six (when the first milk teeth are shed) to about 12.
Permanent dentition (up to 32 teeth) is usually complete by the mid-teens, although the third molars (wisdom teeth) may not appear until around the age of 21.

denudation

natural loss of soil and rock debris, blown away by wind or washed away by running water, laying bare the rock below. Over millions of years, denudation causes a general lowering of the landscape.

deodar

Himalayan cedar tree, often planted as a rapid-growing ornamental. Its fragrant, durable wood is valuable as timber. (*Cedrus deodara*, family Pinaceae.)

deoxyribonucleic acid

full name of DNA.

depilatory

any instrument or substance used to remove growing hair, usually for cosmetic reasons. Permanent eradication is by electrolysis, the destruction of each individual hair root by an electrolytic needle or an electrocautery, but there is a danger of some regrowth as well as scarring.

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depolarizer

oxidizing agent used in dry-cell batteries that converts hydrogen released at the negative electrode into water. This prevents the build-up of gas, which would otherwise impair the efficiency of the battery. Manganese(IV) oxide is often used for this purpose.

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depression

in medicine, an emotional state characterized by sadness, unhappy thoughts, apathy, and dejection. Sadness is a normal response to major losses such as bereavement or unemployment. After childbirth, postnatal depression is common. Clinical depression, which is prolonged or unduly severe, often requires treatment, such as antidepressant medication, cognitive therapy, or, in very rare cases, electroconvulsive therapy (ECT), in which an electrical current is passed through the brain.

Periods of depression may alternate with periods of high optimism, over-enthusiasm, and confidence. This is the manic phase in a disorder known as **manic depression** or **bipolar disorder**. A manic depressive state is one in which a person switches repeatedly from one extreme to the other. Each mood can last for weeks or months. Typically, the depressive state lasts longer than the manic phase.

'Long Term Pharmacotherapy of Depression'

Go to site

Part of a collection of articles maintained by the *British Medical Journal*, this page features the full text of a 18 April 1998 editorial addressing the 'importance of long term psychological and pharmacological treatment'. In addition to the editorial, you will find a list of related articles from the extensive *PubMed* collection. You can also search the collections under which this article appears, search other articles written by the authors of this article, and submit or read responses to this article. A list of references is also included.

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depression

or cyclone or low

in meteorology, a region of relatively low atmospheric pressure. In mid-latitudes a depression forms as warm, moist air from the tropics mixes with cold, dry polar air, producing warm and cold boundaries (fronts) and unstable weather – low cloud and drizzle, showers, or fierce storms. The warm air, being less dense, rises above the cold air to produce the area of low pressure on the ground. Air spirals in towards the centre of the depression in an anticlockwise direction in the northern hemisphere, clockwise in the southern hemisphere, generating winds up to gale force. Depressions tend to travel eastwards and can remain active for several days.

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derivative

or differential coefficient

in mathematics, the limit of the gradient of a chord linking two points on a curve as the distance between the points tends to zero; for a function of a single variable, $y = f(x)$, it is denoted by $f'(x)$, $Df(x)$, or dy/dx, and is equal to the gradient of the curve.

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dermatitis

inflammation of the skin (see eczema), usually related to allergy.
Dermatosis refers to any skin disorder and may be caused by contact or systemic problems.

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dermatology

medical speciality concerned with diagnosis and treatment of skin disorders.

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derrick

simple lifting machine consisting of a pole carrying a block and tackle. Derricks are commonly used on ships that carry freight. In the oil industry the tower used for hoisting the drill pipes is known as a derrick.

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derris

climbing leguminous plant (see legume) of southeast Asia. Its roots contain rotenone, a strong insecticide. (*Derris elliptica*, family Fabaceae.)

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desalination

removal of salt, usually from sea water, to produce fresh water for irrigation or drinking. Distillation has usually been the method adopted, but in the 1970s a cheaper process, using certain polymer materials that filter the molecules of salt from the water by reverse osmosis, was developed.

Desalination plants have been built along the shores of Middle Eastern countries where fresh water is in short supply.

Descartes, René (1596-1650)

French philosopher and mathematician. He believed that commonly accepted knowledge was doubtful because of the subjective nature of the senses, and attempted to rebuild human knowledge using as his foundation the dictum *cogito ergo sum* ('I think, therefore I am'). He also believed that the entire material universe could be explained in terms of mathematical physics, and founded coordinate geometry as a way of defining and manipulating geometrical shapes by means of algebraic expressions. Cartesian coordinates, the means by which points are represented in this system, are named after him. Descartes also established the science of optics, and helped to shape contemporary theories of astronomy and animal behaviour.

Descartes identified the 'thinking thing' (*res cogitans*), or mind, with the human soul or consciousness; the body, though somehow interacting with the soul, was a physical machine, secondary to, and in principle separable from, the soul. He held that everything has a cause; nothing can result from nothing. He believed that, although all matter is in motion, matter does not move of its own accord; the initial impulse comes from God. He also postulated two quite distinct substances: spatial substance, or matter, and thinking substance, or mind. This is called 'Cartesian dualism', and it preserved him from serious controversy with the church.

Descartes, René

Go to site

Extensive treatment of the life and philosophical, scientific, and mathematical achievements of Renatus Cartesius. The restless travels of the young savant are described before a detailed discussion of his contribution to learning.

Discourse on Method

Go to site

Complete text of Descartes' work which includes the phrase 'cogito ergo sum' ('I think, therefore I am').

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desert

arid area with sparse vegetation (or, in rare cases, almost no vegetation). Soils are poor, and many deserts include areas of shifting sands. Deserts can be either hot or cold. Almost 33% of the Earth's land surface is desert, and this proportion is increasing. Arid land is defined as receiving less than 250 mm/9.75 in rain per year.

The **tropical desert** belts of latitudes from 5° to 30° are caused by the descent of air that is heated over the warm land and therefore has lost its moisture. Other natural desert types are the **continental deserts**, such as the Gobi, that are too far from the sea to receive any moisture; **rain-shadow deserts**, such as California's Death Valley, that lie in the lee of mountain ranges, where the ascending air drops its rain only on the windward slopes; and **coastal deserts**, such as the Namib, where cold ocean currents cause local dry air masses to descend. Desert surfaces are usually rocky or gravelly, with only a small proportion being covered with sand (about 3%). Deserts can be created by changes in climate, or by the human-aided process of desertification.

Characteristics common to all deserts include irregular rainfall of less than 250 mm/9.75 in per year, very high evaporation rates of often 20 times the annual precipitation, and low relative humidity and cloud cover. Temperatures are more variable; tropical deserts have a big diurnal temperature range and very high daytime temperatures (58°C/136.4°F has been recorded at Azizia in Libya), whereas mid-latitude deserts have a wide annual range and much lower winter temperatures (in the Mongolian desert the mean temperature is below freezing point for half the year).

Desert soils are infertile, lacking in humus and generally grey or red in colour. The few plants capable of surviving such conditions are widely spaced, scrubby and often thorny. Long-rooted plants (phreatophytes) such as the date palm and musquite commonly grow along dry stream channels. Salt-loving plants (halophytes) such as saltbushes grow in areas of highly saline soils and near the edges of playas (dry saline lakes). Xerophytes are drought-resistant and survive by remaining leafless during the dry season or by reducing water losses with small waxy leaves. They frequently have shallow and widely branching root systems and store water during the wet season (for example, succulents and cacti with pulpy stems).

Deserts

what is a desert?

When people think about deserts, they usually imagine vast sand dunes under a burning sun, with nothing to break the monotony of the landscape except for an occasional palm-filled oasis. Although places like this certainly exist, the word 'desert' encompasses a wide range of landscapes, many of which are rich in wild plants, animals, and people, adapted to difficult conditions. Characteristics of deserts include very low rainfall and humidity, high evaporation rates, and little cloud cover. Many deserts are hot but some can be bitterly cold; there are ice deserts in the polar regions. Desert soils are generally poor because they contain little vegetable matter; if water is supplied, most deserts are capable of sustaining agriculture.

Natural deserts occur when geography and climate combine to prevent significant amounts of rain falling on an area. Tropical deserts are caused by the descent of air that is heated over warm land and has previously lost all its moisture. Continental deserts, such as the Gobi in Mongolia, are too far from the sea and large inland waters to receive any significant moisture. Rain-shadow deserts lie in the lee of mountains where the rain falls on the windward slope, as is the case in the Mojave Desert beyond the Sierra Nevada in California. Coastal deserts, such as the Namib in southern Africa, are formed when cold ocean currents cause local dry air masses to descend.

The location of deserts changes over time, and many of today's deserts were once covered with grassland or forest. In the middle of the Australian desert, for example, isolated valleys of palm trees survive as relics of a vast rainforest that once stretched south from the coast. Remnants of great civilizations in the deserts of Africa and the Middle East are reminders that these places once contained fields rich in agricultural crops.

life adapts to desert conditions

Any living plant or animal that makes its home in the desert has to adapt to some of the harshest conditions imaginable. Plants have to endure long periods of drought and often-dramatic variations in temperature. Most either store water, like many cacti and succulents, or lie dormant until the rains come, like the sagebrush. Some desert trees are extremely deep-rooting, allowing them to reach underground water sources. Plants flower only very rarely, when conditions are suitable. Within a few hours of rainfall, plants that have not flowered for years burst into bloom, and the desert is a mass of colour for a few days.

Animals have also developed special adaptive strategies. In hot deserts, most lie dormant during the day; if the nights are cold, small mammals confine their activities to the hours of sunrise and sunset, and spend the rest of the time sheltering in their burrows. Birds migrating across desert regions follow routes that have remained the same for hundreds or thousands of years, stopping at occasional oases of water and vegetation along the way.

human cultures survive under harsh conditions

Human societies also exist in deserts, although, like any other animal, they have had to adapt. Most live on the edges of desert regions, and the only settled communities are around oases. Truly desert cultures are nomadic, moving constantly to find food for their livestock or fresh supplies of water, and living in temporary accommodation. The Bedouin of Arabia and North Africa (the word *bedouin* means 'desert dweller' in Arabic) lived for centuries in tents made of animal skins, and traded in camels and horses, although they are now increasingly being forced to settle in one place. In the Gobi Desert in Mongolia, nomadic tribes lived in temporary structures known as yurts. The people of the Kalahari Desert in Botswana (formerly known as Bushmen) have no permanent dwellings at all and traditionally live a hunter-gatherer existence; their knowledge of desert survival is so acute that they spend only a small amount of time every day on gathering food and drink.

A nomadic lifestyle has a profound impact on culture. Artistic expression tends to be concentrated on portable objects, like jewellery and ornate clothes, and on dance music and an oral tradition of storytelling.

deserts are expanding

Unfortunately, deserts can also be formed as a result of human mistakes. Degradation of a dry-land area - through deforestation, overgrazing, poorly designed irrigation systems, and soil erosion - can lead to a complex cycle of changes that results in desertification. Loss of trees and ground cover means that water is no longer trapped by vegetation, increasing the evaporation rates and often also the frequency and severity of drought. Mismanagement of irrigation can lead to a raised salt content in the soil, preventing crop growth and adding to risks of desert formation. Overgrazing, particularly by animals like goats that can strip vegetation bare, is often a contributory factor. It is also possible that human-induced climate change, created by the release of carbon dioxide from fossil fuels, is helping to create conditions suitable for desert formation. Throughout the world, desertification is accelerating, and according to the United Nations, a hundred countries are affected.

Desertification is as old as history. The world's oldest known story, the Sumerian *Epic of Gilgamesh*, describes Mount Lebanon as being covered in vast forests of cedars, but overfelling dating from 3000 BC has left an area of desert. Similar changes have taken place as a result of mismanagement by many of the world's oldest human civilizations in the Tigris and Euphrates river basins of present-day Iraq, where the Sumerian, Mesopotamian, Assyrian, and Babylonian cultures all flourished but degraded the land. Further west, the hills of the Mediterranean coast long ago lost their forests and have degraded to semi-desert and maquis scrub. In the 19th century, Italian travellers to the Horn of Africa left vivid accounts of the forests of Eritrea, but most of the country is now desert or semi-desert and only a few tiny remnants of natural woodland remain.

Up to one-third of the world's land area could soon become desert unless urgent steps are taken to address the problem. However, solving it will not be easy. People in arid areas are fully aware of the risks of desertification, but are often forced into unsustainable lifestyles by such factors as lack of suitable land, population growth, poverty, and often also the impact of refugees and war. Most people who live in and around deserts only do so from necessity. Long-term solutions to desertification, including, for example, forest-restoration programmes and the introduction of techniques for stabilizing the soil, have to take place alongside actions to alleviate the immediate problems faced by desert societies. Solutions cannot just be imposed from above. They have a chance of working only if they have the backing of local desert communities. The importance of this has been recognized by the United Nations, which advises that 'public participation should be made an integral part of action to prevent and combat desertification and account should be taken of the needs, wisdom, and aspirations of people'.

where the deserts are

The Earth has five main regions of natural desert. By far the largest is the **Afro-Asian desert**, a vast belt that stretches from the Atlantic Ocean to China, and includes the African Sahara, the Arabian, Iranian, and Touranian deserts of the Middle East and central Asia, the Thar Desert in Pakistan and India, and the Takla Makan and Gobi deserts of China and Mongolia. Also in Africa, the **Namib and Kalahari deserts** cover a large area in the southwest. The **North American desert** covers much of southern USA and northern Mexico. Further south, the Atacama Desert is a thin, arid strip on the coastal side of the Andes, and the **Patagonian desert** covers much of Argentina east of the Andes. The **Australian desert** covers much of the interior of the world's largest island.

Largest deserts in the world

Desert	Location	Area[1]	
		sq km	sq mi
Sahara	northern Africa	9,065,000	3,500,000
Arabian	Arabia	1,700,000	656,300
Gobi	Mongolia/northeastern China	1,295,000	500,000
Patagonian	Argentina	673,000	260,000
Great Victoria	southwestern Australia	647,500	250,000
Kalahari	southwestern Africa	582,800	225,000
Chihuahuan	Mexico/southwestern USA	453,200	175,000
Thar	India/Pakistan	453,200	175,000
Great Sandy	northwestern Australia	338,500	130,700
Colorado	southwestern USA	336,700	130,000
Sonoran	Mexico/southwestern USA	310,800	120,000
Iranian	Iran	259,000	100,000
Atacama	Chile	139,900	54,000
Mojave	southwestern USA	139,900	54,000

[1] Desert areas are very approximate because clear physical boundaries may not occur.

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desertification

spread of deserts by changes in climate, or by human-aided processes. Desertification can sometimes be reversed by special planting (marram grass, trees) and by the use of water-absorbent plastic grains, which, added to the soil, enable crops to be grown. About 30% of land worldwide is affected by desertification (1998), including 1 million hectares in Africa and 1.4 million hectares in Asia. The most rapid desertification is in developed countries such as the USA, Australia, and Spain.

Natural causes of desertification include decreased rainfall, increased temperatures, lowering of the water table, and soil erosion.

The human-aided processes leading to desertification include overgrazing, destruction of forest belts, and exhaustion of the soil by intensive cultivation without restoration of fertility - all of which may be prompted by the pressures of an expanding population or by concentration in land ownership. About 135 million people are directly affected by desertification, mainly in Africa, the Indian subcontinent, and South America. The Sahel region in Africa is one example.

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desktop publishing

DTP

use of microcomputers for small-scale typesetting and page makeup. DTP systems are capable of producing camera-ready pages (pages ready for photographing and printing), made up of text and graphics, with text set in different typefaces and sizes. The page can be previewed on the screen before final printing on a laser printer.

A DTP program is able to import text and graphics from other packages; run text as columns, over pages, and around artwork and other insertions; enable a wide range of fonts; and allow accurate positioning of all elements required to make a page.

Using Computers in Art and Design

art and technology

The process of making art has always been one in which technology and individual creativity have worked together. This has been true from earliest times when painters had a sorcererlike knowledge of how to create vivid colours, and sculptors transformed the materials they had around them into representations of the world.

The development of the computer has been the latest in a long line of more recent technological advances that have brought us new ways of seeing. Photography, cinema, radio, and television have become the key media through which we view and understand the world around us, and it was the art and culture of these forms that defined the 20th century. The computer, the most recent arrival, is still in its infancy as a creative tool, but it is clear that its influence has already been felt in most forms of art and culture.

history

Early computers, although useful in other ways, were not immediately identified as machines through which art might be made. However, technology developed rapidly and useful design tools began to appear throughout the 1950s and 1960s. The **flat-image scanner** (for digitizing photographs and other images) was invented in 1957, closely followed by the **image plotter** (a form of printer) in 1959. In 1960 the term **'computer graphics'** was coined by William A Fetter, who was working for US military and commercial aircraft manufacturer Boeing. He used the term to describe a process of visualizing cockpit designs. In 1962, **Sketchpad**, an interactive graphics system for drawing directly onto a computer screen, was developed by US electronics engineer Ivan Sutherland, and a year later US computer scientist Douglas Engelbart patented the first computer **mouse** prototype.

Computers slowly began to appear in new settings. One of the first artists to explore the potential of electronic technology was the US pop artist Robert Rauschenberg. In 1963 he formed a partnership with US technologist Billy Klüver and they began to produce collaborative performance works under the name 'Experiments in Art and Technology'. Five years later, in 1968, one of the first major art exhibitions to be based around computer technology took place at the Institute of Contemporary Arts in London. This exhibition, entitled 'Cybernetic Serendipity', was curated by Polish-born English art expert Jasia Reichardt and featured computer-generated paintings, sculptures, films, music, and poetry. This landmark show was hugely influential in highlighting the significance of computer technology as a creative tool.

key tools

As computers continued to become smaller and cheaper, and therefore more widespread, the emphasis continued to shift from engineers and technologists to a wider, more diverse group of users. The first mass-market computers such as the Apple II, the Commodore Amiga, and the IBM PC introduced a wide range of people to computers for the first time, and artists were quick to explore the creative possibilities of these new tools. Although by today's standards these computers were expensive and low powered, newer models were developed and an increasing range of application software for graphics began to appear.

One of the most important tools that emerged at this time was a software application called Aldus Pagemaker. This tool was created in 1985 to allow designers to use computers for the layout and typesetting of print. It very quickly became the most popular way to produce publications and spawned a whole new industry called **'desktop publishing'** or DTP. The success of Pagemaker and the introduction of affordable colour graphics systems led to the development of a number of other tools aimed at supporting the publishing industry, most notably Adobe Photoshop, which, for many aspiring computer artists, has provided the canvas for their first explorations of the medium.

High-end graphics tools were also developed through the 1970s and 1980s, many of which have specialist applications such as television graphics, **computer-aided design** (CAD), or **virtual reality simulators**. One ground-breaking tool used by artists in the 1980s was the Quantel Paintbox system, a complete graphics suite that used a pressure-sensitive pen and tablet device with which artists could paint intuitively. This was used by the English painters Howard Hodgkin and David Hockney, but probably was seen by most people in television advertising and news graphics.

As these tools grew in sophistication, two distinct forms of computer graphics emerged: **bitmap editors** and **vector graphics**. Bitmap editors allow the user to change and edit the individual pixels (picture elements) of an image, and are normally used for manipulating photographs or for graphics that will only be displayed on a computer screen or television. Adobe Photoshop is an example of this kind of tool. In vector graphics, the computer uses a special language to describe the shape and form of a computer graphic object. This object can then be rendered into a bitmap for screen display or for printing. This form of tool is mainly used for the creation of 3-D graphics or for architectural or product design. Many of these tools use a software technology called PostScript to create the image. Vector graphics tools include Illustrator, Freehand, and AutoCAD.

work or play

While computer graphics often produce results that are indiscernible from conventional media such as photography or painting, this may not always be the case. Many artists regard digital art as something unique to the computer rather than an emulation of an existing art form. Like cinema, which developed as an art form in its own right out of a hybrid of photography and theatre, digital art will define its own language and codes. But this will take time. US computer scientist Ted Nelson, one of the key proponents of the new technology, believes that many of us are only 'using the computer as a paper simulator'. He coined the term **'hypertext'** to describe the links between items that mean information can be found by following many different paths, rather than following one line from start to finish. In other words, just as this encyclopedia can be read by following cross references from one article to another, rather than starting on page one and reading the pages in order to the end, so the Internet allows many different pieces of information to be accessed from many different starting points. Nelson has been a champion of the development of this form of creativity. The term hypertext has to some extent been displaced by the more popular, but less specific, notion of **'multimedia'**, text accompanied by sound and images, for example. We are still some way away from Nelson's vision of an active virtual world. But while the idea that computer art is a distinct form of creative practice has still to gain wider acceptance, it is clear that some artists are beginning to define a new canon.

Among those who have been significant in defining this new ground, several have chosen to explore games and gameplay, an area that seems to present particularly fertile ground for the interactive potential of the computer. Japanese artist Toshio Iwai, who has created elegant interactive sound games, is one of the foremost exponents of this way of working. His work has been shown in art galleries, museums, and, most recently, in the Play Zone at the Millennium Dome in London. English artist Susan Collins has also created interactive projections that allow Internet users to view and influence images being projected onto pedestrians in city centres around the globe and, at the same time, to enter into dialogue with them. Australian artist Jeffrey Shaw, who is based at the ZKM Institute at Karlsruhe, Germany, has created a number of works, one of which is an interactive piece called 'The Legible City'. In this work, the viewer explores a huge projected map of New York City by pedalling and steering a bicycle which controls the projected image. The streets are made up of enormous texts which the user reads by exploring the complex urban street patterns.

centre stage

While some artists produce digital work for the art gallery, others are experimenting with the rapidly growing world of the Internet, exploring ideas of connectivity, distance, and simultaneity.

However, the first areas to have achieved broad popular success are those in which digital technology has been used to enhance traditional media forms: in music, in photography, and in design, but probably most visibly in Hollywood cinema, where **digital special effects** have become the stars of many films. Organizations like the US digital entertainment company Industrial Light and Magic have specialized in pushing the boundaries of computer-assisted special effects, while US animator John Lasseter has achieved worldwide success with the *Toy Story* movies, in which high-level technical skill has been married with the animator's craft to produce hugely entertaining results.

the future for digital art

Whatever the precise form that digital art will take, it seems that the art of the digital age will emerge in ways that will surround us and define our world view. This may well happen in ways that we cannot yet predict, although many believe that the realm of computer games will mature and produce works that have the resonance of novels or the involvement of cinema. Computer games such as *Myst*, released in 1992 by the Miller Brothers, or *Ceremony of Innocence*, directed by English artist Alex Mayhew, suggest future directions and ways in which the computer can become as challenging and engaging as the best linear media.

However, what will always remain important is what we choose to say within the media forms available to us. It seems likely that, for the next few years at least, digital media will increasingly provide a window on the world and will be the vehicle for much new creativity.

Internet Resources on Desktop Publishing

Go to site

A comprehensive site covering everything you need to know about desktop publishing. Includes news, software tips, and reviews of a number of DTP packages, as well as a number of links to sites on related topics, including free clip art and fonts.

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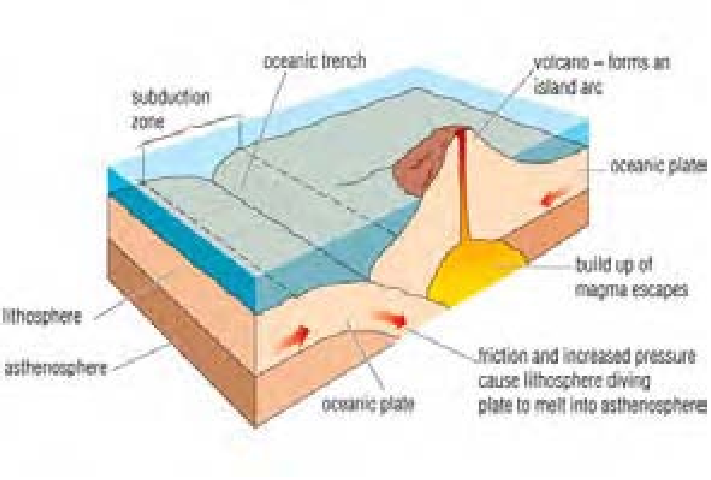
destructive margin

in plate tectonics, the boundary between two lithospheric plates, along which crust is being destroyed. The term refers to a subduction zone, a type of convergent margin in which an oceanic plate subducts (dives) into the mantle beneath a continental plate or another oceanic plate.

destructive margin


oceanic trench
subduction zone
volcano – forms an island arc
oceanic plate
build up of magma escapes
lithosphere
asthenosphere
friction and increased pressure cause lithosphere diving plate to melt into asthenosphere
oceanic plate

(Image © Research Machines plc)

When crustal plates meet, and one plate is denser than the other, the denser plate is forced under the other plate (at the subduction zone) and melts to form magma. If both plates are of equal density they collide and crumple up against each other forming mountains.

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detergent

surface-active cleansing agent. The common detergents are made from fats (hydrocarbons) and sulphuric acid, and their long-chain molecules have a type of structure similar to that of soap molecules: a salt group at one end attached to a long hydrocarbon 'tail'. They have the advantage over soap in that they do not produce scum by forming insoluble salts with the calcium and magnesium ions present in hard water.

To remove dirt, which is generally attached to materials by means of oil or grease, the hydrocarbon 'tails' (soluble in oil or grease) penetrate the oil or grease drops, while the 'heads' (soluble in water but insoluble in grease) remain in the water and, being salts, become ionized. Consequently the oil drops become negatively charged and tend to repel one another; thus they remain in suspension and are washed away with the dirt.

determinant

in mathematics, an array of elements written as a square, and denoted by two vertical lines enclosing the array. For a 2 × 2 matrix, the determinant is given by the difference between the products of the diagonal terms. Determinants are used to solve sets of simultaneous equations by matrix methods.

When applied to transformational geometry, the determinant of a 2 × 2 matrix signifies the ratio of the area of the transformed shape to the original and its sign (plus or minus) denotes whether the image is direct (the same way round) or indirect (a mirror image).

For example

$$\text{if matrix A} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \text{ then}$$

$$\text{determinant } |\mathrm{A}| = ad - bc$$

detonator

or blasting cap or percussion cap

small explosive charge used to trigger off a main charge of high explosive. The relatively unstable compounds mercury fulminate and lead azide are often used in detonators, being set off by a lighted fuse or, more commonly, an electric current.

detritus

in biology, the organic debris produced during the decomposition of animals and plants.

deuterium

or heavy hydrogen

naturally occurring heavy isotope of hydrogen, mass number 2 (one proton and one neutron), discovered by US chemist Harold Urey in 1932. It is sometimes given the symbol D. In nature, about one in every 6,500 hydrogen atoms is deuterium. Combined with oxygen, it produces 'heavy water' (D_2O), used in the nuclear industry.

deuteron

nucleus of an atom of deuterium (heavy hydrogen). It consists of one proton and one neutron, and is used in the bombardment of chemical elements to synthesize other elements.

developing

in photography, the process that produces a visible image on exposed photographic film, involving the treatment of the exposed film with a chemical developer.

The developing liquid consists of a reducing agent that changes the light-altered silver salts in the film into darker metallic silver. The developed image is made permanent with a fixer, which dissolves away any silver salts which were not affected by light. The developed image is a negative, or reverse image: darkest where the strongest light hit the film, lightest where the least light fell. To produce a positive image, the negative is itself photographed, and the development process reverses the shading, producing the final print. Colour and black-and-white film can be obtained as direct reversal, slide, or transparency material. Slides and transparencies are used for projection or printing with a positive-to-positive process such as Cibachrome.

development

in biology, the process whereby a living thing transforms itself from a single cell into a vastly complicated multicellular organism, with structures, such as limbs, and functions, such as respiration, all able to work correctly in relation to each other. Most of the details of this process remain unknown, although some of the central features are becoming understood.

Apart from the sex cells (gametes), each cell within an organism contains exactly the same genetic code. Whether a cell develops into a liver cell or a brain cell depends therefore not on which genes it contains, but on which genes are allowed to be expressed. The development of forms and patterns within an organism, and the production of different, highly specialized cells, is a problem of control, with genes being turned on and off according to the stage of development reached by the organism.

developmental psychology

study of development of cognition and behaviour from birth to adulthood.

devil ray

any of several large rays of the genera *Manta* and *Mobula*, in which two 'horns' project forwards from the sides of the huge mouth. These flaps of skin guide the plankton, on which the fish feed, into the mouth.

The largest of these rays can be 7 m/23 ft across, and weigh 1,000 kg/2,200 lb. They live in warm seas.

devil's coach horse

large, black, long-bodied, omnivorous beetle *Ocypus olens*, about 3 cm/1.2 in long. It has powerful jaws and is capable of giving a painful bite. It emits an unpleasant smell when threatened.

devil wind

minor form of tornado, usually occurring in fine weather; formed from rising thermals of warm air (as is a cyclone). A fire creates a similar updraught.

A **fire devil** or **firestorm** may occur in oil-refinery fires, or in the firebombings of cities, for example Dresden, Germany, in World War II.

Devonian period

period of geological time 408–360 million years ago, the fourth period of the Palaeozoic era. Many desert sandstones from North America and Europe date from this time. The first land plants flourished in the Devonian period, corals were abundant in the seas, amphibians evolved from air-breathing fish, and insects developed on land.

The name comes from the county of Devon in southwest England, where Devonian rocks were first studied.

dew

precipitation in the form of moisture that collects on plants and on the ground. It forms after the temperature of the ground has fallen below the dew point of the air in contact with it. As the temperature falls during the night, the air and its water vapour become chilled, and condensation takes place on the cooled surfaces.

Dewar, James (1842-1923)

Scottish chemist and physicist who invented the vacuum flask (Thermos) in 1872 during his research into the properties of matter at extremely low temperatures. He was knighted in 1904.

Working on the liquefaction of gases, Dewar dicsovered, in 1891, that both liquid oxygen and ozone are magnetic. In 1895 he became the first to produce liquid hydrogen, and then in 1899 succeeded in solidifying hydrogen at a temperature of -259°C/-434°F. He also invented, jointly with Frederick Abel, the explosive cordite in 1889.

dew point

temperature at which the air becomes saturated with water vapour. At temperatures below the dew point, the water vapour condenses out of the air as droplets. If the droplets are large they become deposited on plants and the ground as dew; if small they remain in suspension in the air and form mist or fog.

dhole

wild dog *Cuon alpinus* found in Asia from Siberia to Java. With head and body up to 1 m/39 in long, variable in colour but often reddish above and lighter below, the dhole lives in groups of from 3 to 30 individuals. The species is becoming rare and is protected in some areas.

Dholes can chase prey for long distances; a pack is capable of pulling down deer and cattle as well as smaller prey. They are even known to have attacked tigers and leopards.

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diabase

igneous rock formed below the Earth's surface, a form of basalt, containing relatively little silica (basic in composition).

Diabase is a medium-grained (hypabyssal) basalt and forms in minor intrusions, such as dykes which cut across the rock strata, and sills, which push between beds of sedimentary rock. When exposed at the surface, diabase weathers into spherical lumps.

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diabetes

disease that can be caused by reduced production of the hormone insulin, or a reduced response of the liver, muscle, and fat cells to insulin. This affects the body's ability to use and regulate sugars effectively. Diabetes mellitus is a disorder of the islets of Langerhans in the pancreas that prevents the production of insulin. Treatment is by strict dietary control and oral or injected insulin, depending on the type of diabetes.

Insulin increases glucose uptake from the blood into most body cells, except the brain and liver. In the liver, its effect is to reduce the production of glucose. Insulin works with other hormones to keep the concentration of glucose in the blood stable. A person with diabetes does not have this close regulation and may find that his or her glucose levels rise dangerously after a meal. Normally urine does not contain glucose, but when the blood glucose levels rise in a diabetic person, it appears in the urine. A person with diabetes may also be likely to have glucose levels that are too low at times.

There are two forms of diabetes: type 1, or insulin-dependent diabetes, which usually begins in childhood (early onset) and is an autoimmune condition; and type 2, or non-insulin-dependent diabetes, which occurs in later life (late onset). Without treatment, the patient may go blind, suffer from ulcers, lapse into diabetic coma, and die. Early-onset diabetes tends to be more severe than that developing in later years. There is also a strong link between late-onset diabetes and being seriously overweight (obese) - over 80% of sufferers are obese. Although the precise nature of the link between diabetes and obesity is not known, studies showed that in mice a hormone secreted by fat cells blocked the action of insulin.

Before the discovery of insulin by Frederick Banting and Charles Best, severe diabetics did not survive.

Diabetes UK

Go to site

Diabetes UK is the new name for the British Diabetes Association. The Web site has a tabbed interface, with each tab tackling a certain question or need. The tabs are: 'What is diabetes?', 'Managing your diabetes', 'How we help', 'Get involved', and 'Diabetes research'. On the first page, a section is devoted to recent diabetes-related news.

'Recent Advances: Diabetes'

Go to site

Part of a collection of articles maintained by the *British Medical Journal*, this page features the full text of an 18 April 1998 clinical review regarding the alarming rise in the number of patients with diabetes around the world. The text includes diagrams, and there is a list of references. In addition to the clinical review, you will find a list of related articles from the extensive PubMed collection. You can also search the collections under which this article appears, search other articles written by the author of this article, and submit or read responses to this article. There is a list of references at the bottom of the article.

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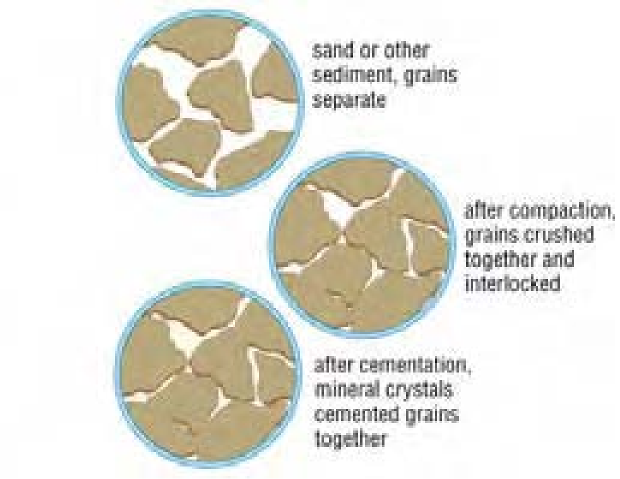
diagenesis

in geology, the physical, chemical, and biological processes by which a sediment becomes a sedimentary rock. The main processes involved include compaction of the grains, and the cementing of the grains together by the growth of new minerals deposited by percolating groundwater. As a whole, diagenesis is actually a poorly understood process.

diagenesis


sand or other sediment, grains separate
after compaction, grains crushed together and interlocked
after cementation, mineral crystals cemented grains together

(Image © Research Machines plc)

The formation of sedimentary rock by diagenesis. Sand and other sediment grains are compacted and cemented together.

dialysis

technique for removing waste products from the blood suffering chronic or acute kidney failure. There are two main methods, haemodialysis and peritoneal dialysis.

In **haemodialysis**, the patient's blood is passed through a pump, where it is separated from sterile dialysis fluid by a semipermeable membrane. This allows any toxic substances which have built up in the bloodstream, and which would normally be filtered out by the kidneys, to diffuse out of the blood into the dialysis fluid. Haemodialysis is very expensive and usually requires the patient to attend a specialized unit.

Peritoneal dialysis uses one of the body's natural semipermeable membranes for the same purpose. About two litres of dialysis fluid is slowly instilled into the peritoneal cavity of the abdomen, and drained out again, over about two hours. During that time toxins from the blood diffuse into the peritoneal cavity across the peritoneal membrane. The advantage of peritoneal dialysis is that the patient can remain active while the dialysis is proceeding. This is known as continuous ambulatory peritoneal dialysis (CAPD).

In the long term, dialysis is expensive and debilitating, and transplants are now the treatment of choice for patients in chronic kidney failure.

diameter

straight line joining two points on the circumference of a circle that passes through the centre of that circle. It divides a circle into two equal halves.

diamond

generally colourless, transparent mineral, an allotrope of carbon. It is regarded as a precious gemstone, and is the hardest substance known (10 on the Mohs scale). Industrial diamonds, which may be natural or synthetic, are used for cutting, grinding, and polishing.

Diamond crystallizes in the cubic system as octahedral crystals, some with curved faces and striations. The high refractive index of 2.42 and the high dispersion of light, or 'fire', account for the spectral displays seen in polished diamonds.

history

Diamonds were known before 3000 BC and until their discovery in Brazil in 1725, India was the principal source of supply. Present sources are Australia, the Democratic Republic of Congo (formerly Zaire), Botswana, Russia (Yakut), South Africa, Namibia, and Angola; the first two produce large volumes of industrial diamonds. Today, about 80% of the world's rough gem diamonds are sold through the De Beers Central Selling Organization in London.

sources

Diamonds may be found as alluvial diamonds on or close to the Earth's surface in riverbeds or dried watercourses; on the sea bottom (off southwest Africa); or, more commonly, in diamond-bearing volcanic pipes composed of 'blue ground', kimberlite or lamproite, where the original matrix has penetrated the Earth's crust from great depths. They are sorted from the residue of crushed ground by X-ray and other recovery methods.

varieties

There are four chief varieties of diamond: well-crystallized transparent stones, colourless or only slightly tinted, valued as gems; **boart**, poorly crystallized or inferior diamonds; **balas**, an industrial variety, extremely hard and tough; and **carbonado**, or industrial diamond, also called black diamond or carbon, which is opaque, black or grey, and very tough. Industrial diamonds are also produced synthetically from graphite. Some synthetic diamonds conduct heat 50% more efficiently than natural diamonds and are five times greater in strength. This is a great advantage in their use to disperse heat in electronic and telecommunication devices and in the production of laser components.

practical uses

Because diamonds act as perfectly transparent windows and do not absorb infrared radiation, they were used aboard NASA space probes to Venus in 1978. The tungsten carbide tools used in steel mills are cut with industrial diamond tools.

cutting

Rough diamonds are often dull or greasy before being polished; around 50% are considered 'cuttable' (all or part of the diamond may be set into jewellery). Gem diamonds are valued by weight (carat), cut (highlighting the stone's optical properties), colour, and clarity (on a scale from internally flawless to having a large inclusion clearly visible to the naked eye). They are sawn and polished using a mixture of oil and diamond powder. The two most popular cuts are the brilliant, for thicker stones, and the marquise, for shallower ones. India is the world's chief cutting centre.

Noted rough diamonds include the Cullinan, or Star of Africa (3,106 carats, over 500 g/17.5 oz before cutting, South Africa, 1905); Excelsior (995.2 carats, South Africa, 1893); and Star of Sierra Leone (968.9 carats, Yengema, 1972).

experiments

Using a device known as a diamond-anvil cell, a moderate force applied to the small tips of two opposing diamonds can be used to attain extreme pressures of millions of atmospheres or more, allowing scientists to subject small amounts of material to conditions that exist deep within planet interiors.

In 1999 US scientists turned a diamond into a metal using a very powerful laser to compress it.

World's largest uncut diamonds

Year found	Name	Where found	Weight (carats)
1905	*Cullinan*	South Africa	3,107.0
1893	*Excelsior*	South Africa	995.0
1972	*Star of Sierra Leone*	Sierra Leone	968.8
1984	*Zale*	Democratic Republic of Congo	890.0
1650	*Great Mogul*	India	787.5
1998	*Millennium Star*	Democratic Republic of Congo	777.0
1945	*Woyie River*	Sierra Leone	770.0
1938	*Presidente Vargas*	Brazil	726.6
1934	*Jonker*	South Africa	726.0
1895	*Reitz*	South Africa	650.8

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diapause

period of suspended development that occurs in some species of insects and other invertebrates, characterized by greatly reduced metabolism. Periods of diapause are often timed to coincide with the winter months, and improve the animal's chances of surviving adverse conditions.

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diaphragm

in mammals, a thin muscular sheet separating the thorax from the abdomen. It is attached by way of the ribs at either side and the breastbone and backbone, and a central tendon. Arching upwards against the heart and lungs, the diaphragm is important in the mechanics of breathing. It contracts at each inhalation, moving downwards to increase the volume of the chest cavity, and relaxes at exhalation.

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diaphragm

barrier contraceptive that is inserted into the vagina and fits over the cervix (neck of the uterus), preventing sperm from entering the uterus. For it to be effective, a spermicide must be used and the diaphragm left in place for six to eight hours after intercourse. This method is 97% effective if practiced correctly.

In the USA, diaphragms are prescribed by physicians who fit them for size; they may then be purchased in drug stores or at clinics.

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diarrhoea

frequent or excessive action of the bowels so that the faeces are liquid or semiliquid. It is caused by intestinal irritants (including some drugs and poisons), infection with harmful organisms (as in dysentery, salmonella, or cholera), or allergies.

Diarrhoea is the biggest killer of children in the world. In 2006 the World Health Organization reported that around 2 million children die from diarrhoeal disease each year. The commonest cause of dehydrating diarrhoea is human rotavirus infection. Dehydration as a result of diarrhoeal disease can be treated by giving a solution of salt and glucose by mouth in large quantities (to restore the electrolyte balance in the blood). Since most diarrhoea is viral in origin, antibiotics are ineffective.

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diastole

in biology, the relaxation of a hollow organ. In particular, the term is used to indicate the resting period between beats of the heart when blood is flowing into it.

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diastolic pressure

in medicine, measurement due to the pressure of blood against the arterial wall during diastole (relaxation of the heart). It is the lowest blood pressure during the cardiac cycle. The average diastolic pressure in healthy young adults is about 80 mmHg. The variation of diastolic pressure due to changes in body position and mood is greater than that of systolic pressure. Diastolic pressure is also a more accurate predictor of hypertension (high blood pressure).

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diathermy

generation of heat in body tissues by the passage of high-frequency electric currents between two electrodes placed on the skin. The heat engendered helps to relieve rheumatic and arthritic pain.

The principle of diathermy is also applied in surgery. The high-frequency current produces, at the tip of a diathermy knife, sufficient heat to cut tissues, or to coagulate and kill cells, with a minimum of bleeding.

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diatom

microscopic alga found in all parts of the world in either fresh or marine waters. Diatoms consist of single cells that secrete a hard cell wall made of silica. There are approximately 10,000 species of diatom. (Division Bacillariophyta.)

The cell wall of a diatom is made up of two overlapping valves known as **frustules**, which are impregnated with silica, and which fit together like the lid and body of a pillbox. Diatomaceous earths (diatomite) are made up of the valves of fossil diatoms, and are used in the manufacture of dynamite and in the rubber and plastics industries.

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diatomic molecule

molecule composed of two atoms joined together. In the case of an element such as oxygen (O_2), the atoms are identical.

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dichloro-diphenyl-trichloroethane

full name of the insecticide DDT.

Dick-Read, Grantly (1890-1959)

British gynaecologist. In private practice in London 1923–48, he developed the concept of natural childbirth: that by the elimination of fear and tension, labour pain could be minimized and anaesthetics, which can be hazardous to both mother and child, rendered unnecessary.

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dicotyledon

major subdivision of the angiosperms, containing the great majority of flowering plants. Dicotyledons are characterized by the presence of two seed leaves, or cotyledons, in the embryo, which is usually surrounded by the endosperm. They generally have broad leaves with netlike veins.

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diecasting

form of casting in which molten metal is injected into permanent metal moulds or dies.

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dielectric

insulator or nonconductor of electricity, such as rubber, glass, and paraffin wax. An electric field in a dielectric material gives rise to no net flow of electricity. However, the applied field causes electrons within the material to be displaced, creating an electric charge on the surface of the material. This reduces the field strength within the material by a factor known as the dielectric constant (or relative permittivity) of the material. Dielectrics are used in capacitors, to reduce dangerously strong electric fields, and have optical applications.

Diels, Otto Paul Hermann (1876-1954)

German chemist. He and his former assistant, Kurt Alder, were awarded the Nobel Prize for Chemistry in 1950 for their research into the synthesis of organic compounds.

In 1927 Diels dehydrogenated cholesterol to produce 'Diels hydrocarbon' ($C_{18}H_{16}$), an aromatic hydrocarbon closely related to the skeletal structure of all steroids, of which cholesterol is one. In 1935 he synthesized it. This work proved to be a turning point in the understanding of the chemistry of cholesterol and other steroids.

Diesel, Rudolf Christian Karl (1858-1913)

German engineer who patented the diesel engine. He began his career as a refrigerator engineer and, like many engineers of the period, sought to develop a better power source than the conventional steam engine. Able to operate with greater efficiency and economy, the diesel engine soon found a ready market.

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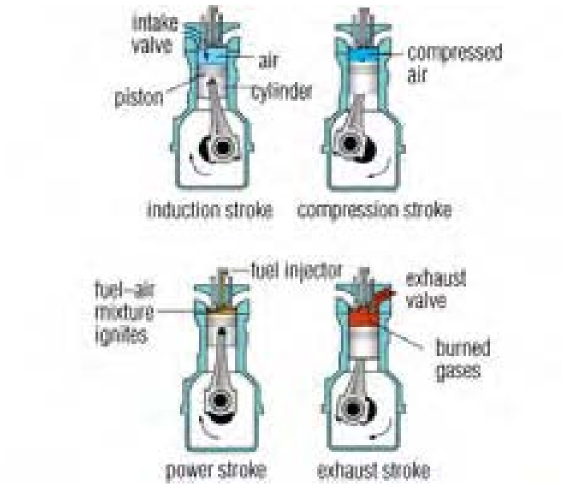
diesel engine

internal-combustion engine that burns a lightweight fuel oil. The diesel engine operates by compressing air until it becomes sufficiently hot to ignite the fuel. It is a piston-in-cylinder engine, like the petrol engine, but only air (rather than an air-and-fuel mixture) is taken into the cylinder on the first piston stroke (down). The piston moves up and compresses the air until it is at a very high temperature. The fuel oil is then injected into the hot air, where it burns, driving the piston down on its power stroke. For this reason the engine is called a compression-ignition engine. Most diesel engines work on a four-stroke cycle, 'stroke' referring to an upward or downward movement of a piston; others operate on a two-stroke cycle.

Diesel engines have sometimes been marketed as 'cleaner' than petrol engines because they do not need lead additives and produce fewer gaseous pollutants. However, they do produce high levels of the tiny black carbon particles called particulates, which are believed to be carcinogenic and may exacerbate or even cause asthma.

The principle of the diesel engine was first explained in England by Herbert Akroyd (1864-1937) in 1890, and was applied practically by Rudolf Diesel in Germany in 1892.

diesel engine



(Image © Research Machines plc)

In a diesel engine, fuel is injected on the power stroke into hot compressed air at the top of the cylinder, where it ignites spontaneously. The four stages are exactly the same as those of the four-stroke or Otto cycle.

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diesel oil

lightweight fuel oil used in diesel engines. Like petrol, it is a petroleum product. When used in vehicle engines, it is also known as **derv** (diesel-engine road vehicle).

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diet

range of foods eaten by an animal each day; it is also a particular selection of food, or the total amount and choice of food for a specific person or group of people. Most animals require seven kinds of food in their diet: proteins, carbohydrates, fats, vitamins, minerals, water, and roughage. A diet that contains all of these things in the correct amounts and proportions is termed a balanced diet. The amounts and proportions required varies with different animals, according to their size, age, and lifestyle. The digestive systems of animals have evolved to meet particular needs; they have also adapted to cope with the foods available in the surroundings in which they live. The necessity of finding and processing an appropriate diet is a very basic drive in animal evolution.
Dietetics is the science of feeding individuals or groups; a dietician is a specialist in this science.

Dietary requirements may vary over the lifespan of an animal, according to whether it is growing, reproducing, highly active, or approaching death. For instance, increased carbohydrate for additional energy, or increased minerals, may be necessary during periods of growth.

An adequate diet for humans is one that supplies the body's daily nutritional needs (see nutrition), and provides sufficient energy to meet individual levels of activity. The average daily requirement for men is 2,500 calories, but this will vary with age, occupation, and weight; in general, women need fewer calories than men. The energy requirements of active children increase steadily with age, reaching a peak in the late teens. At present, about 450 million people in the world - mainly living in famine or poverty-stricken areas, especially in countries of the developing world - subsist on fewer than 1,500 calories per day. The average daily intake in developed countries is 3,300 calories.

Diet: Its Contribution to Good Health

increasing awareness of healthy eating

It has become accepted wisdom that diet plays a key role in health. Furthermore, it is generally understood that some foods, in particular fats, sugars, and salt, are bad if eaten in excess. This has in turn created a vast 'health food' market, both through speciality shops and as particular lines in almost all retailers. However, the theories behind healthy eating are constantly changing.

diseases of Western civilization

Links between diet and health were identified by a few pioneer nutritionists in the first half of the 20th century. Sir Robert McCarrison carried out a series of comparisons on populations in different parts of India and found marked contrasts in average lifespan, which he ascribed to different diets.

Studies of people with a very different diet from that of Western society, such as the Inuit (Eskimo) people of the far north, some African tribespeople, farmers in the Himalayas, and the Japanese, found that these groups were virtually free of many of the major killer diseases of Europe and North America, including heart disease and cancer.

The theory of 'diseases of Western civilization' was developed. This suggested that some factor or factors in our way of life made us particularly susceptible to a range of serious health problems that were virtually unknown in the past.

identifying links between lifestyle and health

For the last few decades, much medical research has been concentrated on identifying these links. Perhaps even more importantly, their relative importance, and the interactions between various factors, have to be distinguished.

This is not as easy as it sounds. Identifying precisely why any particular person becomes ill or dies of heart disease or cancer is impossible, and research depends on complicated statistical analysis, looking at all possible factors affecting a large population and tracking down causes by a process of elimination. For example, it took years to establish links between smoking and lung cancer, and the tobacco companies dispute the connection. Yet in 1993, Sir Richard Doll, one of the main researchers on this issue, announced that his long-term study suggested that one in two regular cigarette smokers would die ahead of time as a result of smoking.

identifying the food connection

Links between food and health are even more difficult to pin down. Harmful factors known or suspected include many additives, including colourings and preservatives, agrochemical residues, microbial contaminants, natural toxins in food, and the type of food itself.

the cholesterol controversy

Over the past few years, the role of different foodstuffs in creating diseases of Western civilization have become the focus of controversy. In particular, links between cholesterol and heart disease have become increasingly well publicized.

Cholesterol is a fatty substance that is important to the functioning of the body and is made in the liver. It is also provided in the diet by dairy products and meat. However, high levels in the blood are thought to contribute to hardening of the arteries, leading to heart attacks. People who are overweight often, but by no means always, have higher levels of cholesterol than thin people. Saturated fatty acids are particularly high in cholesterol-producing factors.

Since heart disease is one of the major killers in Western society, reduction of cholesterol has become a major preoccupation. To date, advice about this has concentrated on reducing consumption of fatty meat and dairy products, with substitution of more vegetables, margarine made with polyunsaturated fats, and so on, but there is also evidence that a low carbohydrate diet can reduce cholesterol levels.

However, as so often in questions of diet, the case is more complicated than it seems at first. Research into links between cholesterol levels and heart disease is ambiguous, as is evidence that lowering cholesterol helps prevent heart disease. It appears that the precise chemical form of cholesterol is important, and perhaps also the way that it reaches the body.

Some people believe that diet is all-important, others that cholesterol formed as a result of stress is more significant.

problems with alternative diets

Some of the alternatives to a high-cholesterol diet are turning out to have problems of their own; for example, partially hydrogenated vegetable oils made from soybeans and maize are now thought to be possibly linked to development of heart disease themselves.

the basis of a healthy diet

People talk about the 'great cholesterol myth' but such disdain is probably premature. There are clearly links between Western diet and both cancer and heart disease, and a range of established health problems linked with being overweight that are at least partially caused by too many fatty foods and sugars.

There is also good evidence that increasing consumption of fruit and vegetables can help prevent such problems, as can regular exercise, relaxation, and a reduction in stress. Although we may well see some modification of ideas about diet and health over the next few years, and fad solutions are unlikely to be of much use, the general principles of increasing fresh food, roughage, and vegetables, and reducing rich foods, remain a good basis for a healthy diet.

Recommended daily intake of nutrients

This table is meant as a guide only. Always consult a qualified dietician if you have any concerns or doubts. (- = not applicable.)

Sex and age		Energy		Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µg)	Thiamine (retinol equivalent) (mg)	Riboflavin (mg)	Niacin (mg)	Vitamin C (mg)	Vitamin D[1] (µg)
		MJ	kcal									
Boys	<1	3.25	780	19	600	6	450	0.3	0.4	5	20	7.5
	1	5.00	1,200	30	600	7	300	0.5	0.6	7	20	10
	2	5.75	1,400	35	600	7	300	0.6	0.7	8	20	10
	3-4	6.50	1,560	39	600	8	300	0.6	0.8	9	20	10
	5-6	7.25	1,740	43	600	10	300	0.7	0.9	10	20	-
	7-8	8.25	1,980	49	600	10	400	0.8	1.0	11	20	-
	9-11	9.50	2,280	56	700	12	575	0.9	1.2	14	25	-
	12-14	11.00	2,640	66	700	12	725	1.1	1.4	16	25	-
	15-17	12.00	2,880	72	600	12	750	1.2	1.7	19	30	-
Girls	<1	3.00	720	18	600	6	450	0.3	0.4	5	20	7.5
	1	4.50	1,100	27	600	7	300	0.4	0.6	7	20	10
	2	5.50	1,300	32	600	7	300	0.5	0.7	8	20	10
	3-4	6.25	1,500	37	600	8	300	0.6	0.8	9	20	10
	5-6	7.00	1,680	42	600	10	300	0.7	0.9	10	20	-
	7-8	8.00	1,900	48	600	10	400	0.8	1.0	11	20	-
	9-11	8.50	2,050	51	700	12[2]	575	0.8	1.2	14	25	-
	12-14	9.00	2,150	53	700	12[2]	725	0.9	1.4	16	25	-
	15-17	9.00	2,150	53	600	12[2]	750	0.9	1.7	19	30	-
Men												
18-34	sedentary	10.50	2,510	62	500	10	750	1.0	1.6	18	30	-
	moderately active	12.00	2,900	72	500	10	750	1.2	1.6	18	30	-
	very active	14.00	3,350	84	500	10	750	1.3	1.6	18	30	-
35-64	sedentary	10.00	2,400	60	500	10	750	1.0	1.6	18	30	-
	moderately active	11.50	2,750	69	500	10	750	1.1	1.6	18	30	-
	very active	14.00	3,350	84	500	10	750	1.3	1.6	18	30	-
65-74		10.00	2,400	60	500	10	750	1.0	1.6	18	30	-
>74		9.00	2,150	54	500	10	750	0.9	1.6	18	30	-
Women												
18-54	most occupations	9.00	2,150	54	500	12[2]	750	0.9	1.3	15	30	-
	very active	10.50	2,500	62	500	12[2]	750	1.0	1.3	15	30	-
Pregnant		10.00	2,400	60	1,200	13	750	1.0	1.6	18	60	10
Lactating		11.50	2,750	69	1,200	15	1,200	1.1	1.8	21	60	10

55-74	8.00	1,900	47	500	10	750	0.8	1.3	15	30	-
>74	7.00	1,680	42	500	10	750	0.7	1.3	15	30	-

[1] Most people who go out in the sun need no dietary source of vitamin D, but children and adolescents in winter, and housebound adults, are recommended to take 10 μg vitamin D daily.

[2] These iron recommendations may not cover heavy menstrual losses.

dietetics

specialized branch of human nutrition, dealing with the promotion of health through the proper kinds and quantities of food.

Therapeutic dietetics has a large part to play in the treatment of certain illnesses, such as allergies, arthritis, and diabetes; it is sometimes used alone, but often in conjunction with drugs. The preventative or curative effects of specific diets, such as the 'grape cure' or raw vegetable diets sometimes prescribed for cancer patients, are disputed by orthodox medicine.

difference

in mathematics, the result obtained when subtracting one number from another. Also, those elements of one set that are not elements of another.

difference engine

mechanical calculating machine designed (and partly built in 1822) by the English mathematician Charles Babbage to produce reliable tables of life expectancy. A precursor of the analytical engine, it was to calculate mathematical functions by solving the differences between values given to variables within equations. Babbage designed the calculator so that once the initial values for the variables were set it would produce the next few thousand values without error.

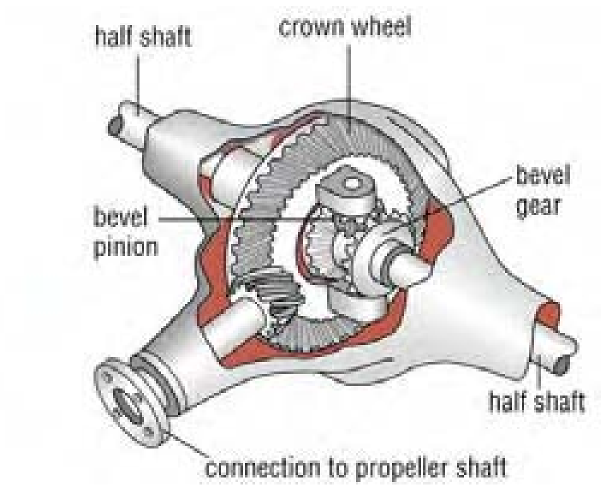
differences

the set of numbers obtained from a sequence by subtracting each element from its successor. For example, in the sequence 1, 4, 9, 16, 25 ..., the differences are 3, 5, 7, 9 ... . The patterns of differences are used to analyse sequences.

differential

arrangement of gears in the final drive of a vehicle's transmission system that allows the driving wheels to turn at different speeds when cornering. The differential consists of sets of bevel gears and pinions within a cage attached to the crown wheel. When cornering, the bevel pinions rotate to allow the outer wheel to turn faster than the inner.

differential



(Image © Research Machines plc)

The differential lies midway between the driving wheels of a motorcar. When the car is turning, the bevel pinions spin, allowing the outer wheel to turn faster than the inner wheel.

differential calculus

branch of calculus involving applications such as the determination of maximum and minimum points and rates of change.

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differentiation

in embryology, the process by which cells become increasingly different and specialized, giving rise to more complex structures that have particular functions in the adult organism. For instance, embryonic cells may develop into nerve, muscle, or bone cells.

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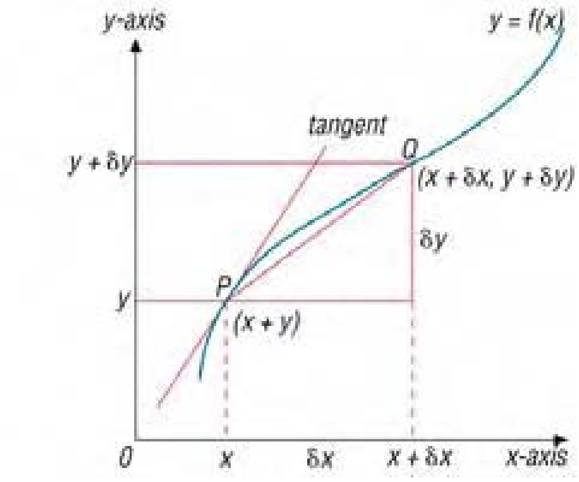
differentiation

in mathematics, a procedure for determining the derivative or gradient of the tangent to a curve *f*(*x*) at any point *x*.

differentiation



(Image © Research Machines plc)

A mathematical procedure for determining the gradient, or slope, of the tangent to any curve *f*(*x*) at any point *x*. Part of a branch of mathematics called differential calculus, it is used to solve problems involving continuously varying quantities (such as the change in velocity or altitude of a rocket), to find the rates at which these variations occur and to obtain maximum and minimum values for the quantities.

---

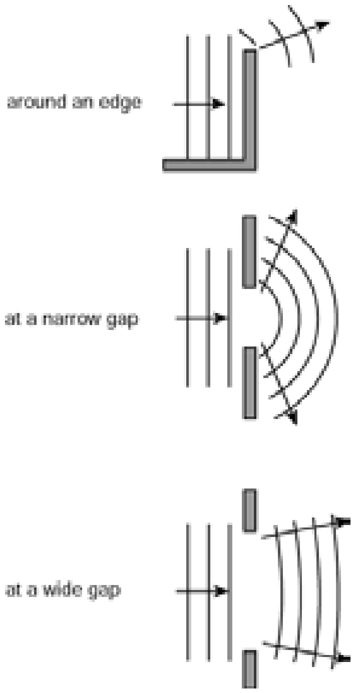
diffraction

the spreading out of waves when they pass through a small gap or around a small object, resulting in some change in the direction of the waves. In order for this effect to be observed, the size of the object or gap must be comparable to or smaller than the wavelength of the waves. Diffraction occurs with all forms of progressive waves - electromagnetic, sound, and water waves - and explains such phenomena as the ability of long-wave radio waves to bend around hills more easily than short-wave radio waves.

The wavelength of visible light ranges from about 400 to 700 nanometres, several orders of magnitude smaller than radio waves. The gap through which light travels must be extremely small for diffraction to be observed. The slight spreading of a light beam through a narrow slit causes the different wavelengths of light to interfere with each other, producing a pattern of light and dark bands. A **diffraction grating** is a plate of glass or metal ruled with close (some diffraction gratings have from 2,000 to 7,000 lines per inch), equidistant, parallel lines used for separating a wave train such as a beam of incident light into its component frequencies. White light passing through a grating will be separated into its constituent colours. Red light is diffracted more as it has a longer wavelength; blue light is diffracted less as it has a shorter wavelength.

The wavelength of sound is between 0.5 m/1.6 ft and 2.0 m/6.6 ft. When sound waves travel through doorways or between buildings they are diffracted significantly, so that the sound is heard round corners.

diffraction



(Image © Research Machines plc)

When waves pass around a barrier or through a gap, they spread out. The effect, known as diffraction, will be more pronounced at a narrow gap than at a wider gap.

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diffusion

net spontaneous and random movement of molecules or particles in a fluid (gas or liquid) from a region in which they are at a high concentration to a region of lower concentration, until a uniform concentration is achieved throughout. The difference in concentration between two such regions is called the **concentration gradient**. No mechanical mixing or stirring is involved. For instance, a drop of ink added to water will diffuse down the concentration gradient until evenly mixed.

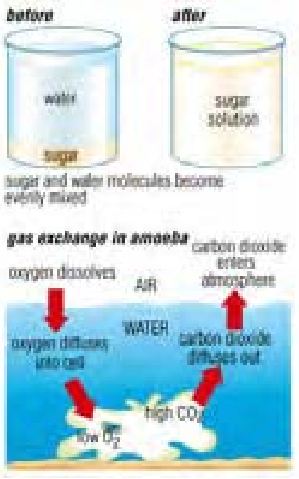
Diffusion occurs because particles in a liquid or gas are free to move according to the kinetic theory of matter. The molecules move randomly, but there is more chance that they will move out of the ink drop than into it, so the molecules diffuse until their colour becomes evenly distributed throughout. Diffusion occurs more rapidly across a higher concentration gradient and at higher temperatures.

Diffusion is quite different from the movement of molecules when a fluid is flowing. In this case movement is not random; all molecules are moving together and in the same direction.

In biological systems, diffusion plays an essential role in the transport, over short distances (for example across cell membranes), of molecules such as nutrients, respiratory gases (carbon dioxide and oxygen), and neurotransmitters. It provides the means by which small molecules pass into and out of individual cells and micro-organisms, such as an amoeba, that possess no circulatory system. Plant and animal organs whose function depends on diffusion - such as the lung - have a large surface area. Diffusion of water across a semi-permeable membrane is termed osmosis. Some important processes which involve diffusion are: the uptake of the products of digestion from the gut, gas exchange in the lungs, and gas exchange in the leaves of plants.

One application of diffusion is the separation of isotopes, particularly those of uranium. When uranium hexafluoride diffuses through a porous plate, the ratio of the 235 and 238 isotopes is changed slightly. With sufficient number of passes, the separation is nearly complete. There are large plants in the USA and UK for obtaining enriched fuel for fast nuclear reactors and the fissile uranium-235, originally required for the first atom bombs. Another application is the diffusion pump, used extensively in vacuum work, in which the gas to be evacuated diffuses into a chamber from which it is carried away by the vapour of a suitable medium, usually oil or mercury.

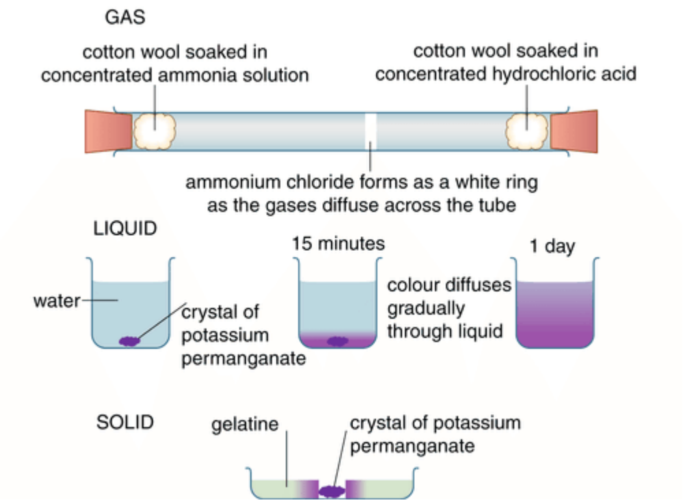
diffusion


before
after
water
sugar
sugar solution
sugar and water molecules become evenly mixed
gas exchange in amoeba
oxygen dissolves
AIR
carbon dioxide enters atmosphere
WATER
oxygen diffuses into cell
carbon dioxide diffuses out
high CO_2
low O_2

(Image © Research Machines plc)

Diffusion is the movement of molecules from a region of high concentration into a region of lower concentration.

diffusion


GAS
cotton wool soaked in concentrated ammonia solution
cotton wool soaked in concentrated hydrochloric acid
ammonium chloride forms as a white ring as the gases diffuse across the tube
LIQUID
15 minutes
1 day
water
crystal of potassium permanganate
colour diffuses gradually through liquid
SOLID
gelatine
crystal of potassium permanganate

(Image © Research Machines plc)

Diffusion can occur in gases, liquids, and solids. Substances diffuse at different speeds, fastest in gases and slowest in solids. In the gas example, the ring of ammonium chloride forms nearest to the hydrochloric acid end because ammonia diffuses faster than hydrochloric acid.

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digestion

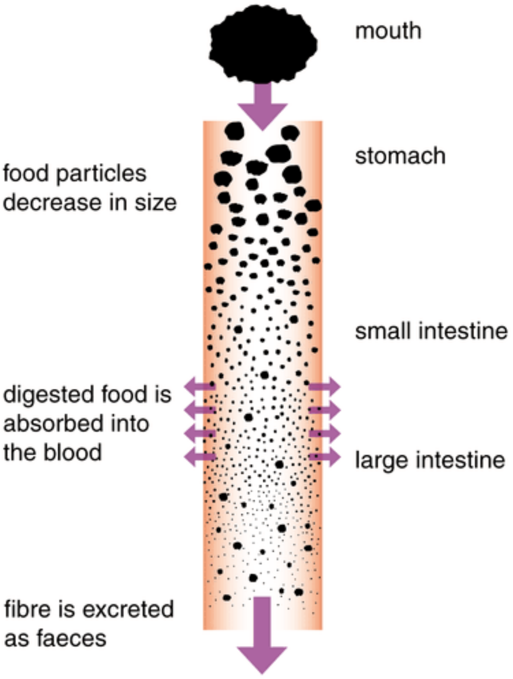
process by which food eaten by an animal is broken down mechanically, and chemically by enzymes, mostly in the stomach and intestines, to make the nutrients available for absorption and cell metabolism. In digestion large molecules of food are broken into smaller, soluble molecules, which are absorbed through the wall of the gut into the bloodstream and carried to individual cells. The first stage of this may involve just the mixing of the food with water and the crushing and chopping of pieces of food by teeth or the mixing of food as it is squeezed along the gut. The second stage is the breakdown of large molecules by enzymes. The uptake of digested foods is mainly by absorption.

The digestion of fats starts with the action of bile. This emulsifies lumps of fat into thousands of tiny droplets, allowing the enzyme lipase to break the fats down into glycerol and fatty acids. Lipase is released from the pancreas and digests fat in the small intestine. Fats are not soluble in water, but glycerol and fatty acids are, and they are easily absorbed into the body.

Not all carbohydrates can be digested, but one important carbohydrate that is digestible is starch. The digestion of starch begins in the mouth. Saliva contains the enzyme amylase, which breaks starch into the complex sugar maltose. Later on, in the small intestine, amylase is released from the pancreas and finishes off the digestion.

Protein is partly digested in the stomach, where the enzyme pepsin breaks large protein molecules into smaller ones. In the small intestine other enzymes break the small proteins into amino acids. Enzymes in different parts of the gut work best at different levels of acidity, so the body makes the conditions in the stomach, for example, very acid, but in the small intestine, slightly alkaline.

digestion


mouth
stomach
food particles decrease in size
small intestine
digested food is absorbed into the blood
large intestine
fibre is excreted as faeces

(Image © Research Machines plc)

During the process of digestion food is broken down into increasingly smaller particles. The dietary fibre and other indigestible particles remain unchanged.

Digestion

Go to site

Clear notes and a description of the digestive system, presented in a plain text-only format. The user can also try out the worksheet at the end of the page.

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digestive system

in the body, all the organs and tissues involved in the digestion of food. In animals, these consist of the mouth, stomach, intestines, and their associated glands. The process of digestion breaks down the food by physical and chemical means into the different elements that are needed by the body for energy and tissue building and repair. Digestion begins in the mouth and continues in the stomach; from there most nutrients enter the small intestine from where they pass through the intestinal wall into the bloodstream; what remains is stored and concentrated into faeces in the large intestine. Birds have two additional digestive organs – the crop and gizzard. In smaller, simpler animals such as jellyfish, the digestive system is simply a cavity (coelenteron or enteric cavity) with a 'mouth' into which food is taken; the digestible portion is dissolved and absorbed in this cavity, and the remains are ejected back through the mouth.

The digestive system of humans consists primarily of the alimentary canal, a tube which starts at the mouth, continues with the pharynx, oesophagus (or gullet), stomach, large and small intestines, and rectum, and ends at the anus. The food moves through this canal by peristalsis whereby waves of involuntary muscular contraction and relaxation produced by the muscles in the wall of the gut cause the food to be ground and mixed with various digestive juices. Most of these juices contain digestive enzymes, chemicals that speed up reactions involved in the breakdown of food. Other digestive juices empty into the alimentary canal from the salivary glands, gall bladder, and pancreas, which are also part of the digestive system.

The fats, proteins, and carbohydrates (starches and sugars) in foods contain very complex molecules that are broken down (see diet; nutrition) for absorption into the bloodstream: starches and complex sugars are converted to simple sugars; fats are converted to fatty acids and glycerol; and proteins are converted to amino acids and peptides. Foods such as vitamins, minerals, and water do not need to undergo digestion prior to absorption into the bloodstream. The small intestine, which is the main site of digestion and absorption, is subdivided into the duodenum, jejunum, and ileum. Covering the surface of its mucous membrane lining are a large number of small prominences called villi which increase the surface for absorption and allow the digested nutrients to diffuse into small blood-vessels lying immediately under the epithelium.

Digestive System: Pioneering Experiments on the Digestive System

an army marches on its stomach

On 6 June 1822 at Fort Mackinac, Michigan, USA, an 18-year-old French Canadian was accidentally wounded in the abdomen by the discharge of a musket. He was brought to the army surgeon, US physician William Beaumont (1785–1853), who noted several serious wounds and, in particular, a hole in the abdominal wall and stomach. The surgeon observed that through this hole in the patient 'was pouring out the food he had taken for breakfast'.

The patient, Alexis St Martin, a trapper by profession, was serving with the army as a porter and general servant. Not surprisingly, St Martin was at first unable to keep food in his stomach. As the wound gradually healed, firm dressings were needed to retain the stomach contents. Beaumont tended his patient assiduously and tried during the ensuing months to close the hole in his stomach, without success. After 18 months, a small, protruding fleshy fold had grown to fill the aperture (fistula). This 'valve' could be opened simply by pressing it with a finger.

digestion ... inside and outside

At this point, it occurred to Beaumont that here was an ideal opportunity to study the process of digestion. His patient must have been an extremely tough character to have survived the accident at all. For the next nine years he was the subject of a remarkable series of pioneering experiments, in which Beaumont was able to vary systematically the conditions under which digestion took place and discover the chemical principles involved.

Beaumont attacked the problem of digestion in two ways. He studied how various substances were actually digested in the stomach, and also how they were 'digested' outside the stomach in the digestive juices he extracted from St Martin. He found it was easy enough to drain out the digestive juices from his fortuitously wounded patient 'by placing the subject on his left side, depressing the valve within the aperture, introducing a gum elastic tube and then turning him ... on introducing the tube the fluid soon began to run.'

a typical experiment

Beaumont was basically interested in the rate and temperature of digestion, and also the chemical conditions that favoured different stages of the process of digestion. He describes a typical experiment (he performed hundreds), where (a) digestion in the stomach is contrasted (b) with artificial digestion in glass containers kept at suitable temperatures, like this:

(a) 'At 9 o'clock he breakfasted on bread, sausage, and coffee, and kept exercising. 11 o'clock, 30 minutes, stomach two-thirds empty, aspects of weather similar, thermometer 298°F, temperature of stomach 1011/28 and 1003/48. The appearance of contraction and dilation and alternative piston motions were distinctly observed at this examination. 12 o'clock, 20 minutes, stomach empty.'

(b) 'February 7. At 8 o'clock, 30 minutes a.m. I put twenty grains of boiled codfish into three drachms of gastric juice and placed them on the bath.'

'At 1 o'clock, 30 minutes, p.m., the fish in the gastric juice on the bath was almost dissolved, four grains only remaining: fluid opaque, white, nearly the colour of milk. 2 o'clock, the fish in the vial all completely dissolved.'

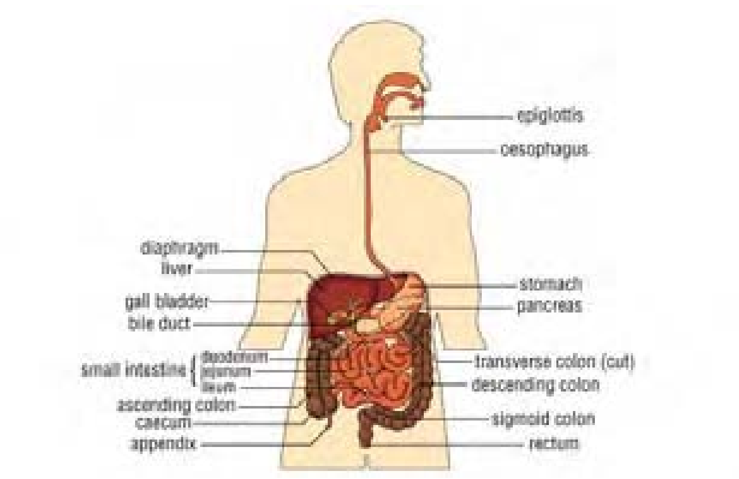
all a matter of chemistry

Beaumont's research showed clearly for the first time just what happens during digestion and that digestion, as a process, can take place independently outside the body. He wrote that gastric juice: 'so far from being inert as water as some authors assert, is the most general solvent in nature of alimentary matter - even the hardest bone cannot withstand its action. It is capable, even out of the stomach, of effecting perfect digestion, with the aid of due and uniform degree of heat (100°Fahrenheit) and gentle agitation ... I am impelled by the weight of evidence ... to conclude that the change effected by it on the aliment, is purely chemical.'

Our modern understanding of the physiology of digestion as a process whereby foods are gradually broken down into their basic components follows logically from his work. An explanation of how the digestive juices flowed in the first place came in 1889, when Russian physiologist Ivan Pavlov (1849-1936) showed that their secretion in the stomach was controlled by the nervous system. By preventing the food eaten by a dog from actually entering the stomach, he found that the secretions of gastric juices began the moment the dog started eating, and continued as long as it did so. Since no food had entered the stomach, the secretions must be mediated by the nervous system.

Later, it was found that the further digestion that takes place beyond the stomach was hormonally controlled. But it was Beaumont's careful scientific work, which was published in 1833 with the title *Experiments and Observations on the Gastric Juice and Physiology of Digestion*, that triggered subsequent research in this field.

digestive system



(Image © Research Machines plc)

The human digestive system. When food is swallowed, it is moved down the oesophagus by the action of muscles (peristalsis) into the stomach. Digestion starts in the mouth and continues in the stomach as the food is mixed with enzymes and strong acid. After several hours, the food passes to the small intestine. Here more enzymes are added and digestion is completed. After all nutrients have been absorbed, the indigestible parts pass into the large intestine and thence to the rectum. The liver has many functions, such as storing minerals and vitamins and making bile, which is stored in the gall bladder until needed for the digestion of fats. The pancreas supplies enzymes. The appendix appears to have no function in human beings.

Digestive System

Go to site

Based around annotated diagrams, linked to clear descriptions, this site has lots of useful facts all about the human digestive system. Each part of digestion is described in a separate window, accessed by clicking on a marker on the body diagram, and further animations are available.

Your Digestive System and How it Works

Go to site

Health information on the digestive system, detailed enough to interest biology students. Part of a much larger site from the US National Institute of Diabetes and Digestive and Kidney Diseases, it explains what happens as food travels through the body, and discusses the hormones and nerves that regulate the digestive process.

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digit

any of the numbers from 0 to 9 in the decimal system. Different bases have different ranges of digits. For example, the hexadecimal system has digits 0 to 9 and A to F, whereas the binary system has two digits (or bits), 0 and 1.

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digital

in electronics and computing, a term meaning 'coded as numbers'. A digital system uses two-state, either on/off or high/low voltage pulses, to encode, receive, and transmit information. A **digital display** shows discrete values as numbers (as opposed to an analogue signal, such as the continuous sweep of a pointer on a dial).

Digital electronics is the technology that underlies digital techniques. Low-power, miniature, integrated circuits (chips) provide the means for the coding, storage, transmission, processing, and reconstruction of information of all kinds.

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digital audio tape

DAT

digitally recorded audio tape produced in cassettes that can carry up to two hours of sound on each side and are about half the size of standard cassettes. DAT players/recorders were developed in 1987. Pre-recorded cassettes are copy-protected.

The first DAT for computer data was introduced in 1988.

DAT machines are constructed like video cassette recorders (though they use metal audio tape), with a movable playback head, the tape winding in a spiral around a rotating drum. The tape can also carry additional information; for example, a time code for instant location of any point on the track. The music industry delayed releasing pre-recorded DAT cassettes because of fears of bootlegging, but a system has now been internationally agreed whereby it is not possible to make more than one copy of any pre-recorded compact disc or DAT. DAT is mainly used in recording studios for making master tapes. The system was developed by Sony.

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digital compact cassette

DCC

digitally recorded audio cassette that is roughly the same size as a standard cassette. It cannot be played on a normal tape recorder, though standard tapes can be played on a DCC machine; this is known as 'backwards compatibility'. The playing time is 90 minutes.

A DCC player has a stationary playback and recording head similar to that in ordinary tape decks, though the tape used is chrome videotape. The cassettes are copy-protected and can be individually programmed for playing order. Some DCC decks have a liquid-crystal digital-display screen, which can show track titles and other information encoded on the tape.

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digital computer

computing device that operates on a two-state system, using symbols that are internally coded as binary numbers (numbers made up of combinations of the digits 0 and 1); see computer.

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digital data transmission

in computing, a way of sending data by converting all signals (whether pictures, sounds, or words) into numeric (normally binary) codes before transmission, then reconverting them on receipt. This virtually eliminates any distortion or degradation of the signal during transmission, storage, or processing.

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digitalis

drug that increases the efficiency of the heart by strengthening its muscle contractions and slowing its rate. It is derived from the leaves of the common European woodland plant *Digitalis purpurea* (foxglove).

It is purified to digoxin, digitoxin, and lanatoside C, which are effective in cardiac regulation but induce the side effects of nausea, vomiting, and pulse irregularities. Pioneered in the late 1700s by William Withering, an English physician and botanist, digitalis was the first cardiac drug.

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digitalis

plant of the genus *Digitalis* of the figwort family Scrophulariaceae, which includes the foxgloves.

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digital recording

technique whereby the pressure of sound waves is sampled more than 30,000 times a second and the values converted by computer into precise numerical values. These are recorded and, during playback, are reconverted to sound waves.

This technique can give very high-quality reproduction. The numerical values converted by computer represent the original sound-wave form exactly and are recorded on compact disc or other media. When this is played back, the exact values are retrieved and the sound does not deteriorate with repeated playback, unlike previous vinyl records or magnetic tape methods. When the signal is fed via an amplifier to a loudspeaker, sound waves exactly like the original ones are reproduced.

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digital root

a digit formed by adding the digits of a number. If this leads to a total of 10 or more, the resultant digits are added. For example, finding the digital root of 365 involves the following computations: 3 + 6 + 5 = 14, followed by 1 + 4 = 5. The digital root of 365 is therefore 5.

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digital sampling

electronic process used in telecommunications for transforming a constantly varying (analogue) signal into one composed of discrete units, a digital signal. In the creation of recorded music, sampling enables the composer, producer, or remix engineer to borrow discrete vocal or instrumental parts from other recorded work (it is also possible to sample live sound).

A telephone microphone changes sound waves into an analogue signal that fluctuates up and down like a wave. In the digitizing process the waveform is sampled thousands of times a second and each part of the sampled wave is given a binary code number (made up of combinations of the digits 0 and 1) related to the height of the wave at that point, which is transmitted along the telephone line. Using digital signals, messages can be transmitted quickly, accurately, and economically.

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digital-to-analogue converter

electronic circuit that converts a digital signal into an analogue (continuously varying) signal. Such a circuit is used to convert the digital output from a computer into the analogue voltage required to produce sound from a conventional loudspeaker.

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digitizer

in computing, a device that converts an analogue video signal into a digital format so that video images can be input, stored, displayed, and manipulated by a computer. The term is also sometimes used to refer to a graphics tablet.

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dihybrid inheritance

in genetics, a pattern of inheritance observed when two characteristics are studied in succeeding generations. The first experiments of this type, as well as in monohybrid inheritance, were carried out by Austrian biologist Gregor Mendel using pea plants.

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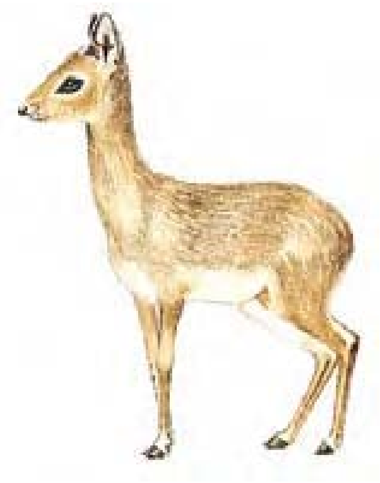
dik-dik

any of several species of tiny antelope, genus *Madoqua*, found in Africa south of the Sahara in dry areas with scattered brush. Dik-diks are about 60 cm/2 ft long and 35 cm/1.1 ft tall, and are often seen in pairs. Males have short, pointed horns. The dik-dik is so named because of its alarm call.

dik-dik



(Image © Research Machines plc)

Dik-diks are shy, secretive animals. At sunset and during the night, they browse on leaves, shoots, and buds. They also eat flowers (especially those of the acacia) and fruit, and dig up roots and tubers. They do not need to drink.

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dilatation and curettage

D and C

common gynaecological procedure in which the cervix (neck of the womb) is widened, or dilated, giving access so that the lining of the womb can be scraped away (curettage). It may be carried out to terminate a pregnancy, treat an incomplete miscarriage, discover the cause of heavy menstrual bleeding, or for biopsy.

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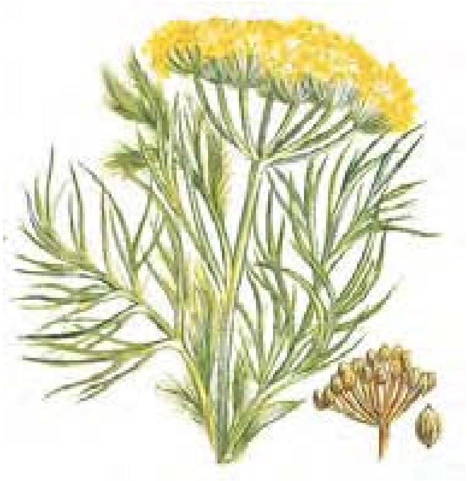
dill

herb belonging to the carrot family, whose bitter seeds and aromatic leaves are used in cooking and in medicine. (*Anethum graveolens*, family Umbelliferae.)

dill



(Image © Research Machines plc)

Dill grows to a height of 45-90 cm/1.5-3 ft, and resembles fennel with feathery leaves and yellow flowers. A native plant of Asia and Eastern Europe, it is now common throughout much of Europe.

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dilution

process of reducing the concentration of a solution by the addition of a solvent.

The extent of a dilution normally indicates the final volume of solution required. A fivefold dilution would mean the addition of sufficient solvent to make the final volume five times the original.

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dimension

in science, any directly measurable physical quantity such as mass (M), length (L), and time (T), and the derived units obtainable by multiplication or division from such quantities. For example, acceleration (the rate of change of velocity) has dimensions (LT^{-2}), and is expressed in such units as km s^{-2}. A quantity that is a ratio, such as relative density or humidity, is dimensionless.

In geometry, the dimensions of a figure are the number of measures needed to specify its size. A point is considered to have zero dimension, a line to have one dimension, a plane figure to have two, and a solid body to have three.

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dimethyl sulphoxide

DMSO; $(CH_3)_2SO$

colourless liquid used as an industrial solvent and an antifreeze. It is obtained as a by-product of the processing of wood to paper.

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dingo

wild dog of Australia. Descended from domestic dogs brought from Asia by Aborigines thousands of years ago, it belongs to the same species *Canis familiaris* as other domestic dogs. It is reddish brown with a bushy tail, and often hunts at night. It cannot bark.

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dinitrogen oxide

alternative name for nitrous oxide, or 'laughing gas', one of the nitrogen oxides.

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dinosaur

(Greek deinos 'terrible', sauros 'lizard')

any of a group (sometimes considered as two separate orders) of extinct reptiles living between 205 million and 65 million years ago. Their closest living relations are crocodiles and birds. Many species of dinosaur evolved during the millions of years they were the dominant large land animals. Most were large (up to 27 m/90 ft), but some were as small as chickens. They disappeared 65 million years ago for reasons not fully understood, although many theories exist, perhaps the most widely accepted being that the Earth was struck by a comet.

classification

Dinosaurs are divisible into two unrelated stocks, the orders **Saurischia** ('lizard-hip') and **Ornithischia** ('bird-hip'). Members of the former group possess a reptile-like pelvis and are mostly bipedal and carnivorous, although some are giant amphibious quadrupedal herbivores. Members of the latter group have a bird-like pelvis, are mainly four-legged, and entirely herbivorous.

The Saurischia are divided into: **theropods** ('beast-feet'), including all the bipedal carnivorous forms with long hindlimbs and short forelimbs (tyrannosaurus, megalosaurus); and **sauropodomorphs** ('lizard-feet forms'), including sauropods, the large quadrupedal herbivorous and amphibious types with massive limbs, long tails and necks, and tiny skulls (diplodocus, brontosaurus).

The Ornithischia were almost all plant-eaters, and eventually outnumbered the Saurischia. They are divided into four suborders: **ornithopods** ('bird-feet'), Jurassic and Cretaceous bipedal forms (iguanodon) and Cretaceous hadrosaurs with duckbills; **stegosaurs** ('plated' dinosaurs), Jurassic quadrupedal dinosaurs with a double row of triangular plates along the back and spikes on the tail (stegosaurus); **ankylosaurs** ('armoured' dinosaurs), Cretaceous quadrupedal forms, heavily armoured with bony plates (nodosaurus); and **ceratopsians** ('horned' dinosaurs), Upper Cretaceous quadrupedal horned dinosaurs with very large skulls bearing a neck frill and large horns (triceratops).

Dinosaur: Cloning from Preserved DNA

the story

The story is told of a mosquito preserved intact from Mesozoic times in a block of amber. The mosquito is found to contain the ingested blood of a dinosaur – its last meal. The dinosaur DNA in the blood is then cloned by scientists to produce living dinosaurs to populate a theme park. Then it all gets out of hand ..

Very dramatic. But how likely is the story?

the reality behind the story

There are many ways in which a fossil can be preserved. Most involve the total destruction of the original organic material and its replacement by minerals. The trees in Arizona's petrified forest, and the casts of seashells in limestone, are examples.

However, should the original organism be completely entombed immediately after death in a sterile medium – such as oxygen-free mud in a stagnant swamp or fresh resin oozing from a tree – then some of the creature's substance may survive for a long time. Mammoths remain intact after being embedded in frozen mud, and coal is formed from the original carbon of the plants that were buried.

collagen in fossils

The search for original biological material in fossils was started with the advent of precise analytical techniques in the early 1960s. Collagen, the protein substance that forms the flexible component of bone, has been found in fossil mammal remains dating from Pleistocene and Miocene times – about 1 million years ago (mya) and 5-24 mya respectively. The problem is that the amino acids that form the collagen are the same as the amino acids that exist in sediments and it is difficult to ascertain how much of the amino acid in the fossil bone is actually original and how much has leached in from outside.

DNA from a preserved quagga skin

Collagen is quite simple and quite sturdy compared with DNA – the organic chemical that defines the whole organism and forms the basis of the organism's growth and reproduction. DNA has been collected from the remains of recently extinct animals.

The quagga – a kind of horse related to the zebra – was hunted to extinction in 1883. In 1984 scientists in Berkeley, California, were able to extract DNA from a preserved quagga skin. After a century there remained only about 1% of the DNA usually present in fresh tissue.

cloning DNA in a bacterium cell

The researchers were able to multiply this by cloning, and obtained enough for experimental purposes. The procedure involved inserting a DNA fragment into the cell of a bacterium and letting the bacterium reproduce it as if it were its own.

This produced enough to enable the scientists to compare the DNA structure with that of the modern mountain zebra. The difference between the two sets of DNA was so small that they could deduce that the common ancestor of the quagga and the mountain zebra must have existed between 3 and 4 mya.

the role of DNA study in plotting evolution

The direct study of DNA from living animals is becoming increasingly useful in plotting evolution. It has recently been found that the genetic differences between the marine iguana and the land iguana of the Galapagos Islands is such that the two animals must have had a common ancestor some tens of millions of years ago.

This is at odds with the knowledge that the oldest of the Galapagos islands is no more than 4 million years old. The inference is that the volcanic Galapagos Islands are continually appearing and eroding away as the oceanic plate passes over a hot spot in the Earth's mantle, and that there were islands in the area much longer ago than was first imagined.

The genetic differences between all populations of modern cheetahs, to give another example, show that they evolved from very few individuals – perhaps a single litter – some time during the last Ice Age. Seemingly the entire population of cheetahs was all but wiped out by the harsh climatic conditions of the time.

cloning DNA by polymerization

An alternative to cloning in a bacterium cell was developed in 1985. This technique is called **polymerase chain reaction** and involves treating the DNA sample with enzymes that promote its reproduction. This has now become important in forensic science, in obtaining enough DNA to identify decomposed bodies.

DNA extracted from 16-million-year-old leaf in lake

In 1992, DNA was extracted from the chloroplasts of a magnolia leaf found in 16-million-year-old lake deposits from the Miocene of Idaho, USA. The ancient lake had waters that were entirely free from oxygen, and as the leaves fell into the water they sank and were buried in a totally sterile environment.

This still does not explain the preservation. Even under oxygen-free conditions moisture tends to break down organic molecules. Such a breakdown is helped by the presence of metals, and possibly the metals that were in the sediments were trapped by the acids in the muds or prevented by bacterial action from taking part in the reaction.

DNA discovered in animal remains trapped up to 130 mya

Then, in 1993, even older DNA fragments were discovered. These belonged to a weevil that was trapped in amber some time between 120 and 130 million years ago - during the Cretaceous period - the time of the dinosaurs.

progress towards cloning dinosaurs

This is all very interesting and has considerable practical application in determining evolutionary sequences and identifying murder victims - but it is still a long way from cloning dinosaurs. The only way of doing this would be to obtain a complete set of dinosaur DNA and then to insert it into the growth cell of some compatible creature, such as a bird.

The original DNA of the cell would have to be destroyed, so that the cell would work as a host for the growth and reproduction of the introduced DNA. This would then develop into an embryo, and form an egg which would hatch into a young dinosaur.

Such techniques have so far worked only in very simple organisms. It is quite beyond the present state of the art to do it with the higher vertebrates. In any case we would need to start with a complete set of DNA from a dinosaur, and it is very unlikely that such delicate organic material would have survived for 65 million years in the guts of a preserved mosquito or any other environment known to geologists.

For the present the story must remain a story.

Dinosaur: The Biggest and the Oldest

the Morrison formation

Some 30 km/19 mi west of Denver, in the foothills of the Rocky Mountains, lies the small town of Morrison. Its main claim to fame is a huge natural amphitheatre which hosts rock concerts and operas. The amphitheatre is known as Red Rocks Stadium, and, indeed, all the rocks around Morrison are a striking red. The town gives its name to the Morrison formation, a stratum of rocks laid down in Jurassic times. The formation meets the surface both east and west of the high Rocky Mountains, and both areas have proved rich in dinosaur fossils. In particular, the Uncompahgre region of western Colorado has yielded enormous numbers of dinosaur remains, and some of those remains have been huge.

the Ultrasaurus

Biggest of all has been the Ultrasaurus. Two specimens of *Ultrasaurus macintoshi* have been found that indicate that this dinosaur was 30 m/98 ft long and weighed a gigantic 100 tonnes - possibly as much as 130 tonnes. The weight is close to the theoretical limit for a land vertebrate: mathematical calculations suggest that a terrestrial creature weighing 140 tonnes would need legs so large that they would be almost impossible to move.

It seems obvious to suggest that such a monster is a rarity, yet Ultrasaurus must have been reasonably successful. Other Ultrasaur bones have been found elsewhere in the Morrison formation, and remains of the closely related *Ultrasaurus tabriensis* have recently been discovered in Cretaceous rocks in South Korea. The presence of Ultrasaur remains in both Jurassic and Cretaceous rocks also suggests that the creature inhabited the Earth for quite a time.

Americans have been quick to celebrate the discovery of this enormous creature. A life-size model has been erected in Paradise Park, Honolulu, Hawaii, and a smaller (but still 7 m/23 ft high) model has been put up in New York's Central Park, where 1,000 local children have been involved in painting it.

Supersaurus and Seismosaurus

Other enormous dinosaurs have also been found in the Morrison formation. From the same region of the Uncompahgre, *Supersaurus viviane* may not have had the same bulk as Ultrasaurus, but probably stood considerably taller. Its height is estimated to have been 16 m/52 ft, and its length to be in the same 30 m/98 ft region.

Some way further to the south, in Albuquerque, New Mexico, the rocks have yielded the remains of Seismosaurus. An estimated weight of 50 tonnes is again less than that of Ultrasaurus, but this dinosaur was over 36 m/118 ft long. Its hefty size gave it its name - Seismosaurus translates as 'earthquake lizard'.

the longest dinosaurs

Seismosaurus may be the longest dinosaur of which remains have been found, but there are signs that others may have been longer still. In Morocco, recently discovered footprints and tracks appear to have been made by a dinosaur a massive 48 m/157 ft long. Two of these would occupy the length of a football pitch. However, as yet no bones of such creatures have been found.

the oldest known dinosaur

Other important dinosaur finds have been made recently in Argentina. The oldest known dinosaur, Herrerasaurus, has been excavated from rock formations in the foothills of the Andes. This dinosaur, named after an early dinosaur hunter, José Herrera, who discovered parts of the skeleton, is estimated to be 230 million years old. At only 2.5 m/8 ft long and with an estimated weight of 100 kg, this is tiny compared to Ultrasaurus, but the find may be of considerable significance. Herrerasaurus has a jaw with dual hinging, a feature that was thought not to have evolved until some 50 million years later.

future discoveries

Recent years have seen an explosion of dinosaur finds, as likely formations are recognized and better techniques of excavation are exploited. Further finds may fill in gaps in the dinosaur story in the not too distant future.

What Killed the Dinosaurs?

introduction

Sixty-five million years ago dinosaurs disappeared. With them went 70% of all species of the time. This 'mass extinction', one of many such events throughout Earth's history, marks the end of the Cretaceous period and the beginning of the Tertiary period, an interval of geological time known as the K-T boundary (K for Kreide, German for Cretaceous). What killed the dinosaurs? Two rival hypotheses dominate. One is that a huge asteroid or comet collided with Earth during K-T time, the other, is that voluminous volcanism in what is now western India was responsible. Distinguishing between these two hypotheses has proven difficult. In either case, the possible link between these events and the demise of the dinosaurs is forcing scientists to reexamine the role of catastrophe in Earth's history.

from Catastrophism to Uniformitarianism

Geology arose as a modern scientific discipline in the early 19th century with the fall of catastrophism, the notion that the history of our planet was shaped by successive catastrophic events and the rise of uniformitarianism, which holds that every-day processes, operating however slowly, are sufficient to explain the principle features of Earth's history. Naturalists of the late 18th century understood that fossil marine animals and the sedimentary rock in which they were found represented ancient sea floors. But the cast accumulations of fossil-bearing rock revealed in the sides of mountains posed a time problem. The Earth is just 6,000 years old, it was believed, and any casual observer of the oceans could see that sediment did not accumulate fast enough to yield kilometre thicknesses of marine sediment (later turned to rock) unless normal processes were somehow accelerated by cataclysmic events. The great flood described in the Old Testament of the Bible was one catastrophe commonly invoked. Catastrophic upheavals were also called upon to explain mountains. Near the end of the 18th century a Scottish scientist named James Hutton reasoned that all of the Earth's geological features could be explained by the slow and unchanging forces operating all around us *if* the Earth was very much older than had been previously imagined. This new view, uniformitarianism, proved immensely successful in explaining geological observations, though not at first. Several decades later another Scot, Charles Lyell, refined and popularized Hutton's uniformitarianism. Lyell emphasized that human kind had existed for sufficient time as to bear witness to all kinds of processes that affect Earth history. Hutton and Lyell imagined Earth where the past looked much like the present, with no beginning nor an end. But it was their principle of uniformitarianism that allowed Charles Darwin to concieve of the evolution of species by natural selection and show that Earth's inhabitants at least, had changes irrevocably over geological time. Without uniformitarianism there could have been no modern geology and no Darwinian theory of evolution and geologists have been understandably reluctant to dismiss the premise that 'the present is the key to the past'.

the new catastrophism

Was Lyell right? Have human beings actually witnessed all of the important agents of Earth change? Since the early years of uniformitarianism we have learned that Earth is 4.5 billion years old and that our Solar System formed from the collapse of a fragment of molecular interstellar cloud approximately 4.6 billion years ago. Human history spans a mere one tenth of one thousandth of this interval and we would have been fortunate indeed if our existence had coincided with all of the forces that periodically effect our planet over millions and even billions of years. Therefore the most likely answer to the question: was Lyell right? must be *no*. Meteorite impact or volcanism on a massive scale may have killed off the dinosaurs. But both of these events, as it turns out, are normal in the course of the evolution of our planet. Should they be considered catastrophes in the context of Earth history? In July of 1994 the comet Shoemaker-Levy 9 collided with Jupiter. The impact was a catastrophe (for Jupiter) the like of which we have not seen before. Despite the fact that this event was unique in terms of human experiences, such colossal collisions are business-as-usual in astronomical terms. Numerous impact craters scar the rocky surfaces of most bodies in our solar system. These craters reveal that prior to 3.8 billion years ago, planets were routinely bombarded by meter to kilometre-sized objects. The collisions constituted the final stages of rocky accretion as the planets swept up the debris from which they were made. After 3.8 billion years accretion was essentially complete and impacts upon the planets became less frequent, but as Shoemaker-Levy 9 reminded us, they have not ceased entirely. Impact structures dating back to the time of frequent bombardment have been destroyed on Earth by erosion and tectonic processes that constantly deform and make over the crust. Nonetheless, scientists have thus far managed to identify more than 100 younger impact craters on Earth. It is estimated that, on average, asteroids or comets measuring 5 to 10 kilometres in diameter impact our planet every 50 to 100 million years. Kilometre-sized bodies are thought to hit roughly every million years. Objects in the order of 50 meters in diameter strike about once every 1000 years. For comparison, Shoemaker-Levy 9 was composed of several objects ranging from one to several kilometres in size, their collision with Jupiter released more energy than all of the nuclear weapons on Earth combined. At present 150 asteroids are known to pass within one Earth orbit of the Sun. They range in size from a few meters to 8 kilometres. A working group under the auspices of the United States National Aeronautics and Space Administration (NASA) suggests that there may be 2100 such bodies in all. The impact of a single asteroid of 2 or more kilometres would have enough energy to profoundly affect Earth's biosphere, hydrosphere, and atmosphere. Fortunately, the likelihood of a collision of severe consequence in the next few hundred years is remote. Not all catastrophes arrive from space. In 1783, just as catastrophism was about to give way to uniformitarianism, the Laki volcano erupted on Iceland. Unusually harsh winter conditions ensued in North America and Europe. Sulphuric acid rain destroyed Iceland's crops and livestock. Several events of comparable magnitude have confirmed that volcanic eruptions can bring about changes in climate. Have human's experienced the full extent of the influence of volcanism on Earth history? The geological record suggests probably not.

the impact hypothesis

In 1980, physicist and Nobel Prize laureate Luis W. Alvarez and his colleagues Walter Alvarez, Frank Asaro and Helen V. Michel suggested that the K-T mass extinction resulted from the impact of an asteroid or comet (the term bolide describes an impactor of any sort). A bolide greater than 10 kilometres in diameter and travelling 10 kilometres per second, they submitted, would liberate enough energy to trigger environmental disaster across the globe. The Earth would be plunged into months of darkness as the dust propelled into the air by the collision blocked the Sun's rays. Photosynthesis would cease and plant-eating animals would be deprived of food, touching off a breakdown in the food chain. Temperatures would fall and as the shroud of dust prevented the Sun from warming Earth's surface, a phenomenon referred to as 'impact winter'. While land-dwelling animals were fighting starvation and the cold, marine creatures would have to battle acidification of the oceans; aerosols of debris and chemical reactions triggered by an atmospheric shock wave would result in nitric and sulphuric acid rain on a grand scale. Alvarez and coworkers made their proposal on the basis of an unusual enrichment of the rare element iridium in a layer of clay marking the K-T boundary in Italy. Iridium, chemically similar to platinum and gold, is rare on Earth but much more abundant in primitive rocky meteorites. Since their original report, the 'iridium anomaly', as it has come to be known, has since been found in rocks and sediments deposited at the K-T boundary around the world. There is other evidence supportive of an impact. Ratios of the isotope of the element osmium, a platinum-group element like iridium, from some K-T samples are similar to primitive meteorites. Large amounts of soot in K-T boundary clay is thought to have come from large-scale burning of vegetation ignited by debris ejected from the atmosphere that fell back to earth like a hail of red-hot meteors. Quartz grains shocked by pressures exceeding one hundred thousand atmospheres have been found in K-T deposits. Previously, shocked quartz had only been found at impact craters (Arizona's Meteor Crater for example) or sites where underground nuclear weapons were tested. In 1991 a circular impact structure of K-T age was found buried beneath one kilometre of Tertiary carbonate rock in Mexico's Yucatan peninsula. The structure is referred to as the Chicxulub crater after the nearby town of Chicxulub Puerto. Experts agree that Chicxulub is the most spectacular crater on Earth and is the best candidate for the K-T impact site envisioned by Alvarez and co-workers. There are only two other impact structures of comparably large size and they are about 2 billion years old and poorly preserved. The precise size of Chicxulub has been debated. Estimates range from 180 to 300 kilometres in diameter. Most recent studies indicate that the hole upon impact was approximately 120 kilometres wide. Despite its obvious attraction, the impact hypothesis is not without problems. Paleontologists find evidence that the K-T extinction was not instantaneous and may have begun up to a million years before K-T time and continued for tens of thousands of years after. Shocked quartz and even the iridium anomaly are found to occur just above and below the K-T sediment. Disastrous environmental conditions that would have besieged the Earth after impact of a large bolide should have lasted about a decade and so none of these observations is easily explained by the crash of a single asteroid or comet. To redress this apparent short-coming of the hypothesis, some proponents have argued that more than one bolide struck Earth at about K-T time.

the volcanism hypothesis

Another competing catastrophe theory has been put forward to explain not only the chemical and physical features of the K-T boundary but are also the protracted nature of the mass extinction. Beginning in the 1970s it was observed that the largest episode of volcanism in the past 200 million years coincided with the K-T mass extinction. Remains of this volcanism are exposed today in the Deccan plateau region of western India. Here, vast quantities of basalt (a type of dark volcanic rock) known as the Deccan Traps are exposed. Combined, the ancient flows are more than two kilometres thick and comprise roughly 3% of the entire Indian continent. Decan volcanism lasted several hundreds of thousands of years and was most active at the time of the K-T mass extinction. US geologist Dewey M McLean and French geophysicist Vincent Courtillot, among others, argue that it was the voluminous Deccan volcanism that was responsible for the K-T mass extinction. Recall the climatic effects of the Laki eruption? Imagine the effects of continuous large-scale volcanism for hundreds of thousands of years. The chemical composition of Earth's mantle is more like that of primitive meteorites than the crust. Deccan lavas came from the mantle. Thus instead of being derived from dust thrown up by an asteroid, the iridium anomaly and other chemical signatures of the K-T boundary could be the result of a deluge of volcanic dust. Similarly, shocked quartz, cited as critical evidence for bolide impact, can apparently be formed by eruption of some types of explosive volcanoes. The environmental effects of large-scale volcanism and bolide impact may be similar. Volcanism, like impact, would loft large amounts of dust high into the atmosphere where it would be transported around the world. As with the impact hypothesis, the Earth might cool as the dust blocked the Sun's rays. Sulphur released by the volcanoes would cause rain to be acidic. Alternatively, McLean has argued that it was carbon dioxide, a greenhouse gas released during volcanism, that was the killer. Large amounts of carbon dioxide released in to the atmosphere would have changed the chemistry of the oceans and caused global warming, both of which would be harmful to life.

an unlucky coincidence

New theoretical studies suggest that without a vulnerability to extinction, catastrophe may have little influence on the diversity of living organisms. Mass extinctions occur with a crude 30 million year periodicity. The largest, in which 90% of species disappeared, was at the end of the Palaeozoic era approximately 250 million years ago. Smaller extinctions are more common. Theoreticians have shown recently that a pattern of frequent smaller extinctions and less frequent larger extinctions is the inevitable consequence of the dependence of living organisms on one another. The disappearance of an animal's prey, for example, may make the animal less fit for survival. The predator species might then vacate its ecological niche and in turn affect fitness of another species and so it goes until eventually an 'avalanche' of linked extinctions occurs. During an extinction 'avalanche' large numbers of species enter new habitats for which they are not well adapted. Mathematical simulations of such processes show that mass extinction requires the coincidence of *both* large numbers of vulnerable species due to an extinction avalanche, the result of normal evolutionary change, and an unusual amount of stress caused by an environmental catastrophe. Thus it seems the dinosaurs that lived during the Cretaceous period must have been ripe for expiration. Unfortunately for them, their vulnerability coincided with a particularly unlucky time in Earth's history when volcanism was rampant and a collision of the sort that occurs just once every 50 million years actually happened.

dinosaur excavation

(Image © Corel)

Dinosaur excavation in the badlands of Alberta, Canada. In this part of the country more than 300 dinosaur skeletons have been found. The Dinosaur Provincial Park in eastern Alberta is now a World Heritage site.

Dinosauria

Go to site

Visit this site for a well-researched, illustrated guide to the different dinosaur groups, dispel some myths, and catch up - in Dinobuzz - with recent topics of investigation.

Dinosaur Trace Fossils

Go to site

All about the trace fossils left by dinosaurs. The site is divided into several categories of dinosaur fossils: tracks, eggs and nests, tooth marks, gastroliths, and coprolites, and also includes images and descriptions of each one.

101 Crazy Theories About Dinosaur Extinction

Go to site

Described by the author as a 'lighthearted overview' of dinosaur extinction theories, this page nonetheless provides a useful guide to the main (and some of the more outlandish) dinosaur extinction theories. There is a glossary to help explain difficult terms and links to other dinosaur sites.

World's First Dinosaur Skeleton: Hadrosaurus Foulkii

Go to site

Explores William Parker Foulke's discovery of the first nearly complete dinosaur skeleton near Haddonfield, New Jersey, USA, in 1858. The site is divided into about a dozen sections, dealing with the site as it appears today, finding the bones in 1858, the meaning of the find, the characteristics of the dinosaur, maps of the area, and more. The site is enhanced by photos and drawings.

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diode

combination of a cold anode and a heated cathode, or the semiconductor equivalent, which incorporates a *p*-*n* junction; see semiconductor diode. Either device allows the passage of direct current in one direction only, and so is commonly used in a rectifier to convert alternating current (AC) to direct current (DC).

Semiconductor diodes are made from silicon-based materials primarily used in electronic circuits to allow an electrical current to flow in one direction only. Silicon on its own is not useful and it is therefore doped (mixed) with other materials in order to achieve the desired physical and chemical properties. The impurity atoms occupy various positions in the silicon crystal. Two types of junctions are produced by doping: *p*-type and *n*-type.

p-type junction

Silicon has four valence (free) electrons in its outer shell. It is doped with boron atoms, with only three valence electrons in their outer shells. The silicon atoms will share their valence electrons with the valence electrons of the boron atoms. This results in a matrix of silicon atoms doped with boron atoms, which are short of one electron in order to form a fourth chemical bond with the silicon atoms. This is called a *p*-type junction (*p* refers to the boron atom being positive as it is short of one electron).

The *p*-type hole can be occupied by an electron moving into it from a neighbouring atom. The *p*-type hole then moves on to a new position in the matrix. As the *p*-type hole moves from one position to another, it is carrying a current with electrons also moving.

n-type junction

Phosphorous has five valence electrons, so if phosphorous atoms are added to wafers of silicon they can donate extra electrons. This is called an *n*-type junction (*n* refers to phosphorous being negative due to an extra electron).

p-n junction

In a diode, wafers of *p*-type and *n*-type are fused together by heating the wafers and the doping substances in a furnace. An *n*-type silicon wafer is placed on top of a *p*-type silicon wafer to form a junction where the two types come into contact. Electrons flow through the silicon semiconductor in one direction only.

types of diode

There are many different types of semiconductor diodes such as light-emitting diodes (LEDs), made from gallium arsenide phosphide and emitting electromagnetic radiation, and light-dependent diodes (photodiodes), allowing a flow of current in the presence of light.

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dioecious

describing plants with male and female flowers borne on separate individuals of the same species. Dioecism occurs, for example, in the willows *Salix*. It is a way of avoiding self-fertilization.

Diophantus (lived AD 250)

Greek mathematician in Alexandria whose *Arithmetica* is one of the first known works on problem solving by algebra, in which both words and symbols are used.

His main mathematical study was in the solution of what are now known as 'indeterminate' or 'Diophantine' equations – equations that do not contain enough facts to give a specific answer but enough to reduce the answer to a definite type. These equations have led to the formulation of the theory of numbers, regarded as the purest branch of present-day mathematics.

Diophantus of Alexandria

Go to site

Devoted to the life and contributions of Diophantus of Alexandria. In addition to biographical information, you will find a list of references about Diophantus and links to essays that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Diophantus. You will also find a map of his birthplace.

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dioptre

optical unit in which the power of a lens is expressed as the reciprocal of its focal length in metres. The usual convention is that convergent lenses are positive and divergent lenses negative. Short-sighted people need lenses of power about -0.7 dioptre; a typical value for long sight is about +1.5 dioptre.

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diorite

igneous rock intermediate in composition between mafic (consisting primarily of dark-coloured minerals) and felsic (consisting primarily of light-coloured minerals) – the coarse-grained plutonic equivalent of andesite. Constituent minerals include feldspar and amphibole or pyroxene with only minor amounts of quartz.

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dioxin

any of a family of over 200 organic chemicals, all of which are heterocyclic hydrocarbons (see cyclic compounds). The term is commonly applied, however, to only one member of the family, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), a highly toxic chemical that occurs, for example, as an impurity in the defoliant Agent Orange, used in the Vietnam War, and sometimes in the weedkiller 2,4,5-T. It has been associated with chloracne (a disfiguring skin complaint), birth defects, miscarriages, and cancer.

Disasters involving accidental release of large amounts of dioxin into the environment have occurred at Seveso, Italy, and Times Beach, Missouri, USA. Small amounts of dioxins are released by the burning of a wide range of chlorinated materials (treated wood, exhaust fumes from fuels treated with chlorinated additives, and plastics) and as a side effect of some techniques of paper-making. Dioxin may also be produced as a by-product in the manufacture of the bactericide hexachlorophene.

The possibility of food becoming contaminated by dioxins in the environment led the European Union (EU) to decrease significantly the allowed levels of dioxin emissions from incinerators.

dioxin

By middle age, everyone has, on average, 9 nanograms of the toxic chemical dioxin accumulated in their tissues for every one kilogram of their weight

diphtheria

acute infectious disease in which a membrane forms in the throat (threatening death by asphyxia), along with the production of a powerful toxin that damages the heart and nerves. The organism responsible is a bacterium (*Corynebacterium diphtheriae*). It is treated with antitoxin and antibiotics.

Although its incidence has been reduced greatly by immunization, an epidemic in the former USSR resulted in 47,802 cases and 1,746 deaths in 1994, and 1,500 deaths in 1995. The epidemic abated in 1996. From 1997 to 2003, World Health Organization (WHO) statistics showed global case numbers to be fluctuating around 10,000 per year.

diploblastic

in biology, having a body wall composed of two layers. The outer layer is the **ectoderm**, the inner layer is the **endoderm**. This pattern of development is shown by coelenterates.

diplodocus

plant-eating sauropod dinosaur that lived about 145 million years ago, the fossils of which have been found in the western USA. Up to 27 m/88 ft long, most of which was neck and tail, it weighed about 11 tonnes. It walked on four elephantine legs, had nostrils on top of the skull, and peglike teeth at the front of the mouth.

diploid

having paired chromosomes in each cell. In sexually reproducing species, one set is derived from each parent, the gametes, or sex cells, of each parent being haploid (having only one set of chromosomes) due to meiosis (reduction cell division).

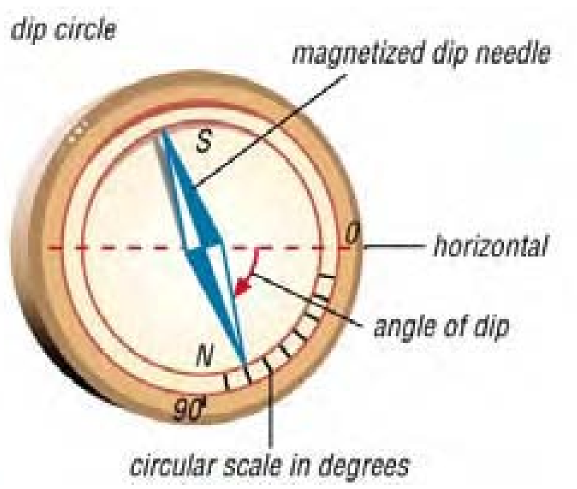
diplopia

double vision, usually due to a lack of coordination of the movements of the eyes. It may arise from disorder in, or damage to, the nerve supply or muscles of the eye, or from intoxication.

dip, magnetic

angle at a particular point on the Earth's surface between the direction of the Earth's magnetic field and the horizontal. It is measured using a **dip circle**, which has a magnetized needle suspended so that it can turn freely in the vertical plane of the magnetic field. In the northern hemisphere the north-seeking end of the needle dips below the horizontal, pointing along the line of the magnetic field towards the Earth's magnetic north pole. At the magnetic north and south poles, the needle dips vertically and the angle of dip is 90°. See also angle of declination.

dip



(Image © Research Machines plc)

A dip circle is used to measure the angle between the direction of the Earth's magnetic field and the horizontal at any point on the Earth's surface.

dipole

uneven distribution of magnetic or electrical characteristics within a molecule or substance so that it behaves as though it possesses two equal but opposite poles or charges, a finite distance apart.

The uneven distribution of electrons within a molecule composed of atoms of different electronegativities may result in an apparent concentration of electrons towards one end of the molecule and a deficiency towards the other, so that it forms a dipole consisting of apparently separated but equal positive and negative charges. The product of one charge and the distance between them is the **dipole moment**. A bar magnet has a magnetic dipole and behaves as though its magnetism were concentrated in separate north and south magnetic poles.

dipole

in radio, a rod aerial, usually one half-wavelength or a whole wavelength long.

dipole, magnetic

see magnetic dipole.

dipper

or water ouzel

any of various birds of the genus *Cinclus*, family Cinclidae, order Passeriformes, found in hilly and mountainous regions across Eurasia and North America, where there are clear, fast-flowing streams. It can swim, dive, or walk along the bottom, using the pressure of water on its wings and tail to keep it down, while it searches for insect larvae and other small animals. Both wings and tail are short, the beak is fairly short and straight, and the general colour of the bird is brown, the throat and part of the breast being white.

Dirac, Paul Adrien Maurice (1902-1984)

English physicist who worked out a version of quantum mechanics consistent with special relativity. The existence of antiparticles, such as the positron (positive electron), was one of its predictions. He shared the Nobel Prize for Physics in 1933 (with Austrian physicist Erwin Schrödinger) for his work on the development of quantum mechanics.

direct access

or random access

type of file access. A direct-access file contains records that can be accessed by the computer directly because each record has its own address on the storage disk. Direct access storage media include CD-ROMs and magnetic disks (such as floppy disks).

direct current

DC

electric current where the electrons (negative charge) flow in one direction, and that does not reverse its flow as alternating current does. The electricity produced by a battery is direct current. Electromagnets and electric trains use direct current.

If in one second one coulomb of electrons passes a given point, then the current flow is 1 amp DC.

A cathode ray oscilloscope (CRO) is used to display the waveforms that show the pattern of how voltage and current vary over a period of time. The waveforms for DC are straight lines, as the voltage and current do not vary over a period of time. If a resistor is connected in a circuit and measurements of voltage across the resistor and current flowing through it are taken over a period of time, then there will be no change in the voltage and current over this period. A plot of voltage or current against time produces a straight line.

directed number

in mathematics, number with a positive (+) or negative (-) sign attached, for example +5 or -5. On a graph, a positive sign shows a movement to the right or upwards; a negative sign indicates movement downwards or to the left.

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directory

in computing, a list of file names, together with information that enables a computer to retrieve those files from backing storage. The computer operating system will usually store and update a directory on the backing storage to which it refers. So, for example, on each disk used by a computer a directory file will be created listing the disk's contents.

The term is also used to refer to the area on a disk where files are stored; the main area, the **root** directory, is at the top-most level, and may contain several separate **sub-directories**.

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dirigible

another name for airship.

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disability

limitation of a person's ability to carry out the activities of daily living, to the extent that he or she may need help in doing so.

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disaccharide

sugar made up of two monosaccharides or simple sugars. Sucrose, $C_{12}H_{22}O_{11}$, or table sugar, is a disaccharide.

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disc

in astronomy, flat, roughly circular region of a spiral or a lenticular (lens-shaped) galaxy containing stars, nebulae, and dust clouds orbiting about the nucleus. Discs contain predominantly young stars and regions of star formation. The disc of our own Galaxy is seen from Earth as the band of the Milky Way.

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discharge tube

device in which a gas conducting an electric current emits visible light. It is usually a glass tube from which virtually all the air has been removed (so that it 'contains' a near vacuum), with electrodes at each end. When a high-voltage current is passed between the electrodes, the few remaining gas atoms in the tube (or some deliberately introduced ones) ionize and emit coloured light as they conduct the current along the tube. The light originates as electrons change energy levels in the ionized atoms.

By coating the inside of the tube with a phosphor, invisible emitted radiation (such as ultraviolet light) can produce visible light; this is the principle of the fluorescent lamp.

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discrete data

in mathematics, data that can take only whole-number or fractional values, that is, distinct values. The opposite is continuous data, which can take all in-between values. Examples of discrete data include frequency and population data. However, measurements of time and other dimensions can give rise to continuous data.

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disease

condition that disturbs or impairs the normal state of an organism. Diseases can occur in all living things, and normally affect the functioning of cells, tissues, organs, or systems. Diseases are usually characterized by specific symptoms and signs, and can be mild and short-lasting - such as the common cold - or severe enough to decimate a whole species – such as Dutch elm disease. Diseases can be classified as infectious or noninfectious. Infectious diseases are caused by micro-organisms, such as bacteria and viruses, invading the body; they can be spread across a species, or transmitted between one or more species. All other diseases can be grouped together as noninfectious diseases. These can have many causes: they may be inherited (congenital diseases); they may be caused by the ingestion or absorption of harmful substances, such as toxins; they can result from poor nutrition or hygiene; or they may arise from injury or ageing. The causes of some diseases are still unknown.

Some diseases occur mainly in certain climates or geographical regions of the world. These are **endemic** diseases. For example, African sleeping sickness, which is carried by the tsetse fly, is found mainly in the very hot, humid regions of Africa. Similarly, malaria, a disease spread by mosquitoes, is usually found in or near the marsh or stagnant water that provide breeding grounds for the insect. Other diseases may be seasonal - such as influenza, which tends to occur mainly in winter, or intestinal illnesses that result from food contamination in summer.

Some age groups may be more prone to certain diseases, such as measles in children, meningitis in young adults, and coronary heart disease in the elderly. Other diseases may tend to occur only in certain racial types and are usually genetic in origin, such as sickle-cell disease which is found mainly among people of black African descent. Other diseases, such as black lung, or coal-workers' pneumoconiosis, result from occupational hazards; some of the 'new' diseases that have appeared in recent years - such as sick building syndrome and legionnaire's disease, result from modern building designs, while the cause of ME (myalgic encephalomyelitis), or chronic fatigue syndrome, is still unknown.

Disease

introduction

The term 'disease' comes from 'dis-ease', and this provides a clue to some of its complexities. In medical parlance, 'disease' is an objective malady, typically caused by some pathogen (such as bacteria or a virus); but it is also the state of being sick (dis-eased), which may be a subjective condition. It is possible to have a disease without being or feeling ill; or to feel sick while having no disease - in an extreme case, this is called hypochondria.

a cursed visitation?

In ancient civilizations, disease was routinely interpreted as the consequence of sin, crime, or moral fault, as precipitated by evil spirits, or as the work of black magic. Disease was thus personalized and given a moral or religious meaning; hence health was to be recovered by some act of propitiation or counter-magic such as prayer, sacrifice, or the performance of ritual. In most tribal societies, disease is thus a public matter, put to rights, by the witch-doctor or medicine man, through public ceremonial.

Beliefs of this kind continued to play a major role throughout the Middle Ages and into the 16th and 17th centuries, with disease being associated with the work of Satan and with demonic possession. Plagues and pestilences were believed to be visitations from God, to punish or try sinful people. Protestants long continued to see disease as the finger of Providence.

the Greek analysis

It was Greek civilization that first, by contrast, viewed disease in a more naturalistic light, seeing it not as an evil assault from outside but as an internal breakdown. Above all, Hippocrates (*c.* 460-370 BC), often called the father of Greek medicine, developed the notion that health and disease hinged upon the quality and balance of the 'humours' within the body.

Four basic qualities characterized the four elements (air, water, fire, and earth) which had their analogues in the four humours of the body: blood, phlegm, choler (yellow bile), and black bile. Hot and dry corresponded to fire and yellow bile, hot and moist to air and blood, cold and dry to earth and black bile, cold and moist to water and phlegm.

the humours

The humours related to the broader order of things, including the four seasons, so that humanity in health and disease was explicable in terms of natural philosophy. The humours were products of digested food and of metabolism, and a person's functions were regulated from the anatomical centres of the liver, heart, and brain, which were the seats of the natural soul (appetites), the vital soul (the passions), and the rational soul (wisdom, judgment, will).

A person was in good health if the body, its parts and humours, had the proper temperament. Otherwise disease, an imbalance of the main constitutional fluids, would strike. Disease could be fought by restoring the balance of the humours - thus anaemia would be countered by eating plenty of red meat and drinking red wine to make more blood. It was thought apoplexy (over-heating of the blood) could be countered by blood-letting.

Greek medicine emphasized the natural origin of even supposedly 'sacred' diseases like epilepsy. It also valued the cultivation of good health through temperance in eating, drinking, and the regulation of sleep, exercise, sex, and the passions.

other theories

Greek theories had great currency within medicine until the last couple of centuries, and still carry popular appeal. Plagues and epidemics were harder to explain. As well as the idea of divine intervention, 'miasmatism' grew popular: epidemics, it was believed, derived from miasmas, or bad gases and smells given off from the soil, from rotting animal and vegetable matter, and from filth. The public health movements of the 19th century were founded on the idea of combating such miasmas, which supposedly caused typhus, typhoid, and cholera.

contagionism

Another theory was 'contagionism', the notion that disease spread through the transmission of a certain unknown entity from person to person. This seemed fairly plausible in the case of diseases like syphilis. The poisonous agent of such contagion long, however, remained a mystery, until the work of Louis Pasteur (1822-1895) and Robert Koch (1843-1910) in the 1870s conclusively demonstrated the presence of injurious bacteria and similar living micro-organisms. Late 19th-century tropical medicine also began to grasp the parasitic (insect-borne) nature of diseases like malaria.

the scientific era

The discovery of the specificity of infectious disease was a tremendous breakthrough, putting medicine on a scientific basis and leading in the 20th century to specific biological cures, such as antibiotics. Chronic disorders, mental diseases, degenerative disorders, and what are often called psychosomatic conditions have remained more difficult both to characterize and especially to cure.

the present day

Critics today widely argue that much modern Western medicine puts the cart before the horse by channelling more resources into curative than into preventive medicine. Scientific medicine's emphasis upon the body as a machine, to be understood primarily in terms of basic science (chemistry, physiology, anatomy) is also challenged by alternative medicine, with its more holistic concept of the unity of mind and body and its insistence that health and disease are located no less in the mind than in the body.

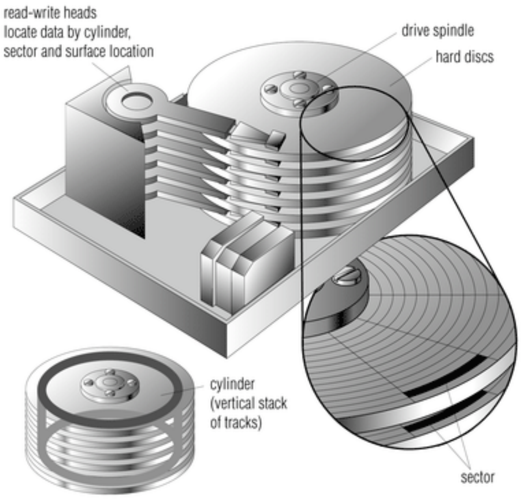
disinfectant

agent that kills, or prevents the growth of, bacteria and other micro-organisms. Chemical disinfectants include carbolic acid (phenol, used by Joseph Lister in surgery in the 1870s), ethanol, methanol, chlorine, and iodine.

disk

in computing, a common medium for storing large volumes of data. A **magnetic disk** is rotated at high speed in a disk-drive unit as a read/write (playback or record) head passes over its surfaces to record or read the magnetic variations that encode the data.
Optical disks, such as CD-ROM (compact-disc read-only memory) and WORM (write once, read many times), are also used to store computer data. Data are recorded on the disk surface as etched microscopic pits and are read by a laser-scanning device.

disk


read-write heads locate data by cylinder, sector and surface location
drive spindle
hard discs
cylinder (vertical stack of tracks)
sector

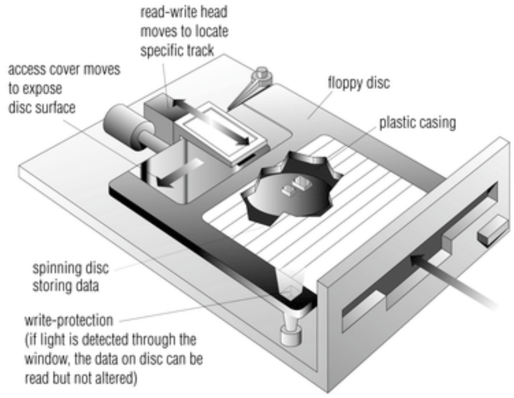
(Image © Research Machines plc)

A hard disk. Data is stored in sectors within cylinders and is read by a head which passes over the spinning surface of each disk.

disk drive

mechanical device that reads data from a disk. Many types can also write data to the disk.

disk drive



(Image © Research Machines plc)

A floppy disk drive. As the disk is inserted into the drive, its surface is exposed to the read-write head, which moves over the spinning disk surface to locate a specific track.

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disk formatting

in computing, preparing a blank magnetic disk in order that data can be stored on it. Data are recorded on a disk's surface on circular tracks, each of which is divided into a number of sectors. In formatting a disk, the computer's operating system adds control information such as track and sector numbers, which enables the data stored to be accessed correctly by the disk-drive unit.

Some floppy disks, called **hard-sectored disks**, are sold already formatted. However, because different makes of computer use different disk formats, disks are also sold unformatted, or **soft-sectored**, and computers are provided with the necessary utility program to format these disks correctly before they are used.

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dispersal

in biology, phase of reproduction during which gametes, eggs, seeds, or offspring move away from the parents into other areas. The result is that overcrowding is avoided and parents do not find themselves in competition with their own offspring. The mechanisms are various, including a reliance on wind or water currents and, in the case of animals, locomotion. The ability of a species to spread widely through an area and to colonize new habitats has survival value in evolution.

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dispersion

in physics, a particular property of refraction in which the angle and velocity of waves passing through a dispersive medium depends upon their frequency. When visible white light passes through a prism it is split into a spectrum (see electromagnetic waves). This occurs because each component frequency of light, which corresponds to a colour, is refracted by a slightly different angle, and so the light is split into its component frequencies (colours). A rainbow is formed when sunlight is dispersed by raindrops.

A white light beam splits up into the colours of which it consists (red, orange, yellow, green, blue, indigo, and violet). Red light has the lowest frequency (longest wavelength) and is the least refracted; violet light has the highest frequency (shortest wavelength) and is the most refracted. The relationship between wavelength and frequency is given by the formula: speed of light = frequency × wavelength (or wavelength = speed of light/frequency).

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displacement activity

in animal behaviour, an action that is performed out of its normal context, while the animal is in a state of stress, frustration, or uncertainty. Birds, for example, often peck at grass when uncertain whether to attack or flee from an opponent; similarly, humans scratch their heads when nervous.

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displacement vector

vector that describes how an object has been moved from one position to another.

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dissociation

in chemistry, the process whereby a single compound splits into two or more smaller products, which may be capable of recombining to form the reactant.

Where dissociation is incomplete (not all the compound's molecules dissociate), a chemical equilibrium exists between the compound and its dissociation products. The extent of incomplete dissociation is defined by a numerical value (dissociation constant).

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distance

the space between two points. Distance is normally measured using centimetres, metres, and kilometres.

Straight-line distances on a map can be easily measured with a ruler or straight edge. Simply convert the ruler measurement to distance, using the scale provided on the map. Twisting routes can be measured with a length of string, which is then straightened and measured in the normal way. For an object travelling at a constant speed the distance travelled can be calculated using the equation:

distance = speed × time.

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distance modulus

in astronomy, measure of the distance to an object in the universe, such as a star or galaxy, expressed as the difference between the object's apparent magnitude (representing its apparent brightness to us) and its absolute magnitude (representing its true brightness). The absolute magnitude is deduced from the object's type and size. The apparent magnitude is obtained by direct observation.

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distance ratio

in a machine, the distance moved by the input force, or effort, divided by the distance moved by the output force, or load. The ratio is equivalent to the machine's velocity ratio and indicates the force multiplication (or reduction) achieved.

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distemper

any of several infectious diseases of animals characterized by catarrh, cough, and general weakness. Specifically, it refers to a virus disease in young dogs, also found in wild animals, which can now be prevented by vaccination.

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distillation

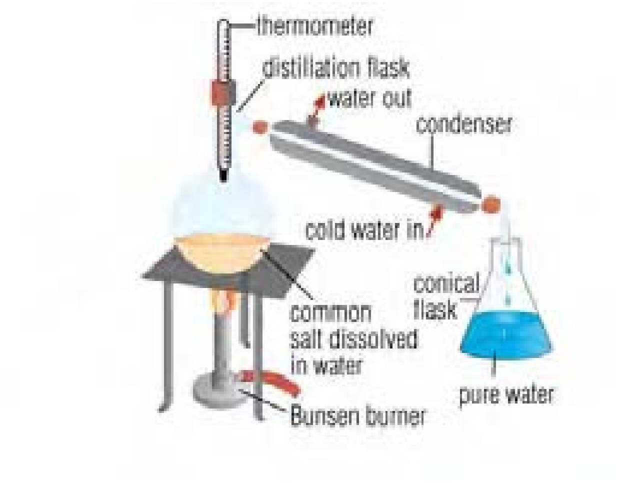
technique used to purify liquids or to separate mixtures of liquids possessing different boiling points. **Simple distillation** is used in the purification of liquids or the separation of substances in solution from their solvents – for example, in the production of pure water from a salt solution or the recovery of sodium chloride (table salt) from sea water.

The solution is boiled and the vapours of the solvent rise into a separate piece of apparatus (the condenser) where they are cooled and condensed. The liquid produced (the distillate) is the pure solvent; the substances (the solutes), now in solid form, remain in the distillation vessel.

Mixtures of liquids, such as crude oil (unrefined petroleum) or aqueous ethanol, are separated by **fractional distillation**, or fractionation, in a fractionating column. When the mixture is boiled, the vapours of its most volatile component (the component with the lowest boiling point) rise into the vertical column where they condense to liquid form. As they descend they are reheated to boiling point by the hotter rising vapours of the next component to reach boiling point. This boiling-condensing process occurs repeatedly inside the column. As the column is ascended, progressive enrichment by the lower-boiling-point components occurs; there is thus a temperature gradient inside the column. The vapours of the more volatile components reach the top of the column and enter the condenser for collection before those of the less volatile components. In the fractional distillation of petroleum, groups of compounds possessing similar relative molecular masses and boiling points (the fractions) are tapped off at different points on the column.

The earliest-known reference to the process is to the distillation of wine in the 12th century by Adelard of Bath. The chemical retort used for distillation was invented by Muslims, and was first seen in the West in about 1570.

distillation



(Image © Research Machines plc)

Laboratory apparatus for simple distillation. Other forms of distillation include steam distillation, in which steam is passed into the mixture being distilled, and vacuum distillation, in which air is removed from above the mixture to be distilled.

distributive operation

in mathematics, an operation, such as multiplication, that bears a relationship to another operation, such as addition, such that $a \times (b + c) = (a \times b) + (a \times c)$. For example, $3 \times (2 + 4) = (3 \times 2) + (3 \times 4) = 18$. Multiplication may be said to be distributive over addition. Addition is not, however, distributive over multiplication because $3 + (2 \times 4) \neq (3 + 2) \times (3 + 4)$.

distributor

device in the ignition system of a piston engine that distributes pulses of high-voltage electricity to the spark plugs in the cylinders. The electricity is passed to the plug leads by the tip of a rotor arm, driven by the engine camshaft, and current is fed to the rotor arm from the ignition coil. The distributor also houses the contact point or breaker, which opens and closes to interrupt the battery current to the coil, thus triggering the high-voltage pulses. With electronic ignition the distributor is absent.

diuresis

in medicine, increase in the production of urine. It may be due to increased fluid intake, decreased levels of antidiuretic hormone (vasopressin), renal disease, or the use of diuretics. Diuretics are used in the treatment of high blood pressure (hypertension) and heart failure.

diuretic

any drug that increases the output of urine by the kidneys. It may be used in the treatment of high blood pressure and to relieve oedema associated with heart, lung, kidney or liver disease, and some endocrine disorders.

diversification

in agriculture and business, the development of distinctly new products or markets. A company or firm may diversify in order to spread its risks or because its original area of operation is becoming less profitable. In the UK agricultural diversification has included offering accommodation and services to tourists – for example, bed and breakfast, camping and caravanning sites, and pony trekking. Another example would be chocolate bar manufacturers diversifying into ice cream versions of their brands to produce revenue in hot summers when traditionally their sales are slacker.

The risk associated with diversification is that the company will lose sight of its core business, lose focus, and suffer as a result of entering new markets it has no expertise in. Few companies have a brand strong enough to stand the degree of diversification a company like Virgin embraces.

diverticulitis

inflammation of diverticula (pockets of herniation) in the large intestine. It is usually triggered by infection and causes diarrhoea or constipation, and lower abdominal pain. Usually it can be controlled by diet and antibiotics.

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dividend

in mathematics, any number that is to be divided by another number. For example in the computation 20 ÷ 4 = 5, 20 is the dividend.

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diving apparatus

any equipment used to enable a person to spend time underwater. Diving bells were in regular use in the 17th century, the diver breathing air trapped in a bell-shaped chamber. This was followed by cumbersome diving suits in the early 19th century. Complete freedom of movement came with the aqualung, invented by Jacques Cousteau in the early 1940s. For work at greater depths the technique of saturation diving was developed in the 1970s in which divers live for a week or more breathing a mixture of helium and oxygen at the pressure existing on the seabed where they work (as in work on North Sea platforms and tunnel building).

The first diving suit, with a large metal helmet supplied with air through a hose, was invented in the UK by the brothers John and Charles Deane in 1828. Saturation diving was developed for working in offshore oilfields. Working divers are ferried down to the work site by a lock-out submersible. When they are not diving, they live in a compression chamber on board a support ship. They thereby avoid frequent periods of slow decompression to avoid the dangerous consequences of an attack of the bends, or decompression sickness.

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divisor

in mathematics, any number that is to be divided into another number. For example in the computation 100 ÷ 25 = 4, 25 is the divisor.

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dizygotic twin

in medicine, one of a pair of twins born to the same parents at the same time following the fertilization of two separate ova. They may be of different sexes and they are no more likely to resemble each other than any other sibling pair.

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dizziness

another word for vertigo.

DNA

abbreviation for deoxyribonucleic acid

molecular basis of heredity. It is a complex giant molecule that contains, in chemically coded form, the information needed for a cell to make proteins. In other words it determines the order in which amino acids are joined to make a specific protein in a cell. DNA is a ladder-like double-stranded nucleic acid, which forms the basis of genetic inheritance in all organisms, except for a few viruses that have only RNA. DNA is organized into chromosomes and, in organisms other than bacteria, it is found only in the cell nucleus.

DNA is a ladder-like molecule, which means that it is made up of two halves (the ladder sides), formed of chains of nucleotide subunits. Each nucleotide contains a deoxyribose sugar, a phosphate, and a base. A set of three bases – known as a **codon** – acts as a blueprint for the manufacture of a particular amino acid, the subunit of a protein molecule. The two halves are joined together by the bases – a purine (adenine or guanine) or pyrimidine (cytosine or thymine) – forming pairs (the rungs). The bases form into two specific base pairs: adenine with thymine and guanine with cytosine. The sequence of base pairs along the DNA acts as a code carrying information about the sequence of amino acids in proteins. Three base pairs in sequence (triplet) name an amino acid and the next three name the next amino acid that needs to be joined and so on, to make a specific protein. The specific way in which the pairs form means that the base sequence is preserved from generation to generation. Hereditary information is stored as a specific sequence of bases.

It is important that inherited information is passed on correctly. In the process of DNA replication, which takes place before any cell divides, the two halves of DNA separate and new halves are made. Because of specific base pairing, the inherited information is copied exactly. Despite this, a mistake sometimes occurs and the sequences of bases is altered. This changes the sequence of amino acids in a protein. This is mutation. Ionizing radiation increases the risk of mutation. In plants and animals DNA is organized into chromosomes and is found in the nucleus of cells. DNA in bacteria is organized differently. Bacteria have one large circular DNA molecule carrying most of their inherited information. Some bacteria also have small circular molecules of DNA, known as plasmids. These may be used in genetic engineering to transfer genes from one organism to another.

DNA and RNA

To remember that although DNA and RNA are both nucleic acids, they do different jobs in the cell:

DNA **d**elivers the blueprint, **R**NA **r**eads it

DNA From The Beginning

Go to site

A very informative, fun site, with lots of animation and multimedia resources, for those who which to learn something about the 'stuff of life'.

Molecular Expressions: The DNA Collection

Go to site

Spectacular gallery of DNA photographic representations in the laboratory as well as *in vivo*. This site also has links to several other sites offering photographs through a microscope of various substances, including computer chips and various pharmaceutical substances.

DNA fingerprinting

or DNA profiling

another name for genetic fingerprinting.

Dobermann

or Dobermann pinscher

breed of smooth-coated dog with a docked tail, much used as a guard dog. It stands up to 70 cm/27.5 in tall, has a long head with a flat, smooth skull, and is often black with brown markings. It takes its name from the man who bred it in 19th-century Germany.

Dobzhansky, Theodosius (1900-1975)

adopted name of Feodosy Grigorevich Dobrzhansky

Ukrainian-born US geneticist who established evolutionary genetics as an independent discipline. He showed that genetic variability between individuals of the same species is very high and that this diversity is vital to the process of evolution.

His book *Genetics and the Origin of Species* (1937) was the first significant synthesis of Darwinian evolutionary theory and Mendelian genetics. Dobzhansky also proved that there is a period when speciation is only partly complete and during which several races coexist.

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dock

or sorrel

in botany, any of a number of plants belonging to the buckwheat family. They are tall, annual or perennial herbs, often with lance-shaped leaves and small greenish flowers. Native to temperate regions, there are 30 North American and several British species. (Genus *Rumex*, family Polygonaceae.)

Docks

Go to site

Features a brief introduction to dock plants, as well as descriptions of a number of different species, including patience dock, great water dock, and sharp-pointed dock. The possible medicinal uses of these plants are also described, where relevant.

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document

in computing, data associated with a particular application. For example, a **text document** might be produced by a word processor and a **graphics document** might be produced with a CAD package. An OMR or OCR document is a paper document containing data that can be directly input to the computer using a document reader.

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documentation

in computing, the written information associated with a computer program or applications package. Documentation is usually divided into two categories: program documentation and user documentation.

Program documentation is the complete technical description of a program, drawn up as the software is written and intended to support any later maintenance or development of that program. It typically includes details of when, where, and by whom the software was written; a general description of the purpose of the software, including recommended input, output, and storage methods; a detailed description of the way the software functions, including full program listings and flow charts; and details of software testing, including sets of test data with expected results.

User documentation explains how to operate the software. It typically includes a nontechnical explanation of the purpose of the software; instructions for loading, running, and using the software; instructions for preparing any necessary input data; instructions for requesting and interpreting output data; and explanations of any error messages that the program may produce.

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document reader

in computing, an input device that reads marks or characters, usually on preprepared forms and documents. Such devices are used to capture data by optical mark recognition (OMR), optical character recognition (OCR), and mark sensing.

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dodder

parasitic plant belonging to the morning-glory family, without leaves or roots. The thin stem twines around the host plant, and penetrating suckers withdraw nourishment. (Genus *Cuscuta*, family Convolvulaceae.)

Dodder

Go to site

Detailed information about this parasitic plant. There is a description of the plant itself, and there are also notes on the possible medicinal uses of dodder, which include treating hoarseness and hastening healing of wounds.

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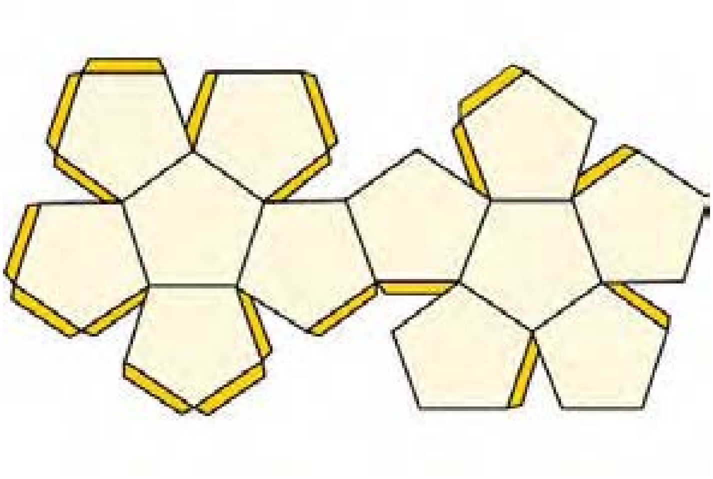
dodecahedron

regular solid with 12 pentagonal faces and 12 vertices. It is one of the five regular polyhedra, or Platonic solids.

dodecahedron



(Image © Research Machines plc)

A flat plan showing the faces of a dodecahedron, a solid figure that has 12 pentagonal faces and 12 vertices.

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dodo

extinct flightless bird *Raphus cucullatus*, order Columbiformes, formerly found on the island of Mauritius, but exterminated by early settlers around 1681. Although related to the pigeons, it was larger than a turkey, with a bulky body, rudimentary wings, and short curly tail-feathers. The bill was blackish in colour, forming a horny hook at the end.

dodo: legs

Most pictures of the dodo show a bird with two right legs. This is because the only person to paint a live dodo, the Belgian artist Roelandt Savery, made an elementary error in drawing the parts that he could not see.

dodo: name origin

The word 'dodo' comes from the Portuguese *doudo*, meaning 'stupid', because the bird was too ignorant of humans to run away before it was killed.

dog

any carnivorous mammal of the family Canidae, including wild dogs, wolves, jackals, coyotes, and foxes. Specifically, the domestic dog *Canis familiaris*, the earliest animal descended from the wolf. Dogs were first domesticated around 14,000 years ago, and migrated with humans to all the continents. They have been selectively bred into many different varieties for use as working animals and pets.

characteristics

The dog has slender legs and walks on its toes (**digitigrade**). The forefeet have five toes, the hind feet four, with non-retractile claws. The head is small and the muzzle pointed, but the shape of the head differs greatly in various breeds. The average life of a dog is from 10 to 14 years, though some live to be 20. The dog has a very acute sense of smell and can readily be trained, for it has a good intelligence.

wild dogs

Of the wild dogs, some are solitary, such as the long-legged maned wolf *Chrysocyon brachurus* of South America, but others hunt in groups, such as the African hunting dog *Lycaonpictus* (classified as a vulnerable species) and the wolf. Jackals scavenge for food, and the raccoon dog *Nyctereutes procyonoides* of east Asia includes plant food as well as meat in its diet. The Australian wild dog is the dingo.

Dog breeds

This is a list of most popular breeds recognized by one or more of the following organizations: The American Kennel Club, The Canadian Kennel Club, La Fédération Cynologique Internationale, The Kennel Club of Great Britain.
Height is given at the dog's withers (the highest point of the body, behind the neck). Where applicable, measurements are given for M = males and F = females. N/A = not available.

Breed	Country of origin	Height	
		cm	in
Gundogs			
Barbet	France	45-50	18-20
Braque[1]	France	variety of sizes	
Drentse Partridge Dog (Drentsche Patrijshond)	Netherlands	55-63	22-25
English Setter	England	65-68.5 M, 61-65 F	25.5-27 M, 24-25.5 F
German Shorthaired Pointer	Germany	58.5-63.5 M, 53-58.5 F	23-25 M, 21-23 F
German Wirehaired Pointer	Germany	61-66	24-26
Gordon Setter	Scotland	66 M, 62 F	26 M, 24.5 F
Hungarian Vizsla	Hungary	56-63.5 M, 53-59 F	22.5-25 M, 21-23.5 F
Irish Setter	Ireland	no size stipulated	
Italian Spinone	France	58-68 M, 56-61 F	23-27.5 M, 22-24 F
Large Münsterländer	Germany	61 M, 58.5 F	24 M, 23 F
Pointer	England	63.5-68.5 M, 61-66 F	25-27 M, 24-26 F
Portuguese Water Dog (Cão de Aua Portugues)	Portugal	51-58	20-23
Retriever (Chesapeake Bay)	USA	56-64 M, 51-59 F	22-25.5 M, 20-23.5 F
Retriever (Curly Coated)	origin unknown	63.5-68.5	25-27
Retriever (Flat Coated)	origin uncertain	63.5-68.5	25-27
Retriever (Golden)	origin uncertain	56-61 M, 51-56 F	22-24 M, 20-22 F
Retriever (Labrador)	Canada	56-57 M, 54-56 F	22-22.5 M, 21.5-22 F
Spaniel (American Cocker)	USA	38 M, 35.5 F	15 M, 14 F
Spaniel (Brittany)	France	48.5-51 M, 45.5-48.5 F	19-20 M, 18-19 F
Spaniel (Clumber)	France	48-50 M, 43-48 F	19-20 M, 17-19 F
Spaniel (Cocker)	Spain	39-41 M, 38-38.5 F	15.5-16 M, 15-15.25 F
Spaniel (English Springer)	England	51	20
Spaniel (Field)	UK	46	18
Spaniel (Irish Water)	Ireland	56-61 M, 53-58 F	22-24 M, 21-23 F
Spaniel (Sussex)	England	38-40	15-16
Spaniel (Welsh Springer)	Wales	48 M, 46 F	19 M, 18 F
Weimaraner	Germany	61-69 M, 56-64 F	24-27 M, 22-25 F
Hounds			
Afghan Hound	Iran	68-73	27-29
Anglo-Français and Français Hounds[2]	France	variety of sizes	
Azawakh	France	60-74	24-29
Balkanski Gonic	Yugoslavia	44-54	17-21
Basenji	central Africa	43 M, 40.5 F	17 M, 16 F
Basse Griffon Vendéen	France	38-43 (grande), 33-38 (petite)	15-17 (grande), 13-15 (petite)
Basset Hound	France	33-38	13-15
Beagle	UK	33-40.5	13-16

Black and Tan Coonhound	USA	63.5-68.5 M, 58.5-63.5 F	25-27 M, 23-25 F
Bloodhound	UK	63.5-68.5 M, 58.5-63.5 F	25-27 M, 23-25 F
Bosanski Ostrodlaki Gonic-Barak	Bosnia	46-56	18-22
Borzoi	Russia	73.5 upwards M, 68.5 upwards F	29 upwards M, 27 upwards F
Bracco Italiano	Italy	55-67	22-26
Ceský Foucek	Czech Republic	58-66	23-26
Chart Polski	Poland	68-80	27-31
Dachshund (Long-Haired)	Germany	12.5-23	5-9
Dachshund (Miniature Long-Haired)	Germany	weight more important than size (5 kg/11 lb preferable)	
Dachshund (Smooth-Haired)	Germany	12.5-23	5-9
Dachshund (Miniature Smooth-Haired)	Germany	weight more important than size (5 kg/11 lb preferable)	
Dachshund (Wire-Haired)	Germany	12.5-23	5-9
Dachshund (Miniature Wire-Haired)	Germany	weight more important than size (5 kg/11 lb preferable)	
Deerhound	UK	no less than 76 M, 71 F	no less than 30 M, 28 F
Elkhound	Norway	51 M, 49 F	20.5 M, 19.5 F
Erdélyi Kopó	Hungary	55-65	22-25.5
Finnish Spitz	Finland	43-51 M, 39.5-45.5 F	17-20 M, 15.5-18 F
Foxhound (English)	England	58	23
Greyhound	ancient (Egyptian) origin	71-76 M, 68-71 F	28-30 M, 27-28 F
Hamiltonstováre	Sweden	57 M, 53 F[3]	22.5 M, 21 F[3]
Harrier	ancient (possibly Greek) origin	46-56	18-22
Hellinikos Ichnilatis	Greece	47-52	18.5-20
Ibizan Hound	Spain (Balearic Islands)	59-71 M, 56-69 F	23.5-28 M, 22.5-27 F
Irish Wolfhound	Ireland	78.7 upwards M, 71 upwards F	31 upwards M, 28 upwards F
Istarski Gonic	Slovenia and Croatia	50-52 (Ostrodlaki, wirehaired); 48-50 (Kratkodlaki, smooth)	19.5-20 (Ostrodlaki, wirehaired); 19-19.5 (Kratkodlaki, smooth)
Kai (Konshu-Tora)	Japan	46-56	18-22
Karelean Bear Dog (Karjalankarhukoira)	Finland	49-60	19-24
Laika, Russko-Evropeiskaia (Russian-European)	Russia	48-58	19-23
Laika, Vostochno-Sibirskaia (East-Siberian)	Russia	51-64	20-25
Laika, Zapadno-Sibirskaia (West-Siberian)	Russia	51-62	20-24
Ogar Polski	Poland	55-65	22-25.5
Otterhound	UK	61-69	24-27
Pharaoh Hound	north Africa	56-63 M, 53-61 F	22-25 M, 21-24 F
Planinsky Gonic	Slovenia	45-55	18-22
Rhodesian Ridgeback	South Africa	63-68 M, 61-66 F	25-27 M, 24-26 F
Saluki[4]	north Africa	58-71	23-28
Whippet	England	46 M, 43.5 F	18.5 M, 17.5 F
Terriers			
Airedale Terrier	England	58-61 M, 56-58 F	23-24 M, 22-23 F
Australian Terrier	Australia	25	10
Bedlington Terrier	England	41	16
Black Russian Terrier (Chernyi terrier)	Russia	64-72	25-28
Border Terrier	Scotland	33	13
Bull Terrier	England	no size stipulated	
Bull Terrier (Miniature)	England	up to 36	up to 14
Cairn Terrier	Scotland	28-30.5	11-12
Dandie Dinmont Terrier	Scotland	20-28	8-11
Fox Terrier	England	N/A	N/A
Fox Terrier (Wire-Haired)	N/A	up to 39	up to 15.5
Glen of Immaal Terrier	Ireland	up to 35.5	up to 14
Irish Terrier	Ireland	48.5 M, 45.5 F	19 M, 18 F
Jack Russell Terrier	England	up to 28 (smaller size), 28-38 (larger size)	up to 11 (smaller size), 11-15 (larger size)
Kerry Blue Terrier[5]	Ireland	46-48	18-19
Lakeland Terrier[6]	England	up to 36	up to 14.5
Manchester Terrier	England	41 M, 38 F	16 M, 15 F
Norfolk Terrier	England	25	10
Norwich Terrier	England	25	10
Scottish Terrier	Scotland	25-28	10-11
Sealyham Terrier	Wales	up to 30	up to 12
Skye Terrier	Scotland	25.5	10
Soft-Coated Wheaten Terrier	Ireland	46-49	18-19.5
Staffordshire Bull Terrier	England	35.5-40.5	14-16
Welsh Terrier	Wales	up to 38	up to 15.5
West Highland White Terrier	Scotland	28	11

Toys			
Affenpinscher	Germany	24-28	9.5-11
Australian Silky Terrier	Australia	23	9
Bichon Frise	France	23-28	9-11
Cavalier King Charles Spaniel	England	25	10
Chihuahua[7] (Long Coat)	Mexico	weight more important than size (1-2 kg/2-4 lb preferable)	
Chihuahua[7] (Smooth Coat)	Mexico	weight more important than size (1-2 kg/2-4 lb preferable)	
Chinese Crested Dog	China	28-33 M, 23-30.5 F	11-13 M, 9-12 F
English Toy Terrier (Black and Tan)[8]	England	25-30	10-12
Griffon Bruxellois	Belgium	weight more important than size (2.7-4.5 kg/6-10 lb preferable)	
Italian Greyhound	Italy	33-38	13-15
Japanese Chin	Japan	no size stipulated	
King Charles Spaniel	England	25	10
Little Lion Dog (Löwchen)	Germany	25-33	10-13
Maltese	Malta	up to 25.5	up to 10
Miniature Pinscher	Germany	25.5-30.5	10-12
Papillon	Spain	20-28	8-11
Pekingese	China	18	7
Pomeranian	Arctic Circle	weight more important than size (1.8-2.25 kg/4-5 lb preferable)	
Pug	China	weight more important than size (6-8 kg/14-18 lb preferable)	
Xoloitzquintli (Mexican Hairless)	Mexico	28-30 (toy), 33-45 (miniature), 45-55 (standard)	11-12 (toy), 13-18 (miniature), 18-22 (standard)
Yorkshire Terrier	England	18	7
Utility Dogs			
Boston Terrier	USA	38 M, 36.5 F	15 M, 14 F
Bulldog	England	weight more important than size (23-25 kg/50-55 lb preferable)	
Chow Chow	China	48.5-56 M, 45.5-51 F	19-22 M, 18-20 F
Dalmatian	Slovenia and Croatia	58-61 M, 56-58 F	23-24 M, 22-23 F
French Bulldog	France	30	12
Hrvatski Ovcar	Croatia	40-50	16-20
Japanese Akita	Japan	66-71 M, 61-66 F	26-28 M, 24-26 F
Japanese Spitz	Japan	30-40 M, 25-35 F	12-16 M, 10-14 F
Keeshond	Netherlands	45.5 M, 43 F	18 M, 17 F
Leonberger	Germany	from 76 M, 68 F	from 30 M, 27 F
Lhasa Apso	Tibet	25	10
Poodle (Standard)	origin uncertain	38	15
Poodle (Miniature)	origin uncertain	28-38	11-15
Poodle (Toy)	origin uncertain	below 28	below 11
Schipperke	Belgium	30.5-33	12-13
Schnauzer (Standard)	Germany	48 M, 45.5 F	19 M, 18 F
Schnauzer (Miniature)	Germany	35 M, 33 F	14 M, 13 F
Shar-Pei	China	45.5-51	18-20
Shih Tzu	Tibet	up to 26	up to 10.5
Tibetan Spaniel	Tibet	25.5	10
Tibetan Terrier	Tibet	35-40	14-16
Working Dogs			
Aïdi (Chien d'Atlas)	Morocco	52-62	20-24
Ainu (Hokkaido)	Japan	45-52	17.5-20.5
Akbash	Turkey	70-86	28-34
Alaskan Malamute	USA	64-71 M, 58-66 F	25-28 M, 23-26 F
Appenzell Cattle Dog	Switzerland	50-56	20-22
Anatolian Shepherd Dog	Turkey	73.5-78.5 M, 71-78.5 F	29-31 M, 28-31 F
Australian Cattle Dog	Australia	46-51 M, 43-48 F	18-20 M, 17-19 F
Bauceron	France	63-75	25-29.5
Bearded Collie	Scotland	53-56 M, 51-53 F	21-22 M, 20-21 F
Belgian Shepherd Dog (Groenendael)	Belgium	61-66 M, 56-61 F	24-26 M, 22-24 F
Belgian Shepherd Dog (Laekenois)	Belgium	61-66 M, 56-61 F	24-26 M, 22-24 F
Belgian Shepherd Dog (Malinois)	Belgium	61-66 M, 56-61 F	24-26 M, 22-24 F
Belgian Shepherd Dog (Tervueren)	Belgium	61-66 M, 56-61 F	24-26 M, 22-24 F
Bergamasco	Italy	54-62	21-24
Berger Picard	France	55-65	22-26
Bernese Mountain Dog	Switzerland	63.5-70 M, 58.5-66 F	25-27.5 M, 23-26 F
Border Collie[9]	Scotland	53	21
Bouvier Des Flanders	Belgium	63.5-68.5 M, 58.5-65 F	25-27 M, 23-25.5 F
Boxer	Germany	57-63.5 M, 53-58.5 F	22.5-25 M, 21-23 F

Briard	France	61-68.5 M, 58.5-65 F	24-27 M, 23-25.5 F
Broholmer	Denmark	over 75 M, 70 F	over 29.5 M, 28 F
Bullmastiff	England	63-68 M, 61-66 F	25-27 M, 24-26 F
Collie (Rough)	Scotland	56-61 M, 51-56 F	22-24 M, 20-22 F
Collie (Smooth)	Scotland	56-61 M, 51-56 F	22-24 M, 20-22 F
Dobermann	Germany	68.5 M, 63.5 F	27 M, 25.5 F
Estrela Mountain Dog (Cão Serra Da Estrela)	Portugal	65-72 M, 62-68 F	25.5-28.5 M, 24.5-27 F
German Shepherd Dog (Alsatian)	Germany	61-66 M, 56-61 F	24-26 M, 22-24 F
Great Dane	Denmark	over 76 M, 71 F	over 30 M, 28 F
Hovawart	Germany	61-70 M, 58.5-65 F	24-27.5 M, 23-25.5 F
Hungarian Puli	Hungary	41-46 M, 36-41 F	16-18 M, 14-16 F
Husky (Eskimo Dog)	Russia	58.5-68.5 M, 51-61 F	23-27 M, 20-24 F
Husky (Siberian)	Russia	53-59 M, 51-56 F	21-23.5 M, 20-22 F
Islenskur Fjárhundur	Iceland	38-48	15-19
Komondor	Hungary	over 63.5 M, 59.5 F	over 25 M, 23.5 F
Krazski Ovcar	Slovenia and Croatia	52-60	20-24
Lancashire Heeler	England	30.5 M, 25.5 F	12 M, 10 F
Maremma Sheepdog	Italy	65-72.5 M, 59.5-67 F	25.5-28.5 M, 23.5-26.5 F
Mastiff	UK	over 76 M, 69 F	over 30 M, 27.5 F
Newfoundland	Canada	71 M, 66 F	28 M, 26 F
Norwegian Buhund	Norway	up to 45	up to 17.75
Old English Sheepdog	England	61 M, 56 F	24 M, 22 F
Ovcharka	Russia	variety of sizes	
Pinscher	Germany	43-48.5	17-19
Polski Owczarek Nizinny	Poland	40-52	16-20
Polski Owczarek Podhalanski	Poland	62-70	24-27.5
Pumi	Hungary	35-44	13.5-17
Pyrenean Mountain Dog	Spain	71 M, 66 F	28 M, 26 F
Rottweiler	Germany	63.5-68.5 M, 58.5-63.5 F	25-27 M, 23-25 F
St Bernard	Switzerland	no maximum height; minimum 70 M, 65 F	no maximum height; minimum 28 M, 26 F
Samoyed	Russia	51-56 M, 46-51 F	20-22 M, 18-20 F
Sarplaninac	Kosovo (Albania)	58-62	23-24
Schnauzer (Giant)	Germany	64-69 M, 59-64 F	25.5-27.5 M, 23.5-25.5 F
Shetland Sheepdog	Scotland	36	14.5
Stumpy Tail Cattle Dog	Australia	46-51 M, 43-48 F	18-20 M, 17-19 F
Vastgotaspets (Swedish Vallhund)	Sweden	33-35 M, 30.5-33 F	13-14 M, 12-13 F
Welsh Corgi (Cardigan)	Wales	30.5	12
Welsh Corgi (Pembroke)	Wales	25-30	10-12

[1] Breed comprises numerous recognized varieties.

[2] 22 French hound breeds recognized by Fédération Cynologique Internationale.

[3] Permitted variation of 49.5-59.5 cm (19.5-23.5 in) for dogs, 45.5-57 cm (18-22.5 in) for bitches.

[4] Probably the oldest known breed of domesticated dog.

[5] Originally known as the Irish blue terrier.

[6] Originally known as the Patterdale terrier.

[7] Chihuahua is thought to be the smallest known dog.

[8] Miniature form of the Manchester terrier.

[9] Originally known as the shepherd's dog, the English collie, the working collie, and finally the Border collie.

Cyber-Pet

Go to site

Lively US site, with information about choosing your dog or cat, health and nutrition, breeding and exhibiting, and pet products and services. It also includes some audio clips explaining various sections of the site.

Dog Lovers Page

Go to site

Information on breeds, ranging from the world's smallest breed (the Chihuahua) to the tallest (the Irish wolfhound). This Australian-based site includes photographs and details of over 100 breeds of dog.

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dogfish

any of several small sharks found in the northeast Atlantic, Pacific, and Mediterranean.

dog's mercury

plant belonging to the spurge family, common in woods of Europe and southwest Asia. It grows to 30 cm/1 ft, has oval, light-green leaves, and spreads over woodland floors in patches of plants of a single sex. Male flowers are small, greenish yellow, and held on an upright spike above the leaves; female flowers droop below the upper leaves. (*Mercurialis perennis*, family Euphorbiaceae.)

dogwhelk

marine mollusc, some of which live on rocky shores whilst others burrow. The shell aperture is grooved to house the inhalant siphon keeping it clear of the mud.

The **common dogwhelk** *Thais lapillus* is a predator of barnacles and mussels and the coloured bands in the shell are believed to be influenced by the food material. The egg capsules are attached singly in crevices and have the appearance of corn grains.

The **netted dogwhelk** *Nassarius reticulatus* is recognizable by the crenulations on the shell. The egg capsules are flat and are deposited in eel-grass. Like the closely related thick-lipped dogwhelk *N. incrassatus*, it is a scavenger.

classifiation

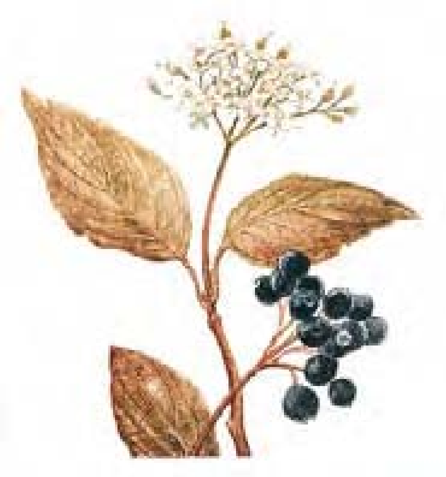
Dogwhelks are in order Neogastropoda, subclass Prosobranchia, class Gastropoda, phylum Mollusca.

dogwood

any of a group of trees and shrubs belonging to the dogwood family, native to temperate regions of North America, Europe, and Asia. The flowering dogwood (*Cornus florida*) of the eastern USA is often cultivated as an ornamental for its beautiful blooms consisting of clusters of small greenish flowers surrounded by four large white or pink petal-like bracts (specialized leaves). (Genus *Cornus*, family Cornaceae.)

Heads of small white flowers, each with four petals joined as a tube, are produced in midsummer, followed by black berries. The dogwood is characteristic of lime soils in southern England, and is found over much of southern Europe. *C. sanguinea* is native to Britain and common in old hedgerows and woods. It takes its name from the redness of the twigs. The introduced red-osier dogwood (*C. sericea*) has longer twigs of a brighter red, with white berries rather than black. Various other species of dogwood are planted in gardens.

dogwood



(Image © Research Machines plc)

There are about 40 different types of shrubs called dogwoods found throughout the temperate parts of the northern hemisphere. Some kinds, such as the cornelian cherry, are grown for their decorative flowers and the wood of this species is also hard enough to be used for skewers. Dogwoods can be very invasive and, if left unchecked, may pose a threat to the survival of downland areas.

doldrums

area of low atmospheric pressure along the Equator, in the intertropical convergence zone where the northeast and southeast trade winds converge. The doldrums are characterized by calm or very light winds, during which there may be sudden squalls and stormy weather. For this reason the areas are avoided as far as possible by sailing ships.

dolmen

prehistoric megalith in the form of a chamber built of three or more large upright stone slabs, capped by a horizontal flat stone. Dolmens are the burial chambers of Neolithic (New Stone Age) chambered tombs and passage graves, revealed by the removal of the covering burial mound. They are found in Europe and Africa, and occasionally in Asia as far east as Japan.

dolmen

(Image © Research Machines plc)

Lanyon Quoit is believed to be the burial chamber of a long mound. In megalithic times, when the dolmen was built, it would have been covered with earth, which has been steadily worn away over millennia. Before 1815, when it collapsed during a storm and was rebuilt, it was said that a man on horseback could pass underneath the capstone.

dolmen

(Image © Research Machines plc)

On the bare limestone of the Burren in County Clare, Ireland, early people erected Poulnabrone dolmen. A megalithic tomb, it consists of one flat stone laid across uprights. It was originally buried under an earthen mound but laid bare by erosion.

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dolomite

in mineralogy, white mineral with a rhombohedral structure, calcium magnesium carbonate ($CaMg(CO_3)_2$). Dolomites are common in geological successions of all ages and are often formed when limestone is changed by the replacement of the mineral calcite with the mineral dolomite.

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dolphin

any of various highly intelligent aquatic mammals of the family Delphinidae, which also includes porpoises. There are about 60 species. Most inhabit tropical and temperate oceans, but there are some freshwater forms in rivers in Asia, Africa, and South America. The name 'dolphin' is generally applied to species having a beaklike snout and slender body, whereas the name 'porpoise' is reserved for the smaller species with a blunt snout and stocky body. Dolphins use sound (echolocation) to navigate, to find prey, and for communication. The common dolphin *Delphinus delphis* is found in all temperate and tropical seas. It is up to 2.5 m/8 ft long, and is dark above and white below, with bands of grey, white, and yellow on the sides. It has up to 100 teeth in its jaws, which make the 15 cm/6 in 'beak' protrude forward from the rounded head. The corners of its mouth are permanently upturned, giving the appearance of a smile, though dolphins cannot actually smile. Dolphins feed on fish and squid.

river dolphins

There are five species of river dolphin, two South American and three Asian, all of which are endangered. The two South American species are the **Amazon river dolphin** or **boto** *Inia geoffrensis*, the largest river dolphin (length 2.7 m/8.9 ft, weight 180 kg/396 lb) and the **La Plata river dolphin** *Pontoporia blainvillei* (length 1.8 m/5.9 ft, weight 50 kg/110 lb). The **tucuxi** *Sotalia fluviatilis* is not a true river dolphin, but lives in the Amazon and Orinoco rivers, as well as in coastal waters.

The Asian species are the **Ganges river dolphin** *Platanista gangetica*, the **Indus river dolphin** *Platanista minor* (length 2 m/6.6 ft, weight 70 kg/154 lb) (fewer than 500 remaining), and the **Yangtze river dolphin** or **baiji** *Lipotes vexillifer* (length 2 m/6.6 ft, weight 70 kg/154 lb). In January 2000, there were believed to be only five Yangtze river dolphins remaining in the wild.

As a result of living in muddy water, river dolphins' eyes have become very small. They rely on echolocation to navigate and find food. Some species of dolphin can swim at up to 56 kph/35 mph, helped by special streamlining modifications of the skin.

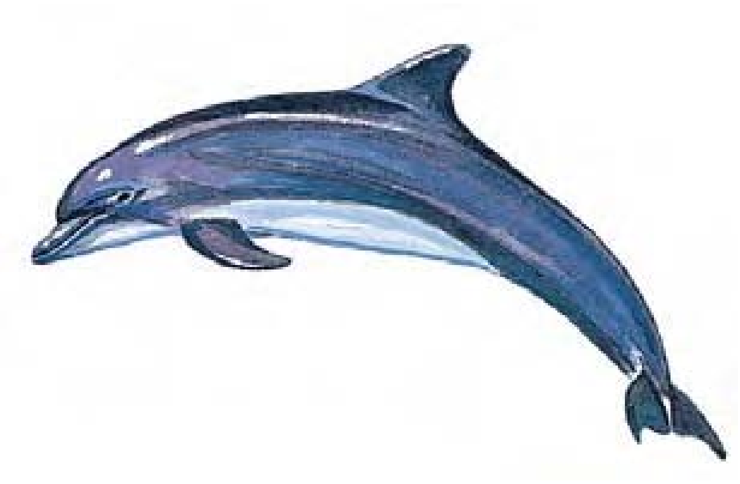
All dolphins power themselves by beating the tail up and down, and use the flippers to steer and stabilize. The flippers betray dolphins' land-mammal ancestry with their typical five-toed limb-bone structure. Dolphins have great learning ability and are popular performers in aquariums. The species most frequently seen is the bottle-nosed dolphin *Tursiops truncatus*, found in all warm seas, mainly grey in colour and growing to a maximum 4.2 m/14 ft. The US Navy began training dolphins for military purposes in 1962, and in 1987 six dolphins were sent to detect mines in the Gulf. Marine dolphins are endangered by fishing nets, speedboats, and pollution. In 1990 the North Sea states agreed to introduce legislation to protect them.

Also known as **dolphin** is the totally unrelated true fish *Coryphaena hippurus*, up to 1.5 m/5 ft long.

dolphin

Dolphins only sleep with half their brain at a time. Whilst one hemisphere goes to sleep, the other remains vigilant, with the two halves swapping over several times a night. If both sides are put to sleep artificially, the dolphin stops breathing.

dolphin



(Image © Research Machines plc)

The bottlenosed dolphin lives in groups of up to 15 individuals. There is extensive communication and cooperation between individuals. They can produce a range of clicks of various frequencies which they use for echolocation.

Bottlenose Dolphin

Go to site

Illustrated guide to the bottlenose dolphin including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

Domagk, Gerhard (1895-1964)

German pathologist who was awarded a Nobel Prize for Physiology or Medicine in 1939 for his discovery of the first antibacterial sulphonamide drug. In 1932 he found that a coal-tar dye called Prontosil red contains chemicals with powerful antibacterial properties. Sulphanilamide became the first of the sulphonamide drugs, used - before antibiotics were discovered - to treat a wide range of conditions, including pneumonia and septic wounds.

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domain

in physics, small area in a magnetic material that behaves like a tiny magnet. The magnetism of the material is due to the movement of electrons in the atoms of the domain. In an unmagnetized sample of material, the domains point in random directions, or form closed loops, so that there is no overall magnetization of the sample. In a magnetized sample, the domains are aligned so that their magnetic effects combine to produce a strong overall magnetism.

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domain

in mathematics, base set of numbers on which a function works, mapping it on to a second set (the range).

---

dominance

in genetics, the masking of one allele (an alternative form of a gene) by another allele. For example, if a heterozygous person has one allele for blue eyes and one for brown eyes, his or her eye colour will be brown. The allele for blue eyes is described as recessive and the allele for brown eyes as dominant.

For every characteristic of a plant or animal that is inherited, there are always two genes present in the cells which determine the characteristic. By 'characteristic' is meant 'height' or 'eye colour' or 'ability to make a particular enzyme'. If the two genes are identical (homozygous state) the characteristic seen in the organism is determined by either one of the two genes. However, one gene may be different from the other (heterozygous state). If so, the two genes are alleles - contrasting genes for a characteristic. In this case it is possible that one of them determines the characteristic seen and the other does not. The characteristic seen in this case is said to be dominant. The other allele, which does not contribute to the appearance of the organism in this case, will only be expressed and contribute to appearance when no dominant gene is present. This characteristic is said to be recessive.

Donald, Ian (1910-1987)

Scottish obstetrician who introduced ultrasound (very high-frequency sound wave) scanning. He pioneered its use in obstetrics as a means of scanning the growing fetus without exposure to the danger of X-rays. Donald's experience of using radar in World War II suggested to him the use of ultrasound for medical purposes.

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donkey

another name for ass.

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dopamine

neurotransmitter, hydroxytyramine $C_8H_{11}NO_2$, an intermediate in the formation of adrenaline. There are special nerve cells (neurons) in the brain that use dopamine for the transmission of nervous impulses. One such area of dopamine neurons lies in the basal ganglia, a region that controls movement. Patients suffering from the tremors of Parkinson's disease show nerve degeneration in this region. Another dopamine area lies in the limbic system, a region closely involved with emotional responses. It has been found that schizophrenic patients respond well to drugs that limit dopamine excess in this area.

Doppler effect

change in the observed frequency (or wavelength) of waves due to relative motion between the wave source and the observer. The Doppler effect is responsible for the perceived change in pitch of a siren as it approaches and then recedes, and for the red shift of light from distant galaxies. It is named after the Austrian physicist Christian Doppler.

Doppler Effect

Go to site

Discussion of the Doppler effect, including an explanation of how astronomers use it to calculate the speed with which celestial bodies are moving in relation to one another.

Dorado

constellation of the southern hemisphere, represented as a goldfish or a swordfish. It is easy to locate, since the Large Magellanic Cloud marks its southern border. Its brightest star is Alpha Doradus, just under 200 light years from Earth.

One of the most conspicuous objects in the Large Magellanic Cloud is the 'Great Looped Nebula' that surrounds 30 Doradus.

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dor beetle

oval-shaped, stout beetle measuring on average 20 mm/0.8 in, and with a metallic sheen. In general, dor beetles feed on dung, mostly of herbivorous animals.

They usually build burrows almost 50 cm/19.5 in deep under an accumulation of dung. The blind end of each burrow is sealed with a portion of dung into which the female deposits a single egg. The developing larva feeds on the dung. Both adults and larvae possess stridulating (sound-producing) organs.

classification

Dor beetles are in the family Geotrupidae (superorder Scarabaeoidea), order Coleoptera, class Insecta, phylum Arthropoda.

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dormancy

in botany, a phase of reduced physiological activity exhibited by certain buds, seeds, and spores. Dormancy can help a plant to survive unfavourable conditions, as in annual plants that pass the cold winter season as dormant seeds, and plants that form dormant buds.

For various reasons many seeds exhibit a period of dormancy even when conditions are favourable for growth. Sometimes this dormancy can be broken by artificial methods, such as penetrating the seed coat to facilitate the uptake of water (chitting) or exposing the seed to light. Other seeds require a period of after-ripening.

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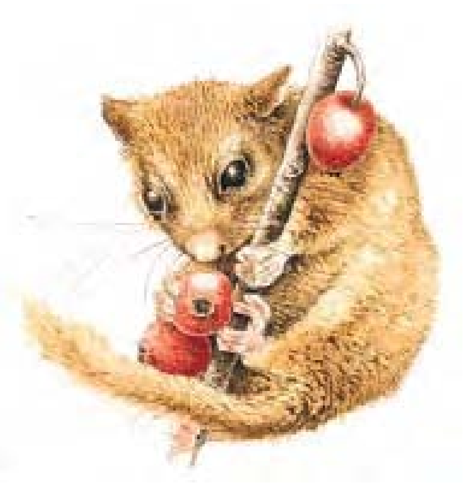
dormouse

small rodent, of the family Gliridae, with a hairy tail. There are about ten species, living in Europe, Asia, and Africa. They are arboreal (live in trees) and nocturnal, hibernating during winter in cold regions. They eat berries, nuts, pollen, and insects.

dormouse



(Image © Research Machines plc)

The 14 species of nocturnal rodents known as dormice resemble small squirrels rather than mice. Dormice feed on seeds, berries, fruits, and nuts during the summer and also store further supplies to sustain them when they wake from hibernation during the winter months. In Victorian England children kept dormice as pets. The edible, or fat, dormouse was considered a delicacy by the Romans and was fattened on walnuts.

---

dorsal

in vertebrates, the surface of the animal closest to the backbone. For most vertebrates and invertebrates this is the upper surface, or the surface furthest from the ground. For bipedal primates such as humans, where the dorsal surface faces backwards, then the word is 'back'.

Not all animals can be said to have a dorsal surface, just as many animals cannot be said to have a front; for example, jellyfish, anemones, and sponges do not have a dorsal surface.

dory

any of several marine fishes of the order Zeiformes. The American John Dory *Zenopsis ocellata*, to 2 ft/60 cm long, is deep-bodied with long spines on the dorsal and ventral fins. It lives in depths of 300 ft/90 m to 1,200 ft/365 m.

DOS

acronym for Disk Operating System

computer operating system specifically designed for use with disk storage; also used as an alternative name for a particular operating system, MS-DOS.

DOS Command Index

Go to site

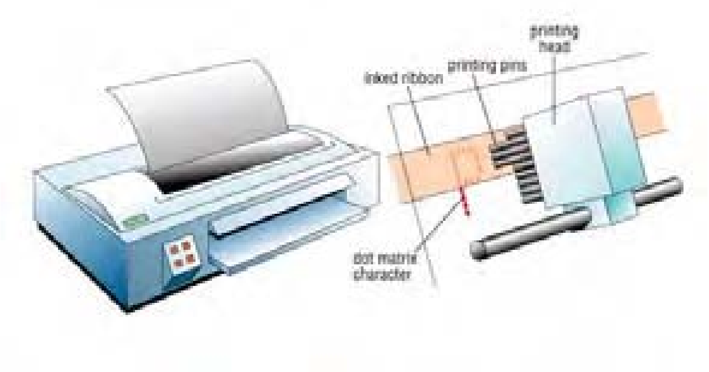
Large and detailed index of commands used in the operating system DOS.

dot matrix printer

computer printer that produces each character individually by printing a pattern, or matrix, of very small dots. The printing head consists of a vertical line or block of either 9 or 24 printing pins. As the printing head is moved from side to side across the paper, the pins are pushed forwards selectively to strike an inked ribbon and build up the dot pattern for each character on the paper beneath.

A dot matrix printer is more flexible than a daisywheel printer because it can print graphics and text in many different typefaces. It is cheaper to buy and maintain than a laser printer or ink-jet printer, and, because its pins physically strike the paper, is capable of producing carbon copies. However, it is noisy in operation and cannot produce the high-quality printing associated with the nonimpact printers.

dot matrix printer



(Image © Research Machines plc)

Impact printers, such as dot matrix printers, have largely been superseded by non-impact models. Both types of printer create images and characters through patterns of ink dots; the difference being in the method of transferring the ink to the paper.

dotterel

bird *Eudromias morinellus* of the plover family, in order Charadriiformes, nesting on high moors and tundra in Europe and Asia, and migrating south for the winter. About 23 cm/9 in long, its plumage is patterned with black, brown, and white in summer, duller in winter, but always with white eyebrows and breastband. The female is larger than the male, and mates up to five times with different partners, each time laying her eggs and leaving them in the sole care of the male, who incubates and rears the brood. Three pale-green eggs with brown markings are laid in hollows in the ground.

While the dotterel males incubate the brood, they often leave the eggs unattended for periods of between two and ten hours, in temperatures as low as 0°C, whilst they seek food. In 2000, Scottish researchers discovered that, contrary to previous belief, the eggs still hatch if their temperature has dropped to such levels during incubation, although they take longer to do so. Researchers have concluded that the embryos enter a form of suspended animation when exposed to harsh conditions.

double bond

two covalent bonds between adjacent atoms, as in the alkenes (—C═C—) and ketones (—C═O).

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double circulation

in mammals, the characteristic blood circulatory system. The heart is divided into two halves, each half working as a separate pump. One side of the heart pumps blood to the lungs and back to the heart. The other side of the heart pumps blood to all other parts of the body and back to the heart.

Deoxygenated blood – that is, blood with a reduced content of oxygen – is pumped to the lungs. Blood returning from the lungs is oxygenated – it is carrying as much oxygen as it is capable of carrying. Oxygenated blood is then pumped by the other half of the heart to all other parts of the body where oxygen is used in respiration in the body tissues. The deoxygenated blood is returned to the heart.

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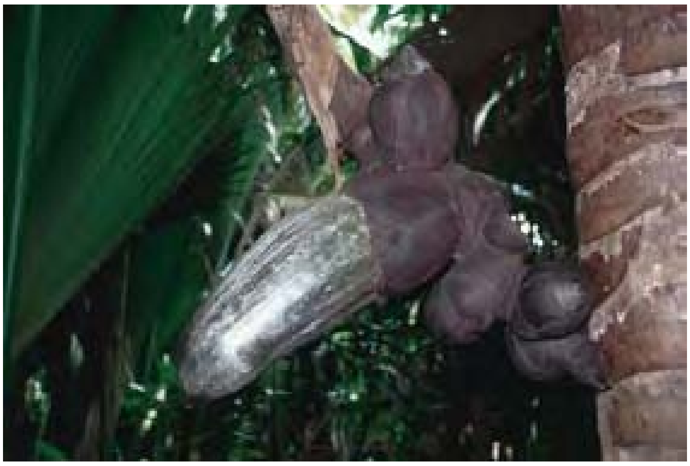
double coconut

treelike palm plant, also known as **coco de mer**, of the Seychelles. It produces a two-lobed edible nut, one of the largest known fruits. (*Lodoicea maldivica*.)

double coconut



(Image © Research Machines plc)

The male flower of the coco de mer (*Lodoicea maldivica*), also known as the double coconut or Seychelles nut palm. It grows uniquely on Praslin, the second-largest of the Seychelles islands. The fruit can weigh up to 20 kg/44 lb and contains the largest seed in the plant kingdom.

double coconut

(Image © Research Machines plc)

The female flower of the coco de mer (*Lodoicea maldivica*), also known as the double coconut or Seychelles nut palm. The Vallée de Mai, on the island of Praslin in the Seychelles, where the densest stands of these trees can be found, is a UNESCO World Heritage Site. The tree is also known as the double coconut or double nut, a reference to its strange double seed, the largest seed in the plant kingdom.

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double decomposition

reaction between two chemical substances (usually salts in solution) that results in the exchange of a constituent from each compound to create two different compounds.

For example, if silver nitrate solution is added to a solution of sodium chloride, there is an exchange of ions yielding sodium nitrate and silver chloride (which is precipitated).

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double refraction

or birefringence

in a crystal, when an unpolarized ray of light entering the crystal is split into two polarized rays, one of which does obey Snell's law of refraction, and the other does not. Calcite is such a crystal.

---

double star

pair of stars that appear close together. Many stars that appear single to the naked eye appear double when viewed through a telescope. Some double stars are physically associated: they orbit each other, forming a genuine binary star. Other double stars are at different distances from Earth, and lie in the same line of sight only by chance. Through a telescope both types look the same.

Double stars of the second kind (which are of little astronomical interest) are referred to as 'optical pairs', those of the first kind as 'physical pairs' or, more usually, 'visual binaries'. They are the principal source from which is derived our knowledge of stellar masses.

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dough

mixture consisting primarily of flour, water, and yeast, which is used in the manufacture of bread.

The preparation of dough involves thorough mixing (kneading) and standing in a warm place to 'prove' (increase in volume) so that the enzymes in the dough can break down the starch from the flour into smaller sugar molecules, which are then fermented by the yeast. This releases carbon dioxide, which causes the dough to rise.

Douglas fir

any of some six species of coniferous evergreen tree belonging to the pine family. The most common is *Pseudotsuga menziesii*, native to western North America and east Asia. It grows up to 60-90 m/200-300 ft in height, has long, flat, spirally-arranged needles and hanging cones, and produces hard, strong timber. *P. glauca* has shorter, bluish needles and grows to 30 m/100 ft in mountainous areas. (Genus *Pseudotsuga*, family Pinaceae.)

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dove

another name for pigeon.

Down's syndrome

condition caused by a chromosomal abnormality (the presence of an extra copy of chromosome 21), which in humans produces mental retardation; a flattened face; coarse, straight hair; and a fold of skin at the inner edge of the eye (hence the former name 'mongolism'). The condition can be detected by prenatal testing.

The incidence for Down's syndrome births in developed countries is one in 700 live births (2000). Mothers aged over 40 are more likely to give birth to a Down's syndrome child, and in 1995 French researchers discovered a link between Down's syndrome incidence and paternal age, with men over 40 having an increased likelihood of fathering a Down's syndrome baby.

The syndrome is named after J L H Down (1828-1896), an English physician who studied it. All people with Down's syndrome who live long enough eventually develop early-onset Alzheimer's disease, a form of dementia. This fact led to the discovery in 1991 that some forms of early-onset Alzheimer's disease are caused by a gene defect on chromosome 21.

Down's Syndrome Web Page

Go to site

Well-organized source of information about the syndrome - with articles, essays, lists of organizations worldwide, toy catalogues, the 'Brag Book' photo gallery, and links to other helpful Web sites.

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dowsing

ascertaining the presence of water or minerals beneath the ground with a forked twig or a pendulum. Unconscious muscular action by the dowser is thought to move the twig, usually held with one fork in each hand, possibly in response to a local change in the pattern of electrical forces. The ability has been known since at least the 16th century and, though not widely recognized by science, it has been used commercially and in archaeology.

Draco

large but faint constellation represented as a dragon coiled around the north celestial pole. Due to precession (Earth's axial wobble), the star Alpha Draconis (Thuban) was the pole star 4,700 years ago.

This star seems to have faded, for it is no longer the brightest star in the constellation as it was at the beginning of the 17th century. Gamma Draconis is more than a magnitude brighter. The latter was extensively observed in the early 18th century by English astronomer James Bradley, who from its apparent changes in position discovered the aberration of starlight and nutation.

The north pole of the ecliptic - the point around which the north celestial pole circles in its precessional motion - lies in Draco.

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drag

resistance to motion a body experiences when passing through a fluid - gas or liquid. The aerodynamic drag aircraft experience when travelling through the air represents a great waste of power, so they must be carefully shaped, or streamlined, to reduce drag to a minimum. Cars benefit from streamlining, and aerodynamic drag is used to slow down spacecraft returning from space. Boats travelling through water experience hydrodynamic drag on their hulls, and the fastest vessels are hydrofoils, whose hulls lift out of the water while cruising.

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dragon

name popularly given to various sorts of lizard. These include the flying dragon*Draco volans* of southeast Asia; the komodo dragon *Varanus komodoensis* of Indonesia, at over 3 m/10 ft the largest living lizard; and some Australian lizards with bizarre spines or frills.

---

dragonfly

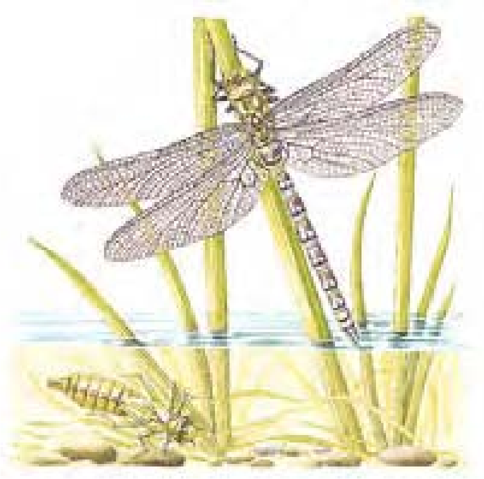
any of numerous insects of the order Odonata, including the damselfly. They all have long narrow bodies, two pairs of almost equal-sized, glassy wings with a network of veins; short, bristlelike antennae; powerful, 'toothed' mouthparts; and very large compound eyes which may have up to 30,000 facets. They can fly at speeds of up to 64-96 kph/40-60 mph.

Dragonflies hunt other insects by sight, both as adults and as aquatic nymphs. The largest species have a wingspan of 18 cm/7 in, but fossils related to dragonflies have been found with wings of up to 70 cm/2.3 ft across.

dragonfly

The male dragonfly *Calopteryx maculata* has a scoop-shaped penis for removing the sperm of other males from a female before he mates with her. Other dragonflies can inflate a lobe at the penis tip to compress sperm from earlier matings. This is important as only the sperm at the top of the female's spermathecae is successful in fertilizing the female.

dragonfly



(Image © Research Machines plc)

Adult dragonflies are long, comparatively slim-bodied insects with two pairs of wings. During the Upper Carboniferous period a giant, dragonflylike insect, Meganeura, had a wingspan of up to 70 cm/28 in. After mating, the female dragonfly lays her egg on a submerged plant stem, in mud, or directly into the water. The egg hatches into a nymph that takes about a year to mature; it is a voracious predator that will even attack small fishes.

DRAM

acronym for Dynamic Random-Access Memory

computer memory device in the form of a silicon chip commonly used to provide the immediate-access memory of microcomputers. DRAM loses its contents unless they are read and rewritten every 2 milliseconds or so. This process is called **refreshing** the memory. DRAM is slower but cheaper than SRAM, an alternative form of silicon-chip memory.

---

dream

series of events or images perceived through the mind during sleep. Their function is unknown, but Sigmund Freud saw them as wish fulfilment (nightmares being failed dreams prompted by fears of 'repressed' impulses). Dreams occur in periods of rapid eye movement (REM) by the sleeper, when the cortex of the brain is approximately as active as in waking hours. Dreams occupy about a fifth of sleeping time.

If a high level of acetylcholine (chemical responsible for transmission of nerve impulses) is present, dreams occur too early in sleep, causing wakefulness, confusion, and depression, which suggests that a form of memory search is involved. Prevention of dreaming, by taking sleeping pills, for example, has similar unpleasant results. For the purposes of (allegedly) foretelling the future, dreams fell into disrepute in the scientific atmosphere of the 18th century.

---

drill

large Old World monkey *Mandrillus leucophaeus* similar to a baboon and in the same genus as the mandrill. Drills live in the forests of Cameroon and Nigeria. Brownish-coated, black-faced, and stoutly built, with a very short tail, the male can have a head and body up to 75 cm/2.5 ft long, although females are much smaller.

---

drilling

common woodworking and metal machinery process that involves boring holes with a drill bit. The commonest kind of drill bit is the fluted drill, which has spiral grooves around it to allow the cut material to escape. In the oil industry, rotary drilling is used to bore oil wells. The drill bit usually consists of a number of toothed cutting wheels, which grind their way through the rock as the drill pipe is turned, and mud is pumped through the pipe to lubricate the bit and flush the ground-up rock to the surface.

In rotary drilling, a drill bit is fixed to the end of a length of drill pipe and rotated by a turning mechanism, the rotary table. More lengths of pipe are added as the hole deepens. The long drill pipes are handled by lifting gear in a steel tower or derrick.

---

driver

in computing, a program that controls a peripheral device. Every device connected to the computer needs a driver program. The driver ensures that communication between the computer and the device is successful.

For example, it is often possible to connect many different types of printer, each with its own special operating codes, to the same type of computer. This is because driver programs are supplied to translate the computer's standard printing commands into the special commands needed for each printer.

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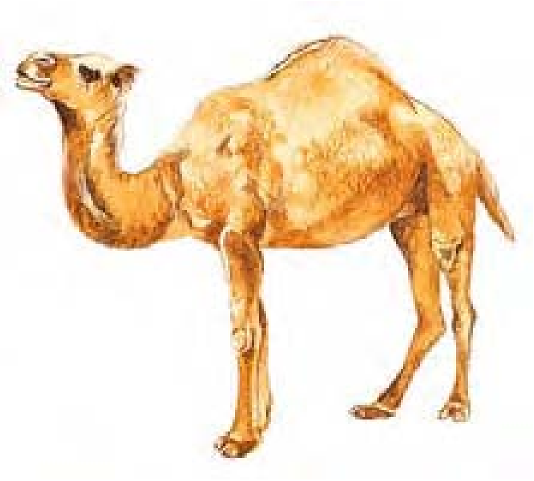
dromedary

variety of Arabian camel. The dromedary or one-humped camel has been domesticated since 400 BC. During a long period without water, it can lose up to one-quarter of its body weight without ill effects.

The dromedary's long domestication means that its original range is not known. It is used throughout Arabia and North Africa, and has been taken to other places such as North America and Australia, in the latter country playing a crucial part in the development of the interior. While the dromedary is a lightly-built variety of the Arabian camel, and the name is often applied to all one-humped camels. They can be used as pack animals, for riding, racing, milk production, and for meat.

dromedary



(Image © Research Machines plc)

The dromedary is superbly adapted for life in hot, dry climates. It can go for long periods without drinking, and its body conserves moisture.

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drug

any of a range of substances, natural or synthetic, administered to humans and animals as therapeutic agents: to diagnose, prevent, or treat disease, or to assist recovery from injury. Traditionally many drugs were obtained from plants or animals; some minerals also had medicinal value. Today, increasing numbers of drugs are synthesized in the laboratory. It is useful to categorize drugs used by humans into three groups: over-the-counter and prescription drugs (medicines) such as paracetamol and penicillin; recreational drugs such as alcohol and nicotine; and the drugs which are taken illegally if they are not prescribed, such as amphetamines, cannabis, and cocaine.

Drugs are administered in various ways, including orally, by injection, as a lotion or ointment, as a pessary, by inhalation, or by transdermal patch.

One of the first scientific investigations of the effect of a drug on the human body was of digitalis. Digitalis is a mixture of drugs from the foxglove (*Digitalis purpurea*). Its effect is to increase the force of contraction of heart muscle. It is still used to help treat a number of heart problems, such as heart failure.

Drugs prescribed by doctors may have unwanted side effects. Side effects are normally slight, but overdoses and mixing with other drugs can make the side effects worse. These effects can be dangerous. Paracetamol reduces pain, but in large doses it is poisonous and can kill.

Some drugs can become addictive (see addiction). The most commonly used addictive drug is nicotine. Regular smokers find that the addiction causes it to be very difficult or impossible to give up smoking even though they try. Even more dangerous than nicotine are some mind-affecting addictive drugs. The illegal drugs cocaine and crack are addictive and users find that they have to take more of the drug to get the same effect once they are addicted. Large doses of these drugs can kill.

Common drugs derived from plants

Many of these plants are poisonous and if swallowed can cause serious illness or unconsciousness. They should only be used if administered by a medically trained professional.

Plant	Drug	Use
Amazonian liana	curare	muscle relaxant
Annual mugwort	artemisinin	antimalarial
Autumn crocus	colchicine	antitumour agent

Camphor tree	camphor	rubefacient; used in insect repellents and medicinal inhalants and liniments
Coca	cocaine	local anaesthetic
Common thyme	thymol	antifungal
Deadly nightshade (belladonna)	atropine	anticholinergic
Dog button (nux-vomica)	strychnine	central nervous system stimulant
Ergot fungus	ergotamine	analgesic
Foxglove	digitoxin, digitalis	cardiotonic
Indian snakeroot	reserpine	antihypertensive
Meadowsweet	salicylate	analgesic
Mexican yam	diosgenin	birth control pill
Mint, peppermint	menthol	rubefacient
Opium poppy	codeine, morphine	analgesic (codeine is also antitussive)
Pacific yew	taxol	antitumour agent
Recured thornapple	scopolamine	sedative
Rosy periwinkle	vincristine, vinblastine	antileukaemia
Tea, coffee, and kola nuts	caffeine	central nervous system stimulant
Velvet bean	L-dopa	antiparkinsonian
White willow	salicylic acid	topical analgesic
Yellow cinchona	quinine	antimalarial, antipyretic

Drugs

Go to site

Split into four stages, this page deals with two main areas: 'Introduction to drugs' and 'Drugs and their effects'. Stage one lists the key topics, for quick revision, and stage two is a detailed guide through them. Stage three contains questions, while stage four is a glossary with all the important key terms. A colourful and easy-to-use site, it also includes further links to other biology topics.

Internet Drug Index

Go to site

Online list of prescription and non-prescription drugs, with a search engine to help find specific types or products and access to information about indications and side effects too.

Molecular Expressions: The Pharmaceutical Collection

Go to site

Fascinating collection of images showing what over 100 drugs look like when recrystallized and photographed through a microscope.

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drug abuse

abuse of narcotic and hallucinogenic substances and stimulants.

They are classified generally as (1) most harmful: heroin, morphine, opium, and other narcotics; cocaine, a powerful, dangerous stimulant and its relative, crack; hallucinogens, such as mescalin and LSD; and injectable amphetamines, such as methedrine; (2) less harmful: narcotics such as codeine and cannabis (marijuana); stimulants of the amphetamine type, such as Benzedrine; and barbiturate sedatives; and (3) least harmful: milder drugs of the amphetamine type. 'Designer drugs', for example ecstasy, are usually modifications of the amphetamine molecule, altered in order to evade the law as well as for different effects, and may be many times more powerful and dangerous. Crack, for example, became available to drug users in the 1980s.

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drug and alcohol dependence

physical or psychological craving for addictive drugs such as alcohol, nicotine, narcotics, tranquillizers, or stimulants (for example, amphetamines). Such substances can alter mood or behaviour. When dependence is established, sudden withdrawal from the drug can cause unpleasant physical and/or psychological reactions, which may be dangerous. See also addiction and alcoholism.

Alcohol Concern

Go to site

Huge resource addressing many of the problems surrounding alcohol abuse. Fact sheets and information are available, as well as the latest news on alcohol abuse.

Institute for the Study of Drug Dependence (ISDD)

Go to site

Aiming to advance 'knowledge, understanding, and policy-making about drugs', this site from the ISDD contains an online drug encyclopedia and a 'Frequently Asked Questions' section that tackles many of the main issues.

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drug, generic

any drug produced without a brand name that is identical to a branded product. Usually generic drugs are produced when the patent on a branded drug has expired, and are cheaper than their branded equivalents.

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drupe

fleshy fruit containing one or more seeds which are surrounded by a hard, protective layer – for example cherry, almond, and plum. The wall of the fruit (pericarp) is differentiated into the outer skin (exocarp), the fleshy layer of tissues (mesocarp), and the hard layer surrounding the seed (endocarp).

The coconut is a drupe, but here the pericarp becomes dry and fibrous at maturity. Blackberries are an aggregate fruit composed of a cluster of small drupes.

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dry-cleaning

method of cleaning textiles based on the use of volatile solvents, such as trichloroethene (trichloroethylene), that dissolve grease. No water is used. Dry-cleaning was first developed in France in 1849.

Some solvents are known to damage the ozone layer and one, tetrachloroethene (perchloroethylene), is toxic in water and gives off toxic fumes when heated.

---

dry ice

solid carbon dioxide (CO_2), used as a refrigerant. At temperatures above -79°C/-110.2°F, it sublimes (turns into vapour without passing through a liquid stage) to gaseous carbon dioxide.

Water vapour in the air cooled by the evaporating carbon dioxide condenses to a visible mist, which is often used in the theatre.

---

dry rot

infection of timber in damp conditions by fungi (see fungus), such as *Merulius lacrymans*, that form a threadlike surface. Whitish at first, the fungus later reddens as reproductive spores are formed. Tentacles from the fungus also work their way into the timber, making it dry-looking and brittle. Dry rot spreads rapidly through a building.

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dry valley

valley without a river at its bottom. Such valleys are common on the dip slopes of chalk escarpments, and were probably formed by rivers. However, chalk is permeable (water passes through it) and so cannot retain surface water. Two popular theories have arisen to explain how this might have happened: 1) During the last ice age the chalk might have frozen and been rendered impermeable. During the summer thaw, water would then have flowed over the land, unable to sink into it, and river valleys would have been formed. When, after the ice age, the chalk thawed and became permeable again, rivers could no longer flow along the valleys and so these became dry. 2) At the end of the last ice age so much meltwater might have been created that the water table would be far higher than it is today. This would have enabled water to flow over the chalk surface without being absorbed, and create valleys. As the water table fell with time, however, water passed through the chalk once more and the valleys became dry. Good examples include Devil's Dyke, Fulking, England, and the Vale of the White Horse, Oxfordshire, England.

DTP

abbreviation for desktop publishing.

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dubnium

chemical symbol Db

synthesized, radioactive, metallic element of the transactinide series, atomic number 105, relative atomic mass 261. Six isotopes have been synthesized, each with very short (fractions of a second) half-lives. Two institutions claim to have been the first to produce it: the Joint Institute for Nuclear Research in Dubna, Russia, in 1967; and the University of California at Berkeley, USA, who disputed the Soviet claim in

1970. It was known by the temporary name unnilpentium until 1997.

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duck

any of about 50 species of short-legged waterbirds with webbed feet and flattened bills, of the family Anatidae, order Anseriformes, which also includes the larger geese and swans. Ducks were domesticated for eggs, meat, and feathers by the ancient Chinese and the ancient Maya (see poultry). Most ducks live in fresh water, feeding on worms and insects as well as vegetable matter. They are generally divided into dabbling ducks and diving ducks.

anatomy

The three front toes of a duck's foot are webbed and the hind toe is free; the legs are scaly. The broad rounded bill is skin-covered with a horny tip provided with little plates (lamellae) through which the duck is able to strain its food from water and mud.

species of duck

The mallard *Anas platyrhynchos*, 58 cm/1.9 ft, found over most of the northern hemisphere, is the species from which all domesticated ducks originated. The male (drake) has a glossy green head, brown breast, grey body, and yellow bill. The female (duck) is speckled brown, with a duller bill. The male moults and resembles the female for a while just after the breeding season. There are many other species of duck including teal, eider, mandarin duck, merganser, muscovy duck, pintail duck, shelduck, and shoveler. They have different-shaped bills according to their diet and habitat; for example, the shoveler has a wide spade-shaped bill for scooping insects off the surface of water.

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duck-billed platypus

another name for the platypus.

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duckweed

any of a family of tiny plants found floating on the surface of still water throughout most of the world, except the polar regions and tropics. Each plant consists of a flat, circular, leaflike structure 0.4 cm/0.15 in or less across, with a single thin root up to 15 cm/6 in long below. (Genus chiefly *Lemna*, family Lemnaceae.)

The plants bud off new individuals and soon cover the surface of the water. Flowers rarely appear, but when they do, they are extremely small and are found in a pocket at the edge of the plant.

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ductless gland

alternative name for an endocrine gland.

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dugong

marine mammal *Dugong dugong* of the order Sirenia (sea cows), found in the Red Sea, the Indian Ocean, and western Pacific Ocean. It can grow to 3.6 m/11 ft long, and has a tapering body with a notched tail and two fore-flippers. All dugongs are listed on the Convention on International Trade in Endangered Species (CITES) Appendix 1, which bans all trade in the species.

The addition of dugongs to CITES Appendix 1 followed a decision made in May 2000 to add Australia's coastal dugongs to the list despite the fact that they are not endangered, to facilitate protection of other dugong populations.

The dugong has a very long hind gut (30 m/98 ft in adults) which functions similarly to the rumen in ruminants. It feeds mostly on sea grasses and seaweeds, and is thought to have given rise to the mermaid myth. The dugong was thought to be the only truly herbivorous marine mammal until Australian research in 1995 showed that some eat sea squirts. These invertebrate creatures were shown to make up 25.5% of the wet weight of faeces from dugongs in Moreton Bay, eastern Australia.

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duiker

(Afrikaans diver)

any of several antelopes of the family Bovidae, common in Africa. Duikers are shy and nocturnal, and grow to 30-70 cm/12-28 in tall.

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duikerbok

small African antelope with crested head, large muzzle, and short, conical horns in the males only.

classification

Duikerboks are in genus *Cephalophus* in the family Bovidae (cattle and antelopes) of order Artiodactyla.

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dulse

any of several edible red seaweeds, especially *Rhodymenia palmata*, found on middle and lower shores of the north Atlantic. They may have a single broad blade up to 30 cm/12 in long rising directly from the holdfast which attaches them to the sea floor, or may be palmate (with five lobes) or fan-shaped. The frond is tough and dark red, sometimes with additional small leaflets at the edge.

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dump

in computing, the process of rapidly transferring data to external memory or to a printer. It is usually done to help with debugging (see bug) or as part of an error-recovery procedure designed to provide data security. A screen dump makes a printed copy of the current screen display.

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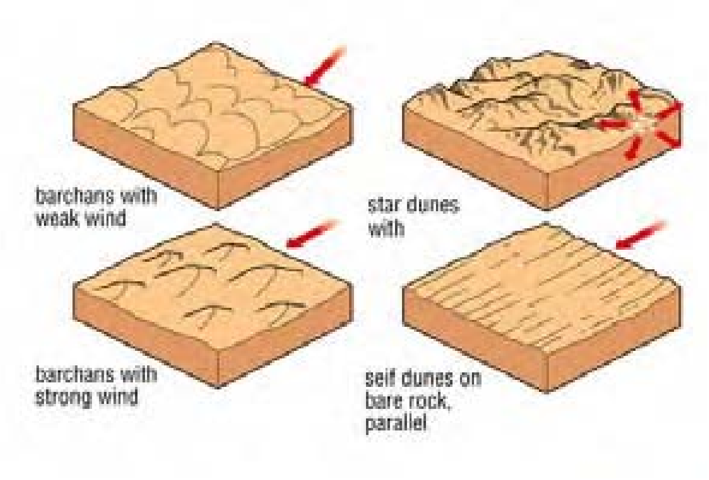
dune

mound or ridge of wind-drifted sand, common on coasts and in deserts. Loose sand is blown and bounced along by the wind, up the windward side of a dune (saltation). The sand particles then fall to rest on the lee side, while more are blown up from the windward side. In this way a dune moves gradually downwind. Dunes occur in areas where there is a large supply of sand, strong winds, low rainfall, and some vegetation or obstructions to trap the sand.

In sandy deserts, the typical crescent-shaped dune is called a **barchan**.
Seif dunes are longitudinal and lie parallel to the wind direction, and **star-shaped dunes** are formed by irregular winds.

dune



(Image © Research Machines plc)

The shape of a dune indicates the prevailing wind pattern. Crescent-shaped dunes form in sandy desert with winds from a constant direction. Seif dunes form on bare rocks, parallel to the wind direction. Irregular star dunes are formed by variable winds.

dune

NO FIRES BARBECUES PLEASE

(Image © Garret Nagle)

A sign requests visitors to refrain from lighting fires or having barbecues on the sand dunes. The ecosystem of the beach can be easily disrupted by fire. Fire destroys the vegetation, which can take up to 50 years to recover. Part of the site has been fenced off, to prevent people from walking over it and thus preserve the dunes.

dunlin

small gregarious shore bird *Calidris alpina* of the sandpiper family Scolopacidae, order Charadriformes, about 18 cm/7 in long, nesting on moors and marshes in the far northern regions of Eurasia and North America. Chestnut above and black below in summer, it is greyish in winter; the bill and feet are black.

dunnock

or hedge sparrow

European bird *Prunella modularis* family Prunellidae, similar in size and colouring to the sparrow, but with a slate-grey head and breast, and more slender bill. It is characterized in the field by a hopping gait, with continual twitches of the wings whilst feeding. It nests in bushes and hedges.

duodecimal system

system of arithmetic notation using 12 as a base, at one time considered superior to the decimal number system in that 12 has more factors (2, 3, 4, 6) than 10 (2, 5).

It is now superseded by the universally accepted decimal system.

duodenum

in vertebrates, a short length of alimentary canal found between the stomach and the small intestine. Its role is in digesting carbohydrates, fats, and proteins. The smaller molecules formed are then absorbed, either by the duodenum or the ileum.

Entry of food to the duodenum is controlled by the pyloric sphincter, a muscular ring at the outlet of the stomach. Once food has passed into the duodenum it is mixed with bile released from the gall bladder and with a range of enzymes secreted from the pancreas, a digestive gland near the top of the intestine. The bile neutralizes the acidity of the gastric juices passing out of the stomach and aids fat digestion.

duralumin

lightweight aluminium alloy widely used in aircraft construction, containing copper, magnesium, and manganese.

durra

or doura

grass, also known as Indian millet, grown as a cereal in parts of Asia and Africa. *Sorghum vulgare* is the chief cereal in many parts of Africa. See also sorghum. (Genus *Sorghum*.)

Durrell, Gerald (Malcolm) (1925-1995)

English naturalist, writer, and zoo curator. He became director of Jersey Zoological Park in 1958, and wrote 37 books, including the humorous memoir *My Family and Other Animals* (1956). He was the brother of the writer Lawrence Durrell.

Durrell was born in Jamshedpur, India, and spent part of his childhood in Corfu, Greece, where he set up his own childhood zoo of scorpions, lizards, and eagle owls. Critical of the conditions in which most zoos kept animals, the lack of interest in breeding programmes, and the concentration on large species, such as the big cats, rhinos, and elephants, Durrell became determined to build up his own zoo, and to run it so that it could supplement conservation programmes in the wild rather than detract from them. He finally settled in Jersey, where he founded the Jersey Zoological Park. Through his work in conservation - within his zoo and as chair of the Flora and Fauna Preservation Society - and perhaps more particularly his many books and television programmes, Durrell encouraged and inspired a whole generation of naturalists, zoologists, and zoo keepers.

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dust bowl

area in the Great Plains region of North America (Texas to Kansas) that suffered extensive wind erosion as the result of drought and poor farming practice in once-fertile soil. Much of the topsoil was blown away in the droughts of the 1930s and the 1980s.

Similar dust bowls are being formed in many areas today, noticeably across Africa, because of overcropping and overgrazing.

Dust Bowl

Go to site

Historical information on the US mid-West dust bowl of the 1930s. The site features period photographs and an MPG video clip of a dust storm taken from original film footage (please beware the lengthy download time for this clip).

Dutch elm disease

disease of elm trees *Ulmus*, principally Dutch, English, and American elm, caused by the fungus *Certocystis ulmi*. The fungus is usually spread from tree to tree by the elm-bark beetle, which lays its eggs beneath the bark. The disease has no cure, and control methods involve injecting insecticide into the trees annually to prevent infection, or the destruction of all elms in a broad band around an infected area, to keep the beetles out.

The disease was first described in the Netherlands and by the early 1930s had spread across Britain and continental Europe, as well as North America.

DVD-ROM

disk format for storing digital information, the DVD equivalent of CD-ROM. Launched in 1997, DVD-ROM disks can store up to 17 gigabytes of data, compared to only 700 megabytes on a CD-ROM. DVD-ROM drives, which are also able to read CD-ROM disks, have a much faster speed of data transfer than CD-ROM drives (a 16× DVD-ROM drive is the equivalent of a 144× CD-ROM drive, with a data transfer rate of 177.28 megabits per second).

As with CD-ROM, there are recordable versions of DVD-ROM, where DVD-R and DVD+R disks can be written to once only, and DVD-RAM, DVD-RW, and DVD+RW can be overwritten. The three rewritable formats are not fully compatible with each other, although 'DVD Multi' drives can read from and record to disks in the DVD-R, DVD-RW, and DVD-RAM formats. 'Super combo' drives can handle DVD-R, DVD-RW, DVD+R, and DVD+RW disks, while 'super multi' drives can read from and write to disks in all five recordable formats.

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dye

substance that, applied in solution to fabrics, stains with a permanent colour. Different types of dye are needed for different types of fibres.
Direct dyes combine with cellulose-based fabrics like cotton, linen, and rayon, to colour the fibres.
Indirect dyes require the presence of another substance (a mordant), with which the fabric must first be treated, to ensure that the dye will remain 'fast' during washing.
Vat dyes are colourless soluble substances that on exposure to air yield an insoluble coloured compound that is resistant to water.

Naturally occurring dyes include indigo and madder (alizarin), which are extracted from plants; logwood, produced from wood; and cochineal, a red dye made from crushed insects. Industrial dyes are usually synthetic and are derived from coal or petroleum. English chemist William Perkin developed the first synthetic dye, mauve, in 1856 and by the early 20th century a wide range of synthetic dyes was available.

Properties of dyes

dye type	characteristics

Natural dyes	
cochineal, lac	red dyes made from crushed insects; cochineal is used in food colouring
woad, indigo	blue or purple dye extracted from plants; also made synthetically
madder	red dye extracted from plants; also synthesized
saffron, safflower, annatto	yellow dyes extracted from plants; annatto is used in food colouring
logwood	black dye extracted from wood
Tyrian purple	purple dye extracted from molluscs; used for Roman emperors' togas
Synthetic dyes	
basic dyes (for example, mauveine)	low fastness on most materials (that is, they tend to run and fade), but used for acrylics
acid dyes (for example, naphthol green	used on protein fibres such as wool and silk
direct dyes (for example, Congo red)	cheap and moderately fast
dispersed dyes	used for synthetic fibres that are difficult to dye with direct dyes
developed dyes (for example, azo dyes)	cheap and very fast; used for printed fabrics
fibre-reactive dyes	very fast to wash in and light, medium-priced, and easy to use; wide range of colours

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dye-transfer print

in photography, a print made by a relatively permanent colour process that uses red, yellow, and blue separation negatives printed together.

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dyke

in earth science, a sheet of igneous rock created by the intrusion of magma (molten rock) across layers of pre-existing rock. (By contrast, a sill is intruded *between* layers of rock.) It may form a ridge when exposed on the surface if it is more resistant than the rock into which it intruded. A dyke is also a human-made embankment built along a coastline (for example, in the Netherlands) to prevent the flooding of lowland coastal regions.

Dynamic HTML

in computing, the fourth version of hypertext markup language (HTML), the language used to create Web pages. It is called Dynamic HTML because it enables dynamic effects to be incorporated in pages without the delays involved in downloading Java applets and without referring back to the server.

Welcome to DHTML School

Go to site

Dedicated to Dynamic HTML, an advanced programming language for the Internet, this site offers a Dynamic HTML tutorial, a selection of articles, a number of demonstrations, and sections on Cascading Style Sheets (CSS).

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dynamics

or kinetics

in mechanics, the mathematical and physical study of the behaviour of bodies under the action of forces that produce changes of motion in them.

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dynamite

explosive consisting of a mixture of nitroglycerine and diatomaceous earth (diatomite, an absorbent, chalklike material). It was first devised by Alfred Nobel.

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dynamo

former name for a generator.

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dyne

symbol dyn

c.g.s. unit of force. 10^5 dynes make one newton. The dyne is defined as the force that will accelerate a mass of one gram by one centimetre per second per second.

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dyscalculia

disability demonstrated by a poor aptitude with figures. A similar disability in reading and writing is called dyslexia.

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dysentery

infection of the large intestine causing abdominal cramps and painful diarrhoea with blood. There are two kinds of dysentery: **amoebic** (caused by a protozoan), common in the tropics, which may lead to liver damage; and **bacterial**, the kind most often seen in the temperate zones.

Both forms are successfully treated with antibacterials and fluids to prevent dehydration.

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dyslexia

(Greek 'bad', 'pertaining to words')

malfunction in the brain's synthesis and interpretation of written information, popularly known as 'word blindness'.

Dyslexia may be described as specific or developmental to distinguish it from reading or writing difficulties which are acquired. It results in poor ability in reading and writing, though the person may excel in other areas, for example, in mathematics. A similar disability with figures is called **dyscalculia**. **Acquired dyslexia** may occur as a result of brain injury or disease.

British Dyslexia Association

Go to site

Huge source of practical information on dyslexia for adult sufferers and parents and teachers of dyslexic children. All aspects of dyslexia, from identifying the condition in toddlers to computer software for dyslexics, are covered by this informative site. There is information about UK support groups and other resources.

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dysmenorrhoea

in medicine, pain during menstruation. Dysmenorrhoea is fairly common during adolescents and it may be due to excessive production of prostaglandins which mediate pain. Psychological factors are sometimes important. In older women, inflammation of the womb, ovaries and Fallopian tubes can result in dysmenorrhoea. Symptoms of dysmenorrhoea include pain in the pelvis, groin, thighs, and lower back. Other symptoms are headache, backache, general lassitude, and irritability. Analgesics and rest can relieve the pain in the majority of women.

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dyspepsia

another word for indigestion.

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dysphagia

difficulty in swallowing. It may be due to infection, obstruction, spasm in the throat or oesophagus (gullet), or neurological disease or damage.

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dyspnoea

difficulty in breathing, or shortness of breath disproportionate to effort. It is mostly caused by circulatory or respiratory diseases.

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dysprosium

chemical symbol Dy

(Greek dusprositos 'difficult to get near')

silver-white, metallic element of the lanthanide series, atomic number 66, relative atomic mass 162.50. It is among the most magnetic of all known substances and has a great capacity to absorb neutrons.

It was discovered in 1886 by French chemist Paul Lecoq de Boisbaudran (1838-1912).

E

abbreviation for **east**.

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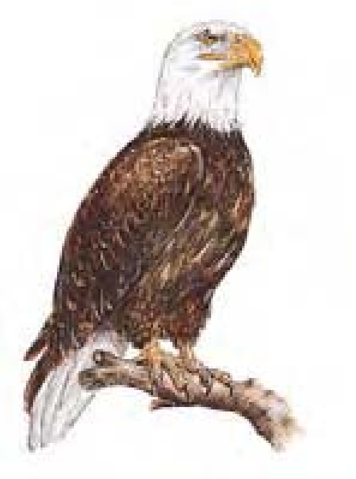
eagle

any of several genera of large birds of prey of the family Accipitridae, order Falconiformes, including the golden eagle *Aquila chrysaetos* of Eurasia and North America, which has a 2 m/6 ft wingspan. Eagles occur worldwide, usually building eyries or nests in forests or mountains, and all are fierce and powerful birds of prey. The harpy eagle is the largest eagle.

The white-headed bald eagle *Haliaetus leucocephalus* is the symbol of the USA; rendered infertile through the ingestion of agricultural chemicals, it is now rare, except in Alaska.

Another endangered species is the Philippine eagle, sometimes called the Philippine monkey-eating eagle (although its main prey is the flying lemur). Loss of large tracts of forest, coupled with hunting by humans, have greatly reduced its numbers.

eagle



(Image © Research Machines plc)

The bald eagle of North America lives along coasts, rivers, and lakes, where food is plentiful. During the mating season, couples indulge in spectacular courtship displays in which male and female birds lock talons in midair and somersault downwards together.

eagle

(Image © Corel)

A white-headed bald eagle *Haliaetus leucocephalus*, the emblem of the USA.

Bald Eagle

Go to site

Illustrated guide to the bald eagle including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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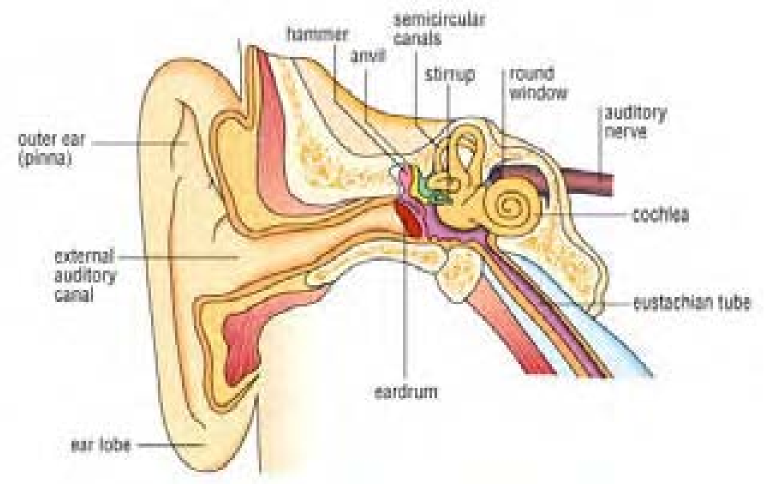
ear

organ of hearing in animals. It responds to the vibrations that constitute sound, which are translated into nerve signals and passed to the brain. A mammal's ear consists of three parts: outer ear, middle ear, and inner ear. The **outer ear** is a funnel that collects sound, directing it down a tube to the **eardrum** (tympanic membrane), which separates the outer and **middle ear**. Sounds vibrate this membrane, the mechanical movement of which is transferred to a smaller membrane leading to the **inner ear** by three small bones, the auditory ossicles. Vibrations of the inner ear membrane move fluid contained in the spiral-shaped cochlea, which vibrates hair cells that stimulate the auditory nerve connected to the brain. There are approximately 30,000 sensory hair cells (**stereocilia**). Exposure to loud noise and the process of ageing damages the stereocilia, resulting in hearing loss. Three fluid-filled canals of the inner ear detect changes of position; this mechanism, with other sensory inputs, is responsible for the sense of balance.

When a loud noise occurs, muscles behind the eardrum contract automatically, suppressing the noise to enhance perception of sound and prevent injury.

ear



(Image © Research Machines plc)

The structure of the ear. The three bones of the middle ear – hammer, anvil, and stirrup – vibrate in unison and magnify sounds about 20 times. The spiral-shaped cochlea is the organ of hearing. As sound waves pass down the spiral tube, they vibrate fine hairs lining the tube, which activate the auditory nerve connected to the brain. The semicircular canals are the organs of balance, detecting movements of the head.

Locating a Mouse by its Sound

Go to site

As part of a much larger site called 'Seeing, Hearing, and Smelling the World', here is a page examining the way we can locate objects through sound alone. It is divided into four sections called 'A brain map of auditory space', 'The value of having two ears', 'Bat sounds and human speech', and 'On the trail of a deafness gene'. This site makes good use of images and animations to help with the explanations, so it is best viewed with an up-to-date browser.

Quivering Bundles That Let Us Hear

Go to site

As part of a much larger site called 'Seeing, Hearing, and Smelling the World', here is a page examining the way our ears work. It is divided into four sections called 'Signals from a hair cell', 'The goal: extreme sensitivity and speed', 'Tip links pull up the gates', and 'On the trail of a deafness gene'. This site makes good use of images and animations to help with the explanations, so it is best viewed with an up-to-date browser.

Earth

third planet from the Sun. It is almost spherical, flattened slightly at the poles, and is composed of five concentric layers: inner core, outer core, mantle, crust, and atmosphere. About 70% of the surface (including the north and south polar ice caps) is covered with water. The Earth is surrounded by a life-supporting atmosphere and is the only planet on which life is known to exist.

mean distance from the Sun

149,500,000 km/92,860,000 mi

equatorial diameter

12,755 km/7,920 mi

circumference

40,070 km/24,900 mi

rotation period

23 hours 56 minutes 4.1 seconds

year

(complete orbit, or sidereal period) 365 days 5 hours 48 minutes 46 seconds. The Earth's average speed around the Sun is 30 kps/18.5 mps. The plane of its orbit is inclined to its equatorial plane at an angle of 23.5°; this is the reason for the changing seasons

atmosphere

nitrogen 78.09%; oxygen 20.95%; argon 0.93%; carbon dioxide 0.03%; and less than 0.0001% neon, helium, krypton, hydrogen, xenon, ozone, and radon

surface

land surface 150,000,000 sq km/57,500,000 sq mi (greatest height above sea level 8,872 m/29,118 ft Mount Everest); water surface 361,000,000 sq km/139,400,000 sq mi (greatest depth 11,034 m/36,201 ft Mariana Trench in the Pacific). The interior is thought to be an inner core about 2,600 km/1,600 mi in diameter, of solid iron and nickel; an outer core about 2,250 km/1,400 mi thick, of molten iron and nickel; and a mantle of mostly solid rock about 2,900 km/1,800 mi thick. The crust and the uppermost layer of the mantle form about twelve major moving plates, some of which carry the continents. The plates are in constant, slow motion, called tectonic drift

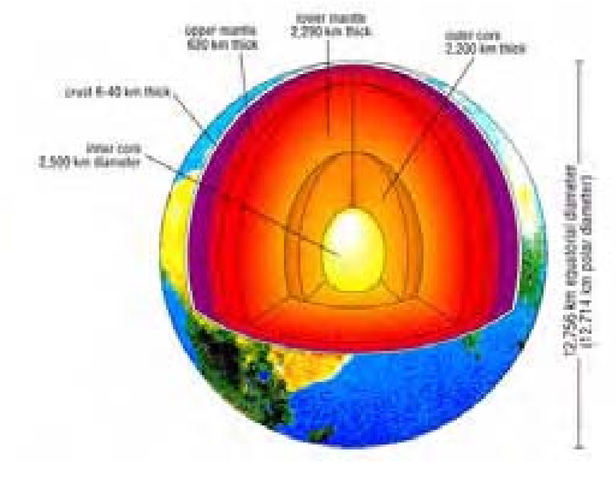
satellite

the Moon

age

4.6 billion years. The Earth was formed with the rest of the Solar System by consolidation of interstellar dust. Life began 3.5-4 billion years ago.

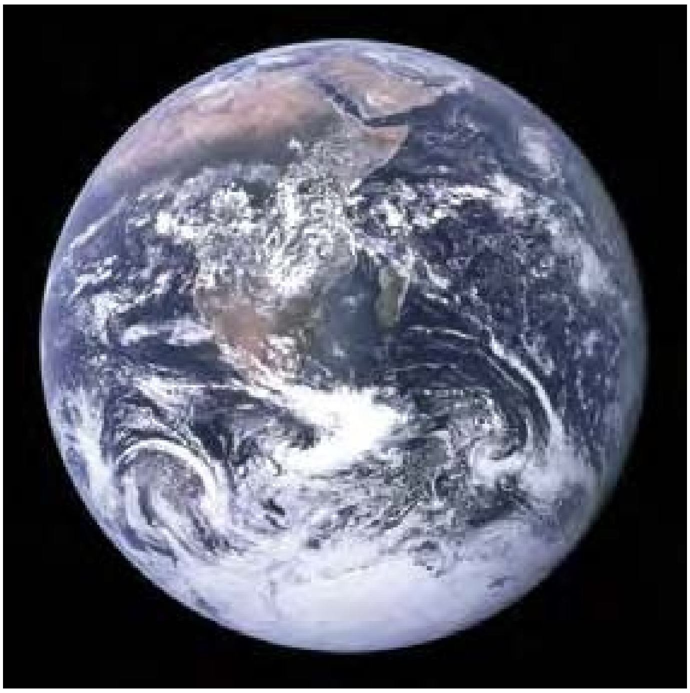
Earth


upper mantle 620 km thick
lower mantle 2,290 km thick
outer core 2,200 km thick
crust 6-40 km thick
inner core 2,500 km diameter
12,756 km equatorial diameter (12,714 km polar diameter)

(Image © Research Machines plc)

Inside the Earth. The surface of the Earth is a thin crust about 6 km/4 mi thick under the sea and 40 km/25 mi thick under the continents. Under the crust lies the mantle, about 2,900 km/1,800 mi thick and with a temperature of 1,500-3,000°C/2,700-5,400°F. The outer core is about 2,250 km/1,400 mi thick, of molten iron and nickel. The inner core is probably solid iron and nickel, at about 5,000°C/9,000°F.

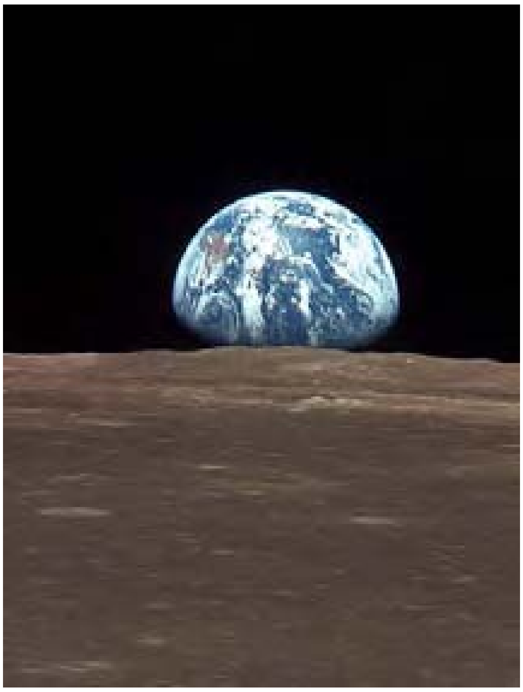
Earth



(Image © NASA)

The Earth photographed by the crew of *Apollo 17* on their way to the Moon. It was the first *Apollo* lunar trajectory that allowed photography of the south pole. Much of Africa and the Mediterranean are cloud-free, whereas large swathes of cloud dominate the southern Atlantic and Indian oceans.

Earth



(Image © NASA)

The Earth rising above the Moon's horizon, as seen from the *Apollo 11* spacecraft in July 1969.

(Image © NASA)

The Earth photographed by the *Apollo 17* spacecraft in December 1972. This photograph extends from the Mediterranean to the Antarctic ice cap. Almost the entire coastline of Africa is visible and the Arabian Peninsula can be seen off the northeast edge of Africa. Asia is on the horizon to the northeast.

Earth

To remember the most common elements of the planet's crust, in descending order:

Only **s**illy **a**sses **i**n **c**ollege **s**tudy **p**ast **m**idnight

Oxygen, **s**ilicon, **a**luminium, **i**ron, **c**alcium, **s**odium, **p**otassium, **m**agnesium

Earth Introduction

Go to site

Everything you ever wanted to know about planet Earth. This site contains a table of statistics, photographs taken from space, radar-generated images of the planet, animations of the Earth rotating, and more.

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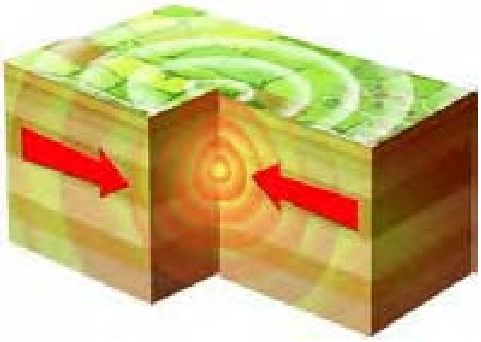
earthquake

abrupt motion of the Earth's surface. Earthquakes are caused by the sudden release in rocks of strain accumulated over time as a result of plate tectonics. The study of earthquakes is called seismology. Most earthquakes occur along faults (fractures or breaks) and Benioff zones. As two plates move past each other they can become jammed. When sufficient strain has accumulated, the rock breaks, releasing a series of elastic waves (seismic waves) as the plates spring free. The force of earthquakes (magnitude) is measured on the Richter scale, and their effect (intensity) on the Mercalli scale. The point at which an earthquake originates is the **focus** or **hypocentre**; the point on the Earth's surface directly above this is the **epicentre**.

The Alaskan (USA) earthquake of 27 March 1964 ranks as one of the greatest ever recorded, measuring 8.3-8.8 on the Richter scale. The 1906 San Francisco earthquake is among the most famous in history. Its magnitude was 8.3 on the Richter scale. The deadliest, most destructive earthquake in historical times is thought to have been in China in 1556. In 1987 a Californian earthquake was successfully predicted by measurement of underground pressure waves; prediction attempts have also involved the study of such phenomena as the change in gases issuing from the crust, the level of water in wells, slight deformation of the rock surface, a sequence of minor tremors, and the behaviour of animals. The possibility of earthquake prevention is remote. However, rock slippage might be slowed at movement points, or promoted at stoppage points, by the extraction or injection of large quantities of water underground, since water serves as a lubricant. This would ease overall pressure. Human activity can create earthquakes. Mining, water extraction, and oil extraction can cause subsidence that helps generate earthquakes, while the building of large dams and underground nuclear testing have also been linked with earthquakes.

earthquake



(Image © Research Machines plc)

The propagation of seismic waves through the Earth. Waves vibrate outwards from the focus of the earthquake, deep within the Earth. As well as the movement of waves from the epicentre the wave frequency contracts and dilates.

Most destructive earthquakes in the world

(N/A = not available.)

Date	Location	Estimated number of deaths	Magnitude (Richter scale)
23 January 1556	Shaanxi, China	830,000	N/A
26 December 2004	Sumatra	283,106	9.0
27 July 1976	Tangshan, China	255,000[1]	8.0
9 August 1138	Aleppo, Syria	230,000	N/A
22 May 1927	near Xining, China	200,000	8.3
22 December 856	Damghan, Iran	200,000	N/A
16 December 1920	Gansu, China	200,000	8.6
23 March 893	Ardabil, Iran	150,000	N/A
1 September 1923	Kwanto, Japan	143,000	8.3
30 December 1730	Hokkaido, Japan	137,000	N/A
September 1290	Chihli, China	100,000	N/A
8 October 2005	Pakistan	80,361	7.6
November 1667	Caucasia, Russia	80,000	N/A
18 November 1727	Tabriz, Iran	77,000	N/A
28 December 1908	Messina, Italy	70,000-100,000	7.5
1 November 1755	Lisbon, Portugal	70,000	8.7
25 December 1932	Gansu, China	70,000	7.6
31 May 1970	northern Peru	66,000	7.8
1268	Cilicia, Asia Minor	60,000	N/A
11 January 1693	Sicily, Italy	60,000	N/A
4 February 1783	Calabria, Italy	50,000	N/A
20 June 1990	Iran	50,000	7.7
30 May 1935	Quetta, Pakistan	30,000-60,000	7.5

[1] This is the official casualty figure; the estimated death toll is as high as 750,000.

Before and After the Great Earthquake and Fire: Early Films of San Francisco, 1897-1916

Go to site

Collection of 26 early films depicting San Francisco before and after the 1906 disaster, including a 1915 travelogue that shows scenes of the rebuilt city and the Panama Pacific Exposition, and a 1916 propaganda film. Should you not wish to download the entire film, each title contains sample still-frames. There is also background information about the earthquake and fire, and a selective bibliography.

British Geological Survey Global Seismology and Geomagnetism Group Earthquake Page

Go to site

Fascinating maps showing the location and relative magnitude of recent UK earthquake activity make up just a small part of this Web site. Also included are historical and archive information, as well as descriptions of effects and hazards.

Earthquakes and Plate Tectonics

Go to site

US Geological Survey National Earthquake Information Centre site, explaining the relationship between plate tectonics and earthquakes.

Worldwide Earthquake Locator

Go to site

Edinburgh University, Scotland, runs this site, which allows visitors to search for the world's latest earthquakes. The locator works on a global map on which perspective can be zoomed in or out. There are normally around five or six earthquakes a day – it is surprising how few make the news. The site also has some general information on earthquakes.

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earth science

scientific study of the planet Earth as a whole. The mining and extraction of minerals and gems, the prediction of weather and earthquakes, the pollution of the atmosphere, and the forces that shape the physical world all fall within its scope of study. The emergence of the discipline reflects scientists' concern that an understanding of the global aspects of the Earth's structure and its past will hold the key to how humans affect its future, ensuring that its resources are used in a sustainable way. It is a synthesis of several traditional subjects such as geology, meteorology, oceanography, geophysics, geochemistry, and palaeontology.

Earth Science

exploring the Earth from above and below

Recent years have seen basic geology merge with other sciences to produce the all-embracing discipline of earth science, and the advent of sophisticated data-gathering systems. There has been much debate amongst the scientists involved. Traditionalists maintain that the only way to study the Earth is go out and sample it, record it, and interpret it directly. Progressives insist that the only way to a full picture of the Earth is through remote sensing and computerized assessment of the data. No matter how the science changes, there will always be room for both approaches.

measuring the Earth

The greatest advances in remote sensing have been in distance measurement. The surface of the Earth can be measured extremely accurately, using global positioning geodesy (detecting signals from satellites by Earth-based receivers), satellite laser ranging (in which satellites reflect signals from ground transmitters back to ground receivers), and very-long-baseline interferometry, comparing signals received at ground-based receivers from distant extraterrestrial bodies. These techniques can measure distances of thousands of kilometres to accuracies of less than a centimetre. Movements of faults can be measured, as can the growth of the tectonic plates. Previously such speeds were calculated by averaging displacements measured over decades or centuries. The results show that in the oceanic crust plate growth is steady: from 12 mm/0.5 in per year across the Mid-Atlantic Ridge to 160 mm/6.5 in per year across the East Pacific Rise. The major continental faults seem to be very irregular in their movement; the Great Rift Valley of East Africa has remained stationary for 20 years, when long-term averages suggest that it would have opened up by about 100 mm/4 in in that time.

offshore petroleum exploration

Petroleum is society's most important raw fuel. The traditional oilfields were on land, but in 1896 wells were drilled into the Summerland oilfield from piers extending from the California coast. Oilwells were sunk in the Caspian Sea, the Gulf of Mexico, and Venezuela's Lake Maracaibo in the 1930s and 1940s, but only in the 1970s with the development of the North Sea and Canadian Arctic oilfields did offshore exploration really start. Even under such hostile sea conditions, wells could be drilled into the continental shelf 125 m/400 ft below sea level.

As the more accessible deposits become depleted, petroleum exploration is going into ever-deeper waters of the world's continental shelves. In 1991 Brazil, currently leading the way in offshore oil exploration, sank a production well in water 752 m/2,467 ft deep off the northeast coast. It is estimated that by the year 2000 more than 30% of the world's petroleum production will be from offshore wells.

alternative sources of petroleum

However, the main oil reserves may lie somewhere else altogether. Accepted theory says that petroleum was formed from the remains of plant and animal matter, in the sedimentary rocks in which they were entombed. An alternative theory proposes inorganic origins for oil, from methane and hydrogen trapped when the Earth was formed in granites or metamorphic rocks, from which the oil seeps into the known traps in surrounding sedimentary basins. One team has been drilling into granite rocks in Sweden since 1987, with apparent success. Another will drill into granite in Canada in 1993, seeking vast new oil deposits in totally different geological sites from those traditionally investigated.

climatic change

The burning of oil and other carbon-based fuels, pumping vast quantities of carbon dioxide into the atmosphere, raises the possibility of climatic change. The prospect is alarming, especially if such change is brought about by human interference with nature. However, the Earth's climate has never been stable, and human effects may be masked by natural variations. Beds of coal in Spitzbergen and glacial debris in the middle of the Australian desert attest to large-scale climate variations over hundreds of millions of years. Other studies show shorter-term variations: temperate tree fossils in Antarctica, 58 from the South Pole, and in the far north of Canada, show that climates were much warmer than now right up to the beginning of the Ice Age.

The international Pliocene Research Interpretation and Synoptic Mapping programme, begun in 1990, should produce fine details of climatic changes before the Ice Age. The Greenland Icecore project has shown that, during the Ice Age, temperatures over the ice caps varied between cold – with temperatures about 12°C lower than at present – and mild, with temperatures about 78°C lower than at present. Each cold period lasted between 500 and 2,000 years, starting abruptly and ending gradually.

Several sudden, catastrophic climate changes may have been caused in the past by the impact of giant meteorites or comets. The crater of one, 214 million years old, has been found in Canada; this seems to relate to a mass extinction in the Triassic period. Scientists are still seeking remains of the meteorite believed to have wiped out the dinosaurs 65 million years ago.

Earth science: key dates

1735	English lawyer George Hadley describes the circulation of the atmosphere as large-scale convection currents centred on the Equator.
1743	Christopher Packe produces the first geological map, of southern England.
1744	The first map using modern surveying principles is produced by César-François Cassini in France.
1745	In Russia, Mikhail Vasilievich Lomonosov publishes a catalogue of over 3,000 minerals.
1746	A French expedition to Lapland proves the Earth to be flattened at the poles.
1760	Mikhail Vasilievich Lomonosov explains the formation of icebergs. John Mitchell proposes that earthquakes are produced when one layer of rock rubs against another.
1766	The fossilized bones of a huge animal (later called *Mosasaurus*) are found in a quarry near the River Meuse, the Netherlands.
1776	James Keir suggests that some rocks, such as those making up the Giant's Causeway in Ireland, may have formed as molten material that cooled and then crystallized.
1779	French naturalist Comte George de Buffon speculates that the Earth may be much older than the 6,000 years suggested by the Bible.
1785	Scottish geologist James Hutton proposes the theory of uniformitarianism: all geological features are the result of processes that are at work today, acting over long periods of time.
1786	German-Swiss Johann von Carpentier describes the European ice age.
1793	Jean Baptiste Lamarck argues that fossils are the remains of once-living animals and plants.
1794	William Smith produces the first large-scale geological maps of England.
1795	In France, Georges Cuvier identifies the fossil bones discovered in the Netherlands in 1766 as being those of a reptile, now extinct.
1804	French physicists Jean Biot and Joseph Gay-Lussac study the atmosphere from a hot-air balloon.
1809	The first geological survey of the eastern USA is produced by William Maclure.
1815	In England, William Smith shows how rock strata (layers) can be identified on the basis of the fossils found in them.
1822	Mary Ann Mantell discovers on the English coast the first fossil to be recognized as that of a dinosaur (an iguanodon). In Germany, Friedrich Mohs introduces a scale for specifying mineral hardness.
1825	Cuvier proposes his theory of catastrophes as the cause of the extinction of large groups of animals.
1830	Scottish geologist Charles Lyell publishes the first volume of *The Principles of Geology*, which describes the Earth as being several hundred million years old.
1839	In the USA, Louis Agassiz describes the motion and laying down of glaciers, confirming the reality of the ice ages.
1842	English palaeontologist Richard Owen coins the name 'dinosaur' for the reptiles, now extinct, that lived about 175 million years ago.
1846	Irish physicist William Thomson (Lord Kelvin) estimates, using the temperature of the Earth, that the Earth is 100 million years old.
1850	US naval officer Matthew Fontaine Maury maps the Atlantic Ocean, noting that it is deeper near its edges than at the centre.
1852	Edward Sabine in Ireland shows a link between sunspot activity and changes in the Earth's magnetic field.
1853	James Coffin describes the three major wind bands that girdle each hemisphere.
1854	English astronomer George Airy calculates the mass of the Earth by measuring gravity at the top and bottom of a coal mine.
1859	Edwin Drake drills the world's first oil well at Titusville, Pennsylvania, USA.
1872	The beginning of the world's first major oceanographic expedition, the four-year voyage of the *Challenger*.
1882	Scottish physicist Balfour Stewart postulates the existence of the ionosphere (the ionized layer of the outer atmosphere) to account for differences in the Earth's magnetic field.
1884	German meteorologist Vladimir Köppen introduces a classification of the world's temperature zones.
1890	English geologist Arthur Holmes uses radioactivity to date rocks, establishing the Earth to be 4.6 billion years old.
1895	In the USA, Jeanette Picard launches the first balloon to be used for stratospheric research.
1896	Swedish chemist Svante Arrhenius discovers a link between the amount of carbon dioxide in the atmosphere and the global temperature.
1897	Norwegian-US meteorologist Jacob Bjerknes and his father Vilhelm develop the mathematical theory of weather forecasting.
1902	English physicist Oliver Heaviside and US engineer Arthur Edwin Kennelly predict the existence of an electrified layer in the atmosphere that reflects radio waves. In France, Léon Teisserenc discovers layers of different temperatures in the atmosphere, which he calls the troposphere and stratosphere.
1906	Richard Dixon Oldham proves the Earth to have a molten core by studying seismic waves.
1909	Yugoslav physicist Andrija Mohorovicic discovers a discontinuity in the Earth's crust, about 30 km/18 mi below the surface, that forms the boundary between the crust and the mantle.
1912	In Germany, Alfred Wegener proposes the theory of continental drift and the existence of a supercontinent, Pangaea, in the distant past.
1913	French physicist Charles Fabry discovers the ozone layer in the upper atmosphere.
1914	German-US geologist Beno Gutenberg discovers the discontinuity that marks the boundary between the Earth's mantle and the outer core.
1922	British meteorologist Lewis Fry Richardson develops a method of numerical weather forecasting.
1925	A German expedition discovers the Mid-Atlantic Ridge by means of sonar. Edward Appleton discovers a layer of the atmosphere that reflects radio waves; it is later named after him.

1929	By studying the magnetism of rocks, Japanese geologist Motonori Matuyama shows that the Earth's magnetic field reverses direction from time to time.
1935	US seismologist Charles Francis Richter establishes a scale for measuring the magnitude of earthquakes.
1936	Danish seismologist Inge Lehmann postulates the existence of a solid inner core of the Earth from the study of seismic waves.
1939	In Germany, Walter Maurice Elsasser proposes that eddy currents in the molten iron core cause the Earth's magnetism.
1950	Hungarian-US mathematician John Von Neumann makes the first 24-hour weather forecast by computer.
1956	US geologists Bruce Charles Heezen and Maurice Ewing discover a global network of oceanic ridges and rifts that divide the Earth's surface into plates.
1958	Using rockets, US physicist James Van Allen discovers a belt of radiation (later named after him) around the Earth.
1960	The world's first weather satellite, *TIROS 1*, is launched. US geologist Harry Hammond Hess shows that the sea floor spreads out from ocean ridges and descends back into the mantle at deep-sea trenches.
1963	British geophysicists Fred Vine and Drummond Matthews analyse the magnetism of rocks in the Atlantic Ocean floor and find conclusive proof of seafloor spreading.
1985	A British expedition to the Antarctic discovers a hole in the ozone layer above the South Pole.
1991	A borehole in the Kola Peninsula in Arctic Russia, begun in the 1970s, reaches a depth of 12,261 m/40,240 ft (where the temperature is found to be 210°C/410°F).
2005	US Scientists confirm that the Earthmanys core rotates at a faster rate than the rest of the planet. A new active 'thrust fault' at the base of the Himalaya Mountains in Nepal is discovered.
2006	Scientists discover that the outermost ring of the planet Uranus has a bright blue colour; the only other blue ring known in the solar system circles the planet Saturn.

Donald L Blanchard's Earth Sciences' Web Site

Go to site

Informative articles on 'paleoclimate', 'plate tectonics', and 'paleontology'.

Earth Sciences

Go to site

Yahoo! directory of earth science, which provides links to hundreds of earth science sites, organized by discipline, and increasing in number every day.

Earth Summit

or World Development Summit or United Nations Conference on Environment and Development

international meetings aiming at drawing up measures for the environmental protection of the world. The first summit took place in Rio de Janeiro, Brazil, in June 1992. Treaties were made to combat global warming and protect biodiversity (the latter was not signed by the USA). The second Earth Summit was held in New York in June 1997 to review progress. The meeting agreed to work towards a global forest convention with the aim of halting the destruction of tropical and old-growth forests. The last Earth Summit took place on 17 March 2004 in Johannesburg, South Africa. Russia backed the Kyoto treaty on global warming, ensuring that it would still go ahead despite US non-participation.

Earth Summit

the Earth summit: progress and setbacks

In June 1992 over a hundred of the world's heads of state met in Rio de Janeiro, Brazil, to take part in the United Nations Conference on Environment and Development (UNCED). The meeting, popularly known as the Earth Summit, was unique in a number of ways. It was the largest gathering of world leaders in history. It was by far the largest conference ever to be held about the environment. And it succeeded in agreeing two globally important treaties, with countries signing up faster then ever before.

a globally significant damp squib

Yet for an event that might almost be compared with the formation of the United Nations in terms of global significance, the meeting gave the distinct impression of being something of a damp squib. Economic interests watered down many of the finer ideals on which the conference had been set up. Although there were many fine words, there is little money to back them up. The rift between North and South was, if anything, widened rather than healed by the discussions in Rio.

high ideals whittled away

The Earth Summit was a UN-sponsored meeting to discuss issues relating to environment and development, and the links between the two. It began with very high ideals, some of which had been whittled away in the two-year build-up process. This included a number of preparatory conferences (precons) in different parts of the world. By the time the conference was actually launched, much had already been argued about, and won or lost, during the precon process.

two important treaties signed

In the event, two significant treaties were signed at Rio, although not by everybody. A treaty on climate change was agreed, calling on countries to commit themselves to stabilize emissions of greenhouse gases by the year 2000, and on signatories to act before the convention becomes effective. A second treaty, on biodiversity, was originally drafted to ensure that signatories took steps to preserve plant and animal life, but eventually also included rights to exploit life in their territories as well.

impact of treaties weakened by rich countries

Unfortunately, both of the treaties were significantly weakened by the time they reached Rio, mainly because of opposition from the rich countries and especially the USA. The greenhouse treaty was originally supposed to be binding, but was reduced through softer wording, less commitment, and a reduction in the support provided by the rich countries to the poor to help in meeting the targets. The biodiversity treaty, which the USA refused to sign owing to fears of losing rights to exploit other country's biological resources in biotechnology, has some high-sounding ideals but little money. Again, the rich nations opposed moves to include provision for much financial support for the poorer countries in conservation of biodiversity.

environmentalists score with Agenda 21

A gain for the environmental lobby was the agreement reached on Agenda 21, an ambitious 500-page plan to protect the environment, with 115 specific clean-up programmes. This caused a furore in discussion because of the enormous costs it was calculated as requiring, some $625 billion a year, most of which was to have come from the South. In practice, and in line with much of the rest of UNCED, far less money was available and the Agenda, although agreed, is nonbinding.

failure on forests

The largest single failure of the conference was the failure to agree any binding treaty on forests. Instead, a nonbinding statement of principles to conserve forests was agreed, which few people expect to make much difference to practical forest-management policies. Here, the main opposition came from the South, and was spearheaded by Malaysia which already has a massive logging programme and plans to continue the exploitation. Malaysia's threat to pull out of UNCED unless the treaty was dropped had a large influence over its abandonment. Here, ironically, the USA was a prime supporter, but there was failure even to agree the need for a convention in the future.

so, was the Earth Summit a success or failure?

It was a failure in that it did not produce the major shift towards greater protection for the environment that was originally hoped. Yet it did result in an unprecedented statement of concern by most of the world's leaders, and it did result in two major treaties being signed. As one environmental lobbyist said, if you read the small print on what was agreed there are a lot of hooks to hang countries on if they don't meet up to the requirements. The UNCED meeting was not the solution to the world's problems that some people were looking for, but it was a step in the right direction.

Earth Summit, Johannesburg, 2002

The 2002 Earth Summit did not fare any better than the previous one in the eyes of the NGOs and charities. Most world leaders were more optimistic, except president Hugo Chavez of Venezuela who said that the meeting had failed. He said, 'It seems to have been a dialogue of the deaf. Some people go from summit to summit. Our people go from abyss to abyss.'

Earth Council

Go to site

Details the aims and activities of the Earth Council, a non-governmental organization promoting the implementation of the Earth Summit agreements. Includes reports from Earth Council meetings and 'Special projects', which include videos.

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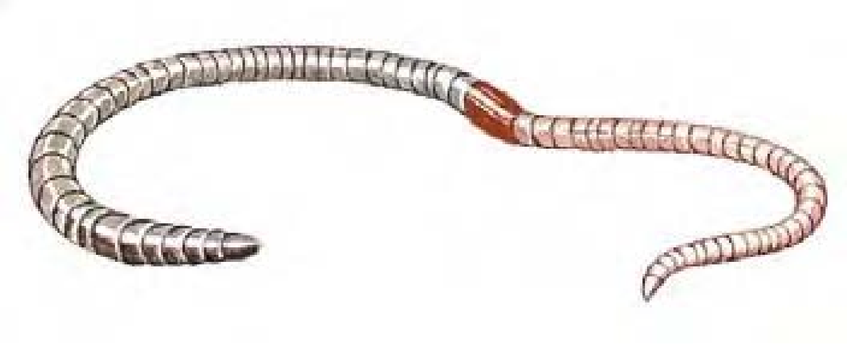
earthworm

annelid worm of the class Oligochaeta. Earthworms are hermaphroditic and deposit their eggs in cocoons. They live by burrowing in the soil, feeding on the organic matter it contains. They are vital to the formation of humus, aerating the soil and levelling it by transferring earth from the deeper levels to the surface as castings.

earthworm



(Image © Research Machines plc)

The earthworm burrows through the soil by pressing its minute bristles into the walls of the tunnel and pulling itself along. The thickened segment, or saddle, towards the front of the body lies near the reproductive organs and secretes the egg cocoons.

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earwig

nocturnal insect of the order Dermaptera. The forewings are short and leathery and serve to protect the hindwings, which are large and are folded like a fan when at rest. Earwigs seldom fly. They have a pincerlike appendage in the rear. The male is distinguished by curved pincers; those of the female are straight. Earwigs are regarded as pests because they feed on flowers and fruit, but they also eat other insects, dead or alive. Eggs are laid beneath the soil, and the female cares for the young even after they have hatched. The male dies before the eggs have hatched.

When threatened, earwigs spray quinones (irritant chemicals stored as crystals), from their abdominal glands.

earwig

In the 18th century, earwigs were prescribed for hearing difficulties. Dr James' *Medicinal Dictionary* of 1743, comments: 'These insects, being dried, pulverized, and mixed with the urine of a hare, are esteemed to be good for deafness, being introduced into the ear.'

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east

one of the four cardinal points of the compass, indicating that part of the horizon where the Sun rises; when facing north, east is to the right.

Easter Island

or Rapa Nui; Spanish Isla de Pascua

Chilean island in the south Pacific Ocean, part of the Polynesian group, about 3,500 km/2,200 mi west of Chile; area about 166 sq km/64 sq mi; population (1998 est) 2,000. The island consists of three extinct volcanoes, reaching a maximum altitude of 538 m/1,765 ft. It was first reached by Europeans on Easter Sunday 1722. On it stand over 800 huge carved statues (*moai*) and the remains of boat-shaped stone houses, the work of Neolithic peoples from Polynesia. The chief centre is Hanga-Roa.

In 1996, following seven years of work, a New Zealand linguist, Dr Steven Fischer, deciphered a script discovered on the island. This script showed the inhabitants were the first in Oceania to write. According to Dr Fischer, the script, known as 'rongorongo', was made up of chants in Rapanui, the island's Polynesian tongue, and told the story of creation.

The carved statues are believed to have been religious icons. However, archaeological evidence suggests that, prior to European contact, the island suffered an environmental or cultural crisis resulting in the inhabitants renouncing their earlier religious values, which caused them to damage or overturn many of the statues.

Secrets of Easter Island

Go to site

Companion site to the PBS television programme *Nova*, this page seeks to answer the many mysteries surrounding the inhabitants of this remote island and the giant statues they produced. Archaeologist Jo Anne Van Tilburg attempts to reconstruct the statues based on her theories of how they might have been built.

Eastman, George (1854-1932)

US entrepreneur and inventor who founded the Eastman Kodak photographic company in 1892. He patented flexible film in 1884, invented the Kodak box camera in 1888, and introduced daylight-loading film in 1892. By 1900 his company was selling a pocket camera for as little as one dollar.

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eau de cologne

refreshing toilet water (weaker than perfume), made of alcohol and aromatic oils. Its invention is ascribed to Giovanni Maria Farina (1685-1766), who moved from Italy to Cologne in 1709 to manufacture it.

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ebony

any of a group of hardwood trees belonging to the ebony family, especially some tropical persimmons native to Africa and Asia. (Genus chiefly *Diospyros*, family Ebenaceae.)

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eccentricity

in geometry, a property of a conic section (circle, ellipse, parabola, or hyperbola). It is the distance of any point on the curve from a fixed point (the focus) divided by the distance of that point from a fixed line (the directrix). A circle has an eccentricity of zero; for an ellipse it is less than one; for a parabola it is equal to one; and for a hyperbola it is greater than one.

Eccles, John Carew (1903-1997)

Australian physiologist who was awarded a Nobel Prize for Physiology or Medicine in 1963 with Alan Hodgkin and Andrew Huxley for their work on ionic mechanisms involved in the communication or inhibition of impulses across neuron (nerve cell) membranes. In some of his later works, he argued that the mind has an existence independent of the brain.

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ecdysis

periodic shedding of the exoskeleton by insects and other arthropods to allow growth. Prior to shedding, a new soft and expandable layer is laid down underneath the existing one. The old layer then splits, the animal moves free of it, and the new layer expands and hardens.

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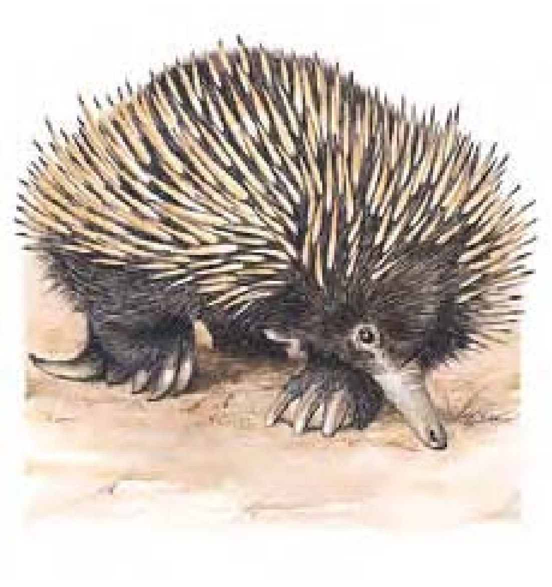
echidna

or spiny anteater

toothless, egg-laying, spiny mammal of the order Monotremata, found in Australia and New Guinea. There are two species: *Tachyglossus aculeatus*, the short-nosed echidna, and the rarer *Zaglossus bruijni*, the long-nosed echidna. They feed entirely upon ants and termites, which they dig out with their powerful claws and lick up with their prehensile tongues. When attacked, an echidna rolls itself into a ball, or tries to hide by burrowing in the earth.

echidna



(Image © Research Machines plc)

A short-nosed echidna. The female develops a temporary pouch during the breeding season, into which she transfers the single egg she has laid. The egg hatches 7-10 days later.

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echinoderm

marine invertebrate of the phylum Echinodermata ('spiny-skinned'), characterized by a five-radial symmetry. Echinoderms have a water-vascular system which transports substances around the body. They include starfishes (or sea stars), brittle-stars, sea lilies, sea urchins, and sea cucumbers. The skeleton is external, made of a series of limy plates. Echinoderms generally move by using tube-feet, small water-filled sacs that can be protruded or pulled back to the body.

Echinodermata

phylum of invertebrate animals, members of which are called echinoderms.

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echo

repetition of a sound wave, or of a radar or sonar signal, by reflection from a hard surface such as a wall or building. By accurately measuring the time taken for an echo to return to the transmitter, and by knowing the speed of a radar signal (the speed of light) or a sonar signal (the speed of sound in water), it is possible to calculate the range of the object causing the echo (echolocation).

The speed of sound can be measured using an echo. The time taken for the sound to be reflected back over a known distance is recorded. The speed of sound can then be calculated using the formula: speed = distance/time.

For an echo to occur, the wavelength of the incident sound must be smaller than the size of the object. Sound obeys the same rules of reflection as for light. If the wavelength of the sound is the same as or greater than the size of the object, then diffraction takes place.

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echolocation

or biosonar

method used by certain animals, notably bats, whales, and dolphins, to detect the positions of objects by using sound. The animal emits a stream of high-pitched sounds, generally at ultrasonic frequencies (beyond the range of human hearing), and listens for the returning echoes reflected off objects to determine their exact location.

The location of an object can be established by the time difference between the emitted sound and its differential return as an echo to the two ears. Echolocation is of particular value under conditions when normal vision is poor (at night in the case of bats, in murky water for dolphins). A few species of bird can also echolocate, including cave-dwelling birds such as some species of swiftlets and the South American oil bird.

The frequency range of bats' echolocation calls is 20-215 kHz. Many species produce a specific and identifiable pattern of sound. Bats vary in the way they use echolocation: some emit pure sounds lasting up to 150 milliseconds, while others use a series of shorter 'chirps'. Sounds may be emitted through the mouth or nostrils depending on species.

Blind or blindfolded human subjects can also learn echolocation to a certain degree. People who have used it from an early age are particularly successful with the technique, using tongue-clicking, tapping with a stick, or stamping sounds to create the required echoes.

Echolocation was first described in the 1930s, though it was postulated by Italian biologist Lazzaro Spallanzani (1729-1799).

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echo sounder

or sonar device

device that detects objects under water by means of sonar - by using reflected sound waves. Most boats are equipped with echo sounders to measure the water depth beneath them. An echo sounder consists of a transmitter, which emits an ultrasonic pulse, and a receiver, which detects the pulse after reflection from the seabed. The time between transmission and receipt of the reflected signal is a measure of the depth of water. Fishing boats use echo sounders to detect shoals of fish and navies use them to find enemy submarines.

Eckert, J(ohn) Presper (1919-1995)

US electronics engineer and mathematician who collaborated with John Mauchly on the development of the early ENIAC (1946) and UNIVAC 1 (1951) computers.

Eckert, John Presper

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of John Eckert. In addition to biographical information, you will find a list of references about Eckert and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Eckert. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

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eclampsia

convulsions occurring during pregnancy following pre-eclampsia.

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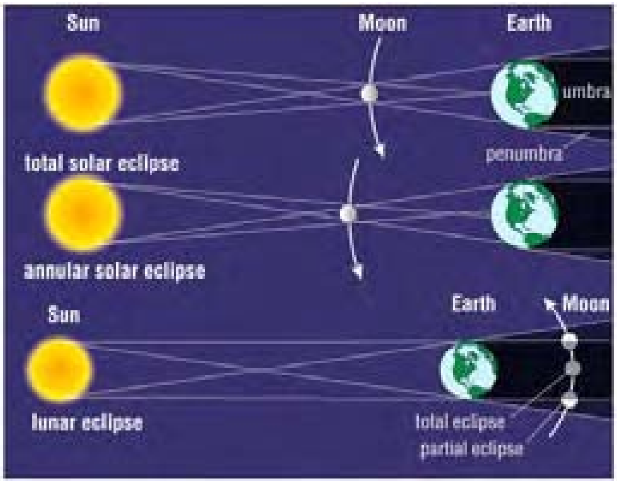
eclipse

passage of one astronomical body through the shadow of another. The term is usually used for solar and lunar eclipses. A **solar eclipse** occurs when the Moon is between the Earth and the Sun (which can happen only at new Moon), the Moon blocking the Sun's rays and casting a shadow on the Earth's surface. A **lunar eclipse** occurs when the Earth is between the Moon and the Sun (which can happen only at full Moon), the Earth blocking the Sun's rays and casting a shadow on the Moon's surface.

During a total solar eclipse the Moon appears to cover the Sun's disc completely, as viewed from a small region around the centre of the Moon's shadow. In this area day turns into night. A total solar eclipse can last up to 7.5 minutes, and the Sun's corona can be seen. Between two and five solar eclipses occur each year but each is visible only in the band of the Earth's surface traversed by the Moon's shadow. Away from the centre of the shadow, the solar eclipse is partial; sunlight reaches the Earth around the edge of the Moon. When the Moon is at its furthest from the Earth it does not completely cover the face of the Sun, leaving a ring of sunlight visible. This is an **annular eclipse** (from the Latin word *annulus* meaning 'ring').

Lunar eclipses can also be partial or total. Total lunar eclipses last for up to 100 minutes; the maximum number each year is three. A lunar eclipse is visible from the whole night-time hemisphere of the Earth.

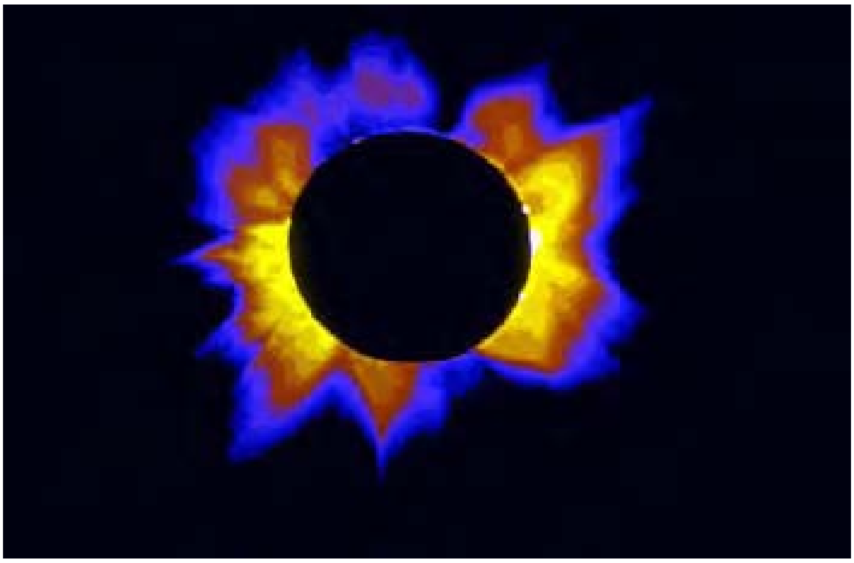
eclipse



(Image © Research Machines plc)

The two types of eclipse: lunar and solar. A lunar eclipse occurs when the Moon passes through the shadow of the Earth. A solar eclipse occurs when the Moon passes between the Sun and the Earth, blocking out the Sun's light. During a total solar eclipse, when the Moon completely covers the Sun, the Moon's shadow sweeps across the Earth's surface from west to east at a speed of 3,200 kph/2,000 mph.

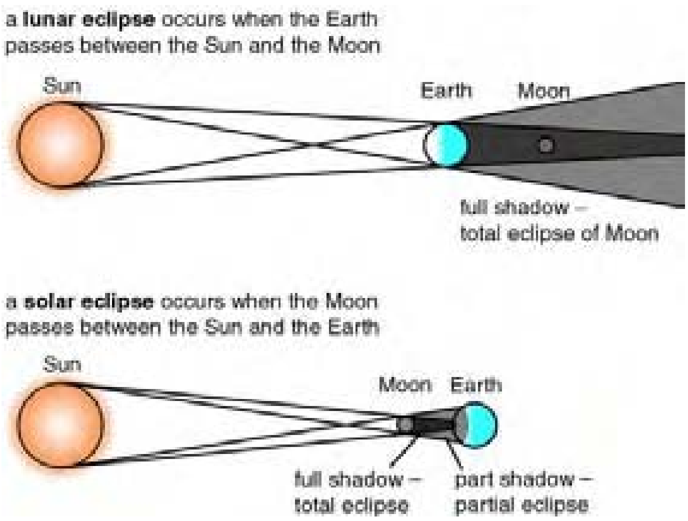
eclipse



(Image © NASA)

During a total solar eclipse the Sun's corona (halo of hot gases) becomes visible.

eclipse


a lunar eclipse occurs when the Earth passes between the Sun and the Moon
Sun
Earth
Moon
full shadow – total eclipse of Moon
a solar eclipse occurs when the Moon passes between the Sun and the Earth
Sun
Moon
Earth
full shadow – total eclipse
part shadow – partial eclipse

(Image © Research Machines plc)

A solar eclipse occurs when the Moon, passing between the Earth and the Sun, blocks the Sun's rays and casts a shadow on the Earth. A lunar eclipse occurs when the Earth, passing between the Moon and Sun, blocks the Sun's rays and casts a shadow on the Moon. Both solar and lunar eclipses can be partial or total.

Lunar Eclipse Computer

Go to site

Part of a larger site on astronomical data maintained by the US Naval Observatory, this site provides data on recent and upcoming lunar eclipses for any location around the world. The data available includes the local time of each eclipse 'event'; the altitude and azimuth of the Moon at each of the events; plus the time of moonrise immediately preceding, and the time of moonset immediately following, the eclipse. Sections of Frequently Asked Questions and research information are also included.

Solar Eclipse

Go to site

Pages dedicated to the eclipse that was visible over the UK on 11 August 1999. This site contains detailed information on the science of eclipses, and includes images of the event.

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eclipsing binary

binary (double) star in which the two stars periodically pass in front of each other as seen from Earth.

When one star crosses in front of the other the total light received on Earth from the two stars declines. The first eclipsing binary to be noticed was Algol.

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ecliptic

path, against the background of stars, that the Sun appears to follow each year as it is orbited by the Earth. It can be thought of as the plane of the Earth's orbit projected onto the celestial sphere.

The ecliptic is tilted at about 23.5° with respect to the celestial equator, a result of the tilt of the Earth's axis relative to the plane of its orbit around the Sun.

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ecliptic coordinates

in astronomy, system for measuring the position of astronomical objects on the celestial sphere with reference to the plane of the Earth's orbit, the ecliptic.

Ecliptic latitude (symbol β) is measured in degrees from the ecliptic ($\beta = 0°$) to the north ($\beta = 90°$) and south ($\beta = -90°$) ecliptic poles.

Ecliptic longitude (symbol λ) is measured in degrees eastward along the ecliptic ($\lambda = 0°$ to 360°) from a fixed point known as the first point of Aries or the vernal equinox. Ecliptic coordinates are often used to measure the positions of the Sun and planets with respect to the Earth.

Ecliptic latitude and longitude are sometimes known as celestial latitude and longitude. The ecliptic longitude of the Sun (solar longitude) is a convenient measure of the position of the Earth in its orbit.

E. coli

abbreviation for Escherichia *coli*.

What the Heck is an E. coli?

Go to site

Explains the basics behind this bacterium which can cause food poisoning, including information on the dangerous strain of the bacterium and how it developed. It contains guidelines to reduce the risk of infection. There are a number of links throughout the article to sites expanding on issues raised.

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ecology

(Greek oikos 'house')

study of the relationship among organisms and the environments in which they live, including all living and nonliving components. The chief environmental factors governing the distribution of plants and animals are temperature, humidity, soil, light intensity, day length, food supply, and interaction with other organisms. The term ecology was coined by the biologist Ernst Haeckel in 1866.

Ecology may be concerned with individual organisms (for example, behavioural ecology, feeding strategies), with populations (for example, population dynamics), or with entire communities (for example, competition between species for access to resources in an ecosystem, or predator-prey relationships). Applied ecology is concerned with the management and conservation of habitats and the consequences and control of pollution.

Shades of Green: Ethics and Value in Ecology

the intellectual roots of attitudes to nature

The 1960s was a decade of rising ecological consciousness in the West. The World Wildlife Fund (now the World Wide Fund for Nature) was founded in 1961, and in 1962 Rachel Carson published her influential work *Silent Spring*. It was becoming clear that humans, despite their incredible technical achievements, were transforming whole areas of the planet for the worse for themselves and many other species. This was clearly a problem in need of explanation and remedy, and economists, ecologists, and historians were not slow in supplying answers. In 1967 the historian Lynn White Jr published an influential paper entitled 'The Historical Roots of Our Ecologic Crisis'. White laid the blame for the environmental problems of the West firmly at the door of orthodox Christian attitudes to nature that had shaped science, technology, and people's value systems. White thought that the answer to the crisis did not lie in more or better science: 'our present science and our present technology are so tinctured with orthodox Christian arrogance toward nature that no solution for our ecologic crisis can be expected from them alone'.

White's thesis provoked much controversy. Theologians, understandably, were annoyed. Conceding the point that the Bible did enjoin humans to 'fill the earth and subdue it' and to 'rule over the fish of the sea and ⟩ over all creatures that move along the ground', they were keen to point out that elsewhere in the Bible the relationship suggested is one of stewardship, where humans look after God's creation as would a tenant after an owner's property. Philosophers such as John Passmore, however, in his *Man's Responsibility for Nature* (1974), although disagreeing with White's emphasis on Christianity as the sole source of anthropocentrism, nevertheless was in accord that 'Western metaphysics and Western ethics ⟩ have done a great deal to encourage the ruthless exploitation of nature'.

The sense that science had somehow taken a wrong turn was not a new one. As early as 1926 the philosopher Alfred North Whitehead was stating that the future task of philosophy should be to 'end the divorce of science from the affirmations of our aesthetic and ethical experiences'. But it was in the last quarter of the 20th century that the feeling that humans were steadily destroying the ecological base to their own existence became acute. For many, reductionism, materialism, and consumerism were to blame. Some seemed to revel in the new responsibility that the scientific world view laid on the shoulders of its adherents. The French Nobel prize winner Jacques Monod, for example, noted in his work *Chance and Necessity* (1970) how 'The ancient covenant is in pieces; man at last knows that he is alone in the unfeeling immensity of the universe, out of which he emerged by chance. Neither his destiny nor his duty have been written down'. Others turned to the science of ecology for ethical and practical guidance on how to manage both the planet and human affairs. With its holistic emphasis on the interconnectedness of things, and the important role played by even the smallest of organisms in the great economy of nature, ecology seemed a likely source of value in a world deprived of ultimate meaning by the reductionism of physics, chemistry, and biochemistry.

the deep and the shallow ecology movement

A distinction useful to understanding the multifarious ways in which ecology and ethics became entangled was introduced by the Norwegian philosopher Arne Naess in his paper of 1973 entitled 'The Shallow and the Deep, Long-Range Ecology Movement'. Naess distinguished between 'shallow' and 'deep' environmental thought. Shallow ecology expresses concern for the environment on the basis that a deteriorating environment would worsen the conditions for human existence. Shallow ecology is therefore anthropocentric and takes the view that the environment must be properly managed to foster human welfare. Deep ecology, in contrast, shows respect for all organisms irrespective of their use value to humans. Here we meet a distinction that is fundamental to understanding environmental debates.

Shallow greens subscribe to a belief in instrumental value, the view that the environment as a whole and other life forms in it are worthy of respect in so far as they are instrumental in satisfying human needs and desires. This need not be so callous as it sounds. We should conserve forests and fish stocks and manage them properly, for example, because they are a source of timber and food, respectively. But this same ethic would lead to the conservation of wilderness and endangered species in so far as humans take delight in these things. Within this mindset, the values ascribed to other living things are hierarchical.

Hence, we would probably place more value on, say, pandas than on parasites that cause disease. Deep greens, however, argue that the world has intrinsic value, a value that is irrespective of its use for humans. From this position, we should make efforts to conserve whales not because their sustainable hunting provides useful products such as sushi for expensive restaurants, nor solely because humans take pleasure in seeing them or knowing of their existence, but because whales have their own life interests and hence a right to exist; a right that brings into question, therefore, whether they should be hunted at all. This division between intrinsic and instrumental value, between deep and shallow green positions, and between ecocentric and anthropocentric philosophies, is now a fundamental component of environmental debates.

catastrophists and cornucopians

As the deep greens debated with the shallow greens, another polarization of opinion was taking place. In the 1970s a group, sometimes called the 'catastrophists' or neo-Malthusians, were predicting dire shortages of resources, and widespread famine on a massive scale by the end of the 20th century as the effects of the human population explosion were felt. Typical of this view was the report *The Limits to Growth* issued by Dennis Meadows and his co-workers in the USA in 1972, which painted a bleak future for the human race unless drastic measures were taken. The fact that some of the more depressing predictions of the catastrophists failed to materialize, lent credence to a group (usually economists) who came to be called the 'cornucopians'. True to their name, these thinkers, exemplified in the USA by Julian Simon and Herman Kahn and in the UK by Wilfred Beckerman, argued that the world's resources are not running out, that there is no environmental crisis, and that industrial capitalism and free enterprise will ultimately deliver solutions to any short-term problems.

For many politicians, alarmed at the radical and almost certainly unpopular measures proposed by the catastrophists to avert an ecological crisis, yet worried that environmental issues were not entirely safe in the hands of the free market, the concept of sustainable development, highlighted in the Brundtland Report of 1987, became a sort of intellectual life raft. It seemed as if humans could have their cake and eat it. One of the most widely quoted definitions of sustainability comes from the Brundtland Report itself: 'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. Some on the 'New Right' questioned whether there was any ethical obligation to future generations, and if so how far into the future this should extend. Ecocentrics pointed out that the whole concept rested upon the old anthropocentric notion of meeting human needs. They were also concerned that economic growth got the noun (development) while ecology had to make do with the adjective (sustainable).

Following the publication of the Brundtland Report, the UN General Assembly resolved in 1989 to convene a conference on environment and development. That conference was held in Rio de Janeiro, Brazil, in June 1992 and became known as the Earth Summit. States participating in the summit agreed four documents:

- the Forest Principles – a non-binding statement of principles for the sustainable management of forests
- the Biodiversity Convention – an agreement on how to protect the earth's wide range of species and habitats
- the Climate Change Convention – an agreement on a framework to proceed with the reduction of greenhouse gas emissions
- Agenda 21 – a plan of action for the 21st century intended to promote sustainable development.

It can be seen that sustainability is a concept that infused the thinking of the summit. There are, however, many problems, both theoretical and political, that remain with the whole concept of sustainability. At the theoretical level, much effort is expended in refining the notion of sustainability and in developing indicators that enable it to be measured. At the political level, there is the danger that sustainability becomes a concept that no one disagrees with and, consequently, is not taken seriously as a guide to action. More than ever before, politicians, scientists, economists, and the consuming public need to talk and listen.

Ecology: key events

c. 325 BC	Greek scholar Theophrastus writes about the relationship between organisms, and between organisms and their environment – the first ecological study.
1735	Swedish naturalist Carl Linnaeus develops his system for classifying and naming plants and animals.
1798	English cleric Thomas Malthus produces the earliest theoretical study of population dynamics.
1859	English naturalist Charles Darwin publishes his *On the Origin of Species*.
1869	German zoologist Ernst Haeckel first defines the term 'ecology'.
1899	US botanist Henry Cowles publishes his classic paper on succession in sand dunes on Lake Michigan, USA.
1913	British Ecological Society founded.
1915	Ecological Society of America founded.
1916	US ecologist Frederic Clements coins the phrase 'climax communities' for large areas of rather uniform vegetation which he attributes to climactic factors.
1926	Russian botanist N I Vavilov publishes *Centres of Origin of Cultivated Plants*, concluding that there are relatively few such centres, many of which are located in mountainous areas.
1934	Russian ecologist G F Gause first states the principles of competitive exclusion, related to the niche of a species.
1935	British ecologist Arthur Tansley first coins the term 'ecosystem'.
1938	The coelacanth, a marine fish believed to have become extinct 65 million years ago, is ' rediscovered' in the Indian Ocean.
1940	Population biologist Charles Elton develops the idea of trophic levels in a community of organisms.
1950	The theory that natural selection may favour either individuals with high reproductive rates and rapid development (*r*-selection) or individuals with low reproductive rates and better competitive ability (*k*-selection) is first discussed.
1967	US biologists MacArthur and Wilson propose their 'Theory of Island Biogeography' which relates population and community size to island size. The theory is still widely used in the design of nature reserves today.
1979	English naturalist James Lovelock proposes his Gaia hypothesis, viewing the planet as a single organism.
1993	UN Convention on Biological Diversity comes into force.

2002	The worldmanys first large intact piece of oceanic mantle from the Archean or the planetmanys earliest period is discovered; the piece of rock which measures nearly a mile long and is billions of years old may help scientists further develop and test theories on when life developed on the planet.
2006	US researchers discover how whales lost their hind limbs, one of the best examples of evolutionary change in the fossil record.

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ecosystem

in ecology, a unit consisting of living organisms and the environment that they live in. A simple example of an ecosystem is a pond. The pond ecosystem includes all the pond plants and animals and also the water and other substances that make up the pond itself. Individual organisms interact with each other and with their environment in a variety of relationships, such as two organisms in competition, predator and prey, or as a food source for other organisms in a food chain. These relationships are usually complex and finely balanced, and in natural ecosystems should be self-sustaining. However, major changes to an ecosystem, such as climate change, overpopulation, or the removal of a species, may threaten the system's sustainability and result in its eventual destruction. For instance, the removal of a major carnivore predator can result in the destruction of an ecosystem through overgrazing by herbivores. Ecosystems can be large, such as the global ecosystem (the ecosphere), or small, such as the pools that collect water in the branch of a tree, and they can contain smaller systems.

Introduction to the Ecosystem Concept

Go to site

Clear and well-organized hyperlinked explanation of ecosystems, supported by a diagram showing the components of an ecosystem and their inter-relatedness. Part of a much larger site 'Fundamentals of Physical Geography' set up by a Canadian University, the page covers many aspects of the area of study.

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ecotourism

growing trend in tourism to visit sites that are of ecological interest, for example the Galapagos Islands, or Costa Rica. Ecotourism can bring about employment and income for local people, encouraging conservation, and is far less environmentally damaging than mass tourism.

One of the ideas behind ecotourism is that it is the practice of using money raised through tourism to pay for conservation and community projects, and putting this spending power in the hands of local people. However, if carried out unscrupulously it can lead to damage of environmentally-sensitive sites. In the late 1990s, ecotourism became increasingly popular, with many 'green' travel groups attempting to make entire holiday packages ecologically sound.

Ecotourism: Positive Strategy or Marketing Ploy?

introduction

'Ecotourism' is sometimes regarded as a rather nebulous term used to give tourism greater respectability. The Ecotourism Society – an organization for professionals involved in tourism – defines ecotourism as 'responsible travel to natural areas that conserves the environment and sustains the well-being of local people'. Is this a genuinely attainable goal and deliberate strategy, or just another marketing ploy in an industry that is becoming ever more anxious to be perceived as credible and respectable? Tourism is a very diverse area of business, as it includes the development, management, and marketing not only of tours but also of destinations and travel facilities. It is becoming increasingly harder to monitor the movements and activities of tourists and travellers, as more choose to devise, plan, and undertake trips on their own, without the mediation of an agency or a tour organizer. How, then, in such a vast and diverse sector can responsible travel be encouraged and natural areas protected?

tourism distribution

In spite of the familiar, alluring advertisements of faraway places beside palm-fringed beaches, reached by sleek aeroplanes, holidays within our own country or quite nearby are still quite popular. This is particularly true of wealthy countries, such as the USA, or regions of a similar scale, such as the European Union (EU). Indeed, in most developed countries, domestic tourists put the most pressure on their own surroundings; international visitors, often receiving adverse press, are in fact in the minority and therefore impact less on the environment. It is in smaller and less affluent regions, especially in South America and in and around the Pacific, that international travellers have a disproportionate effect on the environment. So how can the ethos that underlies ecotourism reduce the impact of millions of domestic and inbound leisure and business travellers on the environment? Does that ethos even survive intact? Paradoxically, ecotourism has now become one of the most rapidly growing domains of the tourism industry, particularly in its outbound, exploratory sector. It is therefore often identified as a niche marketing slant that is effectively selling unique aspects of our ecosystem to tourists.

who are the ecotourists?

In practice, most 'ecotourists' are aged between 45 and 64 and fit, roughly speaking, within four categories. The 'hard core', as it were, are the professionals who have a vested interest in the environment, such as scientists and teachers. Dedicated travellers who seek to learn about places and people are the second group. The third group are mainstream tourists who are seeking new experiences and may happen to choose a trip to the Galapagos or to see the gorillas in Rwanda. Finally, there are the 'accidental' ecotourists who happen to include a tour to a natural site within their holiday trip, most of which is actually spent on the beach and by the bar. Precise figures are not easy to establish, but in the USA, tour operators estimate that between 4 and 6 million Americans now travel overseas annually (and so become international or outbound tourists) for nature-related trips. Popular destinations include Costa Rica and other places with exotic landscapes and wildlife. Within the USA there are an estimated 80 million birdwatchers and scores of enthusiastic scuba- and skin-divers, many of whom have an interest in marine wildlife. This data alone would indicate that there could potentially be a very large market for 'nature-based' holidays and activities.

profitability

Thus, ecotourism has the potential to make developing and less-known regions more profitable by creating a respectable market niche in them. That could be very positive because visitors bring in money that helps support such areas. Having been there, they may also exert pressure to help gain resources to protect an area and even help by contributing resources themselves. However, it appears that such direct benefits from visitors are limited. Research indicates that international visitors on ecotourism package holidays do not spend much money in the locality they are visiting other than on accommodation and on food. Most also expect comfort and convenience, which puts a lot of pressure on fragile environments. The tourism-carrying capacity of these areas is low and we are exceeding it in many fragile areas. The problem in attempting to make the impact of tourism more advantageous is that tourism does not function in a vacuum: people travel to work, move goods, live in, and extract a living from, the same environment. We have done so for so long that few places have remained totally unspoilt and 'natural'.

appreciation

Areas designated as 'protected' achieve that status because governments and other public, charitable, or private bodies have deemed supporting such a venture beneficial and valuable. It is also clear that many people cherish such places, to the extent that the National Trust, for example, now finds that fundraising for the purchase and protection of landscapes that are perceived as natural, distinctive, and high profile (such as Snowdonia in Wales) becomes easier than raising money for the restoration and maintenance of country houses. However, these areas must then earn some income to help pay for their management, for no matter what many visitors may think, all such places have to be managed today in order to cope with the impacts that visitors have, and will have, upon them, and that requires sufficient finance. Many people who go to fragile areas such as Antarctica, the Lake District in England, or the Yellowstone National Park in the USA, either do not appear to realize that they are wearing away the landscape, or refuse to accept this altogether. However, their impact is far-reaching and includes eroding the footpaths, causing fires, leaving litter that has to be removed, damaging indigenous plants, absorbing space for car parks, to name but a few. Tourism needs to become a vital source of income to offset the wear and tear that visitors cause and also to keep the landscape as we wish to see it.

potential solutions

If it is possible to awaken the consciences of more of us about the impact we make on the landscape and on the environment in general as we travel, then any emphasis on responsible tourism that helps to reduce the wear and tear on these fragile locations should be encouraged. The tourism industry does use the uniqueness of natural areas as a means of marketing tours such as those to Antarctica and Nepal. The industry can do much to help us consider the environmental implications of our travel by, for example, choosing appropriate approaches to sell such trips. The public sector, as legislators and managers of many fragile areas, can also help by limiting access whenever that is viable. The final test of responsible tourism may be the use of pricing strategies: as the conservation of fragile areas depends on limited access, visitors may find camp sites and other accommodation expensive, seemingly out of proportion to the facilities offered on-site. You will pay the price and so make it clear that you value the place to which you are going.

Ecotourism Explorer

Go to site

Attractive home page of the International Ecotourism Society. The Web site outlines the society's goals and activities, and forms a useful gateway to ecotourism on the Internet. There are articles, announcements, and links to companies who offer environmentally friendly travel.

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ecstasy

or MDMA

(3,4-methylenedioxymethamphetamine) illegal recreational drug in increasing use since the 1980s. It is a modified amphetamine with mild psychedelic effects, and works by depleting serotonin (a neurotransmitter) in the brain. The effects of the drug are to intensify the perception of colour, sound, and even emotion in a user, which can last up to six hours, depending on the dose taken. The comedown from the drug causes lethargy and depression that can persist for several weeks. It has been found that ecstasy permanently reduces serotonin levels, but most of its other long-term effects are unknown.

An international study carried out by the University of Newcastle upon Tyne, England, in 2004 reported that ecstasy users were 23% more likely to suffer long-term memory loss that non-users. A United Nations report in 2003 showed that some 8 million people worldwide used the drug.

Ecstasy was first synthesized in 1914 by the Merck pharmaceutical company in Germany, and was one of eight psychedelics tested by the US army in 1953, but was otherwise largely forgotten until the mid-1970s. It can be synthesized from nutmeg oil. Since 1996 chemical recipes for making the drug have been circulated on the Internet.

ecstasy

Ecstasy was used originally as an appetite suppressant by German troops during World War I.

Ecstasy.org

Go to site

Huge clearing house for information on this popular recreational drug. This includes instructions for paramedics and hospital staff, how to get an ecstasy sample chemically assessed, how to recognize danger signs, notes on the dance-music scene, and what to do if arrested for possession. On the question of the dangers of the drug, the site is noncommittal, presenting a huge sample of contradictory scientific opinion.

ECT

abbreviation for electroconvulsive therapy.

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ectoparasite

parasite that lives on the outer surface of its host.

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ectopic

in medicine, term applied to an anatomical feature that is displaced or found in an abnormal position. An ectopic pregnancy is one occurring outside the womb, usually in a Fallopian tube.

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ectoplasm

outer layer of a cell's cytoplasm, as opposed to the inner endoplasm.

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ectotherm

'cold-blooded' animal (see poikilothermy), such as a lizard, that relies on external warmth (ultimately from the Sun) to raise its body temperature so that it can become active. To cool the body, ectotherms seek out a cooler environment.

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eczema

inflammatory skin condition, a form of dermatitis, marked by dryness, rashes, itching, the formation of blisters, and the exudation of fluid. It may be allergic in origin and is sometimes complicated by infection.

Eddington, Arthur Stanley (1882-1944)

English astrophysicist who studied the motions, equilibrium, luminosity, and atomic structure of the stars. In 1919 his observation of stars during a solar eclipse confirmed German-born US physicist Albert Einstein's prediction that light is bent when passing near the Sun, in accordance with the general theory of relativity. In *The Expanding Universe* (1933) Eddington expressed the theory that in the spherical universe the outer galaxies, or spiral nebulae, are receding from one another.

Eddington discovered the fundamental role of radiation pressure in the maintenance of stellar equilibrium, explained the method by which the energy of a star moves from its interior to its exterior, and in 1924 showed that the luminosity of a star depends almost exclusively on its mass - a discovery that caused a complete revision of contemporary ideas on stellar evolution.

Eddington, Arthur Stanley

Go to site

Devoted to the life and contributions of astrophysicist Arthur Eddington. In addition to biographical information, you will find a list of references about Eddington and links to essays that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Eddington. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

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eddy current

electric current induced, in accordance with Faraday's laws of electromagnetic induction, in a conductor located in a changing magnetic field. Eddy currents can cause much wasted energy in the cores of transformers and other electrical machines.

Edelman, Gerald Maurice (1929-)

US biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1972 with Rodney Porter for their work on the chemical structure of antibodies. Edelman worked out the sequence of the 1,330 amino acids that makes up human immunoglobulin, a task completed in 1969. He is head of the Neurosciences Institute, La Jolla, California.

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edelweiss

perennial alpine plant belonging to the daisy family, with a white, woolly, star-shaped flower, found in the high mountains of Europe and Asia. (*Leontopodium alpinum*, family Compositae.)

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edge

in topology, link on a topological map. Where edges meet and intersect, nodes are formed.

Edison, Thomas Alva (1847-1931)

US scientist and inventor, whose work in the fields of communications and electrical power greatly influenced the world in which we live. With more than 1,000 patents, Edison produced his most important inventions in Menlo Park, New Jersey 1876-87, including the phonograph. He obtained a US patent for the electric light bulb in 1879. He also constructed a system of electric power distribution for consumers, the telephone transmitter, and the megaphone.

telegraphy and telephony

Edison's first success came in the area of telegraphy. Perceiving the need for rapid communications after the Civil War, his first invention was an automatic repeater for telegraphic messages. He then invented a tape machine called a 'ticker', which communicated stock exchange prices across the country.

Turning his attention to the transmission of the human voice over long distances in 1876, he patented an electric transmitter system that proved to be less commercially successful than the telephone of Bell and Gray, patented a few months later. Undeterred, Edison set about improving their system, culminating in his invention of the carbon transmitter, which so increased the volume of the telephone signal that it was used as a microphone in the Bell telephone.

the light bulb

While experimenting with the carbon microphone in the 1870s, Edison had toyed briefly with the idea of using a thin carbon filament as a light source in an incandescent electric lamp. He returned to the idea in 1879. His first major success came on 19 October of that year when, using carbonized sewing cotton mounted on an electrode in a vacuum (one millionth of an atmosphere), he obtained a source that remained aglow for 45 hours without overheating - a major problem with all other materials used. He and his assistants tried 6,000 other organic materials before finding a bamboo fibre that gave a bulb life of 1,000 hours. In 1878 English physicist Joseph Swan had also developed an electric lamp, and after a legal wrangle the joint company Edison and Swan United Electric Light Company came into being in 1883.

generators and the first power stations

To produce a serious rival to gas illumination, a power source was required as well as a cheap and reliable lamp. The alternatives were either generators or heavy and expensive batteries. At that time, the best generators rarely converted more than 40% of the mechanical energy into electrical energy. Edison's first generator consisted of a drum armature of soft iron wire and a simple bi-polar magnet, and was designed to operate one arc lamp and some incandescent lamps in series.

A few months later he built a much more ambitious generator, the largest built to date, weighing 500 kg/1,103 lb and with an efficiency of 82%. Edison's team were at the forefront of development in generator technology over the next decade, during which efficiency was raised above 90%. To complete his electrical system he designed cables to carry power into the home from small (by modern standards) generating stations, and also invented an electricity meter to record its use.

the phonograph

In 1877 he began the era of recorded sound by inventing the phonograph, a device in which the vibrations of the human voice were engraved by a needle on a revolving cylinder coated with tin foil.

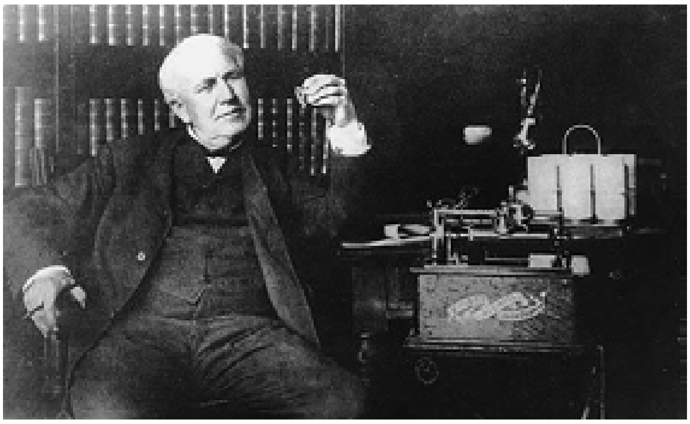
Edison, Thomas Alva: light bulb

Thomas Edison's invention of the light bulb did not meet with universal approval. When a British Parliamentary Committee was set up in the late 1870s to investigate its potential value, the report described it as 'good enough for our transatlantic friends... but unworthy of the attention of practical or scientific men'.

Edison, Thomas Alva: tribute

When Thomas Edison, inventor of the light bulb, died (on 18 October 1931), all non-essential electric lights in the USA - including the torch on the Statue of Liberty - were turned off for one minute.

Edison



(Image © Billie Love)

US inventor Thomas Edison, who became known internationally after his invention of the phonograph (pictured). His original instrument used a cylinder coated with tinfoil to record sounds and was patented in 1878. Edison did not initially think of using the machine to record music for pleasure but as an office dictating machine.

Inventing Entertainment: The Early Motion Pictures of the Edison Company

Go to site

Part of the American Memory presentation of the US Library of Congress, this collection was designed in celebration of US inventor Thomas Edison's 150th birthday. It includes eight motion pictures produced by the Edison Manufacturing Company, including *The Great Train Robbery*. Each film has a brief description. This site includes a brief biography of Edison, plus information on the Edison Manufacturing Company and the advent of motion pictures. In addition, there is information on sound recordings and the invention of the phonograph. The site organizers plan to add samples of early sound recordings soon.

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educational psychology

the work of psychologists primarily in schools, including the assessment of children with achievement problems and advising on problem behaviour in the classroom.

EEG

abbreviation for electroencephalogram.

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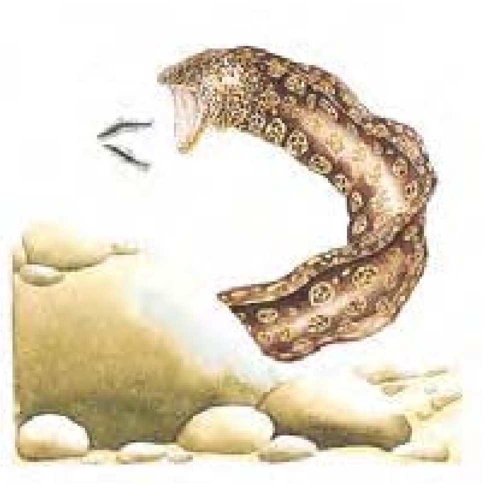
eel

any fish of the order Anguilliformes. Eels are snakelike, with elongated dorsal and anal fins. They include the freshwater eels of Europe and North America (which breed in the Atlantic), the marine conger eels, and the morays of tropical coral reefs.

The gulper eel, *Eurypharynx pelecanoides*, is found in all the world's oceans to depths of 3,000 m/9,800 ft. It has a huge mouth and a long whiplike tail, and can reach up to 2 m/6.6 ft in length.

eel



(Image © Research Machines plc)

There are about 100 species of moray eels found throughout tropical and temperate seas. They generally lurk in rocky crevices from where they can ambush their prey, usually hunting by night. Some morays can reach over 4 m/13 ft in length and, because of their aggression, are considered dangerous to divers.

eelgrass

or tape grass or glass wrack

any of several aquatic plants, especially *Zostera marina*. Eelgrass is found in tidal mud flats and is one of the few flowering plants to adapt to marine conditions, being completely submerged at high tide.
(Genus *Zostera*, family Zosteraceae.)

EEPROM

acronym for Electrically Erasable Programmable Read-Only Memory

computer memory that can record data and retain it indefinitely. The data can be erased with an electrical charge and new data recorded.

Some EEPROM must be removed from the computer and erased and reprogrammed using a special device. Other EEPROM, called **flash memory**, can be erased and reprogrammed without removal from the computer.

Effelsberg

site, near Bonn, Germany, of the 100-m/328-ft radio dish of the Max Planck Institute for Radio Astronomy, opened in 1971. It was the world's largest fully steerable radio telescope until the building of the Green Bank Telescope (GBT) at Green Bank, West Virginia, USA.

efficiency

in physics, a general term indicating the degree to which a process or device can convert energy from one form to another without loss, or how effectively energy is used, and wasted energy, such as heat and sound, minimized. It is normally expressed as a fraction or a percentage, where 100% indicates conversion with no loss. The efficiency of a machine, for example, is the ratio of the energy output to the energy input; in practice it is always less than 100% because of frictional heat losses.

For example, 75% of the electrical energy of an electric light bulb is converted into heat and only 25% is converted into light. Therefore, an electric light bulb is not an efficient energy converter. Certain electrical machines with no moving parts, such as transformers, can approach 100% efficiency.

EFTPOS

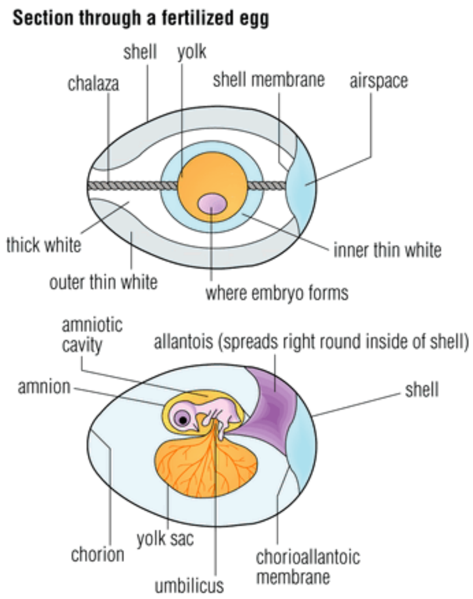
acronym for **electronic funds transfer at point of sale**, a form of electronic funds transfer.

egg

in animals, the ovum, or female gamete (reproductive cell).

After fertilization by a sperm cell, it begins to divide to form an embryo. Eggs may be deposited by the female (ovipary) or they may develop within her body (vivipary and ovovivipary). In the oviparous reptiles and birds, the egg is protected by a shell, and well supplied with nutrients in the form of yolk.

egg


Section through a fertilized egg
shell
yolk
chalaza
shell membrane
airspace
thick white
inner thin white
outer thin white
where embryo forms
amniotic cavity
allantois (spreads right round inside of shell)
amnion
shell
yolk sac
chorion
chorioallantoic membrane
umbilicus

(Image © Research Machines plc)

Section through a fertilized bird egg. Inside a bird's egg is a complex structure of liquids and membranes designed to meet the needs of the growing embryo. The yolk, which is rich in fat, is gradually absorbed by the embryo. The white of the egg provides protein and water. The chalaza is a twisted band of protein which holds the yolk in place and acts as a shock absorber. The airspace allows gases to be exchanged through the shell. The allantois contains many blood vessels which carry gases between the embryo and the outside.

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eggar-moth

large reddish-brown moth with a highly developed hindwing. The length across the wings is 3.8-11.5 cm/1.5-4.5 in.

The walls of the cocoons sometimes have a smooth, shell-like appearance, hence the name.

classification

The eggar-moth in the family Lasiocampidae, order Lepidoptera, class Insecta, phylum Arthropoda.

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eggplant

perennial plant, *Solanum melongena*, a member of the nightshade family Solanaceae, originally native to tropical Asia. Its purple-skinned fruits are eaten as a vegetable.

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ego

(Latin 'I')

in psychology, the processes concerned with the self and a person's conception of himself or herself, encompassing values and attitudes. In Freudian psychology, the term refers specifically to the element of the human mind that represents the conscious processes concerned with reality, in conflict with the id (the instinctual element) and the superego (the ethically aware element).

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egret

any of several herons with long tufts of feathers on the head or neck. They belong to the order Ciconiiformes.

Ehrlich, Paul (1854-1915)

German bacteriologist and immunologist who was awarded a Nobel Prize for Physiology or Medicine in 1908 with Ilya Mechnikov for their work on immunity. He produced the first cure for syphilis, developing the arsenic compounds, in particular Salvarsan, that were used in the treatment of syphilis before the discovery of antibiotics.

Ehrlich founded chemotherapy – the use of a chemical substance to destroy disease organisms in the body. He was also one of the earliest workers on immunology, and through his studies on blood samples the discipline of haematology was recognized.

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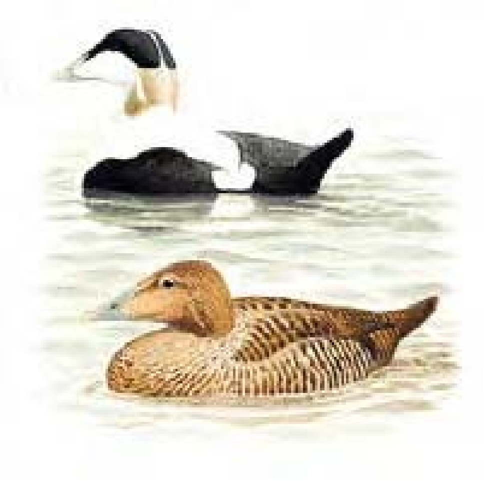
eider

large marine duck of the genus *Somateria*, family Anatidae, order Anseriformes. They are found on the northern coasts of the Atlantic and Pacific oceans. The **common eider** *S. molissima* is highly valued for its soft down, which is used in quilts and cushions for warmth. The adult male has a black cap and belly and a green nape. The rest of the plumage is white with a pink breast and throat, while the female is a mottled brown. The bill is large and flattened and both bill and feet are olive green.

Other species are the **king eider-duck** *S. spectablis*, **Steller's eider** *Polysticta stelleri*, and the **spectacled eider** *S. fischeri*.

eider



(Image © Research Machines plc)

Eider ducks are robustly built sea ducks that dive in shallow waters to feed on shellfish and even crabs. The female plucks the soft downy feathers from her breast and uses them to line the nest. Sitting eiders will allow humans to approach the nest without deserting. The bold markings of the male and the heavy-based bill make this duck easy to identify.

Eiffel, (Alexandre) Gustave (1832-1923)

French engineer who constructed the **Eiffel Tower** for the 1889 Paris Exhibition. The tower, made of iron, is 320 m/1,050 ft high and stands in the Champ de Mars, Paris. Sightseers may ride to the top for a view.

Eiffel set up his own business in Paris in 1867 and quickly established his reputation with the construction of a series of ambitious railway bridges, of which the span across the Douro at Oporto, Portugal, was the longest at 160 m/525 ft. In 1881 he provided the iron skeleton for the Statue of Liberty.

Tour Eiffel

Go to site

History, technical details, and practical information about the Eiffel Tower. There are also some bizarre facts about the Tower. Visitors are warned of the prohibitive cost of dining atop the Tower.

Eijkman, Christiaan (1858-1930)

Dutch bacteriologist who was awarded a Nobel Prize for Physiology or Medicine in 1929 for his discovery of a cure for beriberi, a vitamin-deficiency disease. He pioneered the recognition of vitamins as essential to health and identified vitamin B_1 deficiency as the cause of beriberi. He shared the prize with Frederick Gowland Hopkins, who received the award for his discovery of trace substances, now known as vitamins, that stimulate growth.

Einstein, Albert (1879-1955)

German-born US physicist whose theories of relativity revolutionized our understanding of matter, space, and time. Einstein established that light may have a particle nature. He was awarded the Nobel Prize for Physics in 1921 for his work on theoretical physics, especially the **photoelectric law**. He also investigated Brownian motion, confirming the existence of atoms. His last conception of the basic laws governing the universe was outlined in his unified field theory, made public in 1953.

Brownian motion

Einstein's first major achievement concerned Brownian movement, the random movement of fine particles that can be seen through a microscope, which was first observed in 1827 by Robert Brown when studying a suspension of pollen grains in water. The motion of the pollen grains increased when the temperature increased but decreased if larger particles were used. Einstein explained this phenomenon as being the effect of large numbers of molecules (in this case, water molecules) bombarding the particles. He was able to make predictions of the movement and sizes of the particles, which were later verified experimentally by the French physicist Jean Perrin. Einstein's explanation of Brownian motion and its subsequent experimental confirmation was one of the most important pieces of evidence for the hypothesis that matter is composed of atoms. Experiments based on this work were used to obtain an accurate value of Avogadro's number (the number of atoms in one mole of a substance) and the first accurate values of atomic size.

the photoelectric effect and the Nobel Prize

Einstein's work on photoelectricity began with an explanation of the radiation law proposed in 1901 by Max Planck: $E = hv$, where E is the energy of radiation, h is Planck's constant, and v is the frequency of radiation. Einstein suggested that packets of light energy are capable of behaving as particles called 'light quanta' (later called photons). Einstein used this hypothesis to explain the photoelectric effect, proposing that light particles striking the surface of certain metals cause electrons to be emitted. It had been found experimentally that electrons are not emitted by light of less than a certain frequency v^0; that when electrons are emitted, their energy increases with an increase in the frequency of the light; and that an increase in light intensity produces more electrons but does not increase their energy. Einstein suggested that the kinetic energy of each electron, $1/2mv^2$, is equal to the difference in the incident light energy, hv, and the light energy needed to overcome the threshold of emission, hv^0. This can be written mathematically as: $1/2mv^2 = hv - hv^0$

the speed of light and the special theory of relativity

The **special theory of relativity** started with the premises that (1) the laws of nature are the same for all observers in unaccelerated motion, and (2) the speed of light is independent of the motion of its source. Until then, there had been a steady accumulation of knowledge that suggested that light and other electromagnetic radiation does not behave as predicted by classical physics. For example, various experiments, including the **Michelson-Morley experiment**, failed to measure the expected changes in the speed of light relative to the motion of the Earth. Such experiments are now interpreted as showing that no 'ether' exists in the universe as a medium to carry light waves, as was required by classical physics. Einstein recognized that light has a measured speed that is independent of the speed of the observer. Thus, contrary to everyday experience with phenomena such as sound waves, the velocity of light is the same for an observer travelling at high speed *towards* a light source as it is for an observer travelling rapidly *away* from the light source. To Einstein it followed that, if the speed of light is the same for both these observers, the time and distance framework they use to measure the speed of light cannot be the same. Time and distance vary, depending on the velocity of each observer. From the notions of relative motion and the constant velocity of light, Einstein derived the result that, in a system in motion relative to an observer, length would be observed to decrease, time would slow down, and mass would increase. The magnitude of these effects is negligible at ordinary velocities and Newton's laws still hold good. But at velocities approaching that of light, they become substantial. As a system approaches the velocity of light, relative to an observer at rest, its length decreases towards zero, time slows almost to a stop, and its mass increases without limit. Einstein therefore concluded that no system can be accelerated to a velocity equal to or greater than the velocity of light. Einstein's conclusions regarding time dilation and mass increase were verified with observations of fast-moving atomic clocks and cosmic rays. Einstein showed in 1907 that mass is related to energy by the famous equation $E=mc^2$, which indicates the enormous amount of energy that is stored as mass, some of which is released in radioactivity and nuclear reactions, for example in the Sun.

gravity and the general theory of relativity

In the **general theory of relativity** (1916), the properties of space-time were to be conceived as modified locally by the presence of a body with mass; and light rays should bend when they pass by a massive object. A planet's orbit around the Sun arises from its natural trajectory in modified space-time. General relativity theory was inspired by the simple idea that it is impossible in a small region to distinguish between acceleration and gravitation effects (as in a lift one feels heavier when it accelerates upwards). Einstein used the general theory to account for an anomaly in the orbit of the planet Mercury that could not be explained by Newtonian mechanics. Furthermore, the general theory made two predictions concerning light and gravitation. The first was that a red shift is produced if light passes through an intense gravitational field, and this was subsequently detected in astronomical observations in 1925. The second was a prediction that the apparent positions of stars would shift when they are seen near the Sun because the Sun's intense gravity would bend the light rays from the stars as they pass the Sun. Einstein was triumphantly vindicated when observations of a solar eclipse in 1919 showed apparent shifts of exactly the amount he had predicted.

Einstein, Albert

Einstein collaborated with Hungarian physicist Leo Szilard on a number of designs for a refrigerator. A series of patents was taken out in their names, although nothing was actually developed commercially.

relativity

The manuscript for Einstein's special theory of relativity sold for $5 million in 1996.

Science in Britain in the 20th Century

introduction

As the 20th century began, Britain was slowly awakening to the realisation that the world's first industrial power had not only lost its pre-eminence, but was sliding down the international technological rankings, In part this could be traced to the industrial revolution, which owed very little to university research or scientists. Indeed, the great engineer Sir John Rennie recorded that his father dissuaded him from going to Oxford or Cambridge on the grounds that it would make him unfit for practical work. The industrial world was, however, changing. The new, huge chemical industry was dominated by Germany, a country with some 4000 graduate chemists - Britain could scarcely muster half that number for the entire range of sciences. The universities were still dominated by the public schools, and science was very much a poor relation. In 1913, the USA had four science students per 10,000 of population, Britain only 1.6. It was clear that if Britain was to be internationally competitive, industry must employ more scientists, and more young people would need to turn to science. To attract the best minds, science had to be seen to be both relevant and intellectually exciting. Fortunately, in the 20th century, physicists in Britain were to be seen as among those tackling some of the greatest challenges the world has known.

achievements in physics

Einstein's theory of relativity, with its fundamental challenge to Newtonian physics and its revolutionary reappraisal of the relationship of space and time, excited the world in a way no scientific theory had done since Darwin. But, for a time, it remained just that - a theory that still required experimental proof. That proof was supplied in 1919 by Arthur Eddington, Professor of Astronomy at Cambridge. The theory predicted that light passing a massive object such as the sun, would be bent by a calculable amount. Eddington's measurements made during a solar eclipse triumphantly confirmed Einstein's theoretical figures: 'Some of the most beautiful results that science has produced', as Einstein himself proclaimed. Relativity established, speculation turned to such fundamental questions as the origins of the universe itself. One of the earliest theorists was Fred Hoyle, who supported a steady-state model, in which matter was continuously created. Even if now discredited, the theory opened up debate, in which the Big Bang came out as the winner. Cosmologists have also had to take into account one of the century's other great ideas - quantum theory - and among those who have wrestled with the problems of uniting this theory with relativity, Stephen Hawking has been pre-eminent. The theories of the universe continue to give scientists some of their greatest challenges. Yet it is in work on a very different scale, in molecular and particle physics, that advances have impinged most directly on everyday life, and in these areas the work of British scientists has been crucial.

splitting the atom

By the end of the 19th century, J J Thomson had succeeded in identifying the electron, the first subatomic particle to be isolated. At the start of the new century, he was joined at the Cavendish Laboratory, Cambridge, by a young New Zealander, Ernest Rutherford, who advanced the work, demonstrating that the electron had a definite mass. Further investigation with the positively-charged alpha particles produced in radioactive decay, enabled him to produce a new model for the atom, consisting of a nucleus of heavy, positively charged particles, protons, around which the tiny electrons whirled. In 1932, when James Chadwick established the existence of neutrons in the nucleus, the atomic model seemed complete. We now know that the atom is a good deal more complex than that, but by splitting the atom in 1919, Rutherford had opened the way to a vast array of new subjects.

paving the way for genetic engineering

Even before the nature of the electron was known, the science of electronics had found practical uses. John Alexander Fleming's diode valve marked a start. In pre-transistor days they were essential components in radio equipment and in the first cumbersome electronic computers. Other developments may not have had such immediately obvious appeal, but scientists were acquiring essential tools for investigating the structures of atoms and molecules. Thomson's assistant, Francis William Aston, devised the mass spectrograph, soon an indispensable tool in organic chemistry analysis. William and Lawrence Bragg - the only father and son to receive a joint Nobel prize - developed X-ray crystallography for solving complex molecular structures. This process culminated in the unravelling of the basic genetic material DNA by Francis Crick and James D Watson in 1953. The results of this work can be seen in genetic engineering and phenomena that were once present only in the realms of science fiction, such as the cloned sheep Dolly.

cooperation and training

British physicists have been, and are, major players on the world stage, but there have been other equally notable achievements in other sciences. To select just one name from among many, can there have been a more valuable contribution to human health in the 20th century than Alexander Fleming's discovery of penicillin? It has, however, become increasingly difficult to talk of any science in terms of national contributions. Particle physics research has become so hugely expensive that projects such as JET in England, investigating nuclear fusion, and CERN on the Swiss-French border, housing a vast particle accelerator, are the results of European cooperation. If at the beginning of the century, the pattern of education showed the sciences as being the poor relation, the position had been transformed at the end. One notable trend is the increased numbers of women studying science at university level. In medicine, dentistry and allied subjects, female students outnumbered men for the first time in 1995, and even in such traditionally male oriented subjects as engineering and technology, women represent around 20% of all students. Science and technology students make up nearly half the student body, but the changes have not been uniform. Whereas in the past, universities seemed slow to respond to change, they now reflect the outside world more accurately. In 1985 there were no courses in computer science; ten years later there were over 50,000 students. Even the less obviously commercial subjects, such as the physical sciences, have seen dramatic increases.

conclusion

Did the role of the scientist in Britain change over the century? Clearly it did, even if British companies regularly spend less on research than their competitors. Paradoxically, as the scientific method has shown itself to be one of the most powerful inventions of the human brain, science itself has become more and more distrusted. Atomic and chemical weapons, nuclear power and genetic engineering are seen as products of a mad, Frankensteinian world, and for every one who contemplates the nature of a black hole, there are hundreds who consult horoscopes. The challenge now seems to be to provide science with a moral framework, and to make scientific ideas comprehensible to a larger public.

Einstein's Legacy

Go to site

Illustrated introduction to the man and his greatest legacy - relativity and the concept of space-time. There is a video- and audio-clip version of the page courtesy of a US scientist and details about how current research is linked to Einstein's revolutionary ideas.

Einstein: Still Right After All These Years

Go to site

Easy-to-understand explanation of some of Einstein's theories. The explanations are grouped under several headings, such as: 'The speed of light', 'Black holes', and 'Gravity'.

Life and Theories of Albert Einstein

Go to site

Heavily illustrated site on the life and theories of Einstein. There is an illustrated biographical chart, including a summary of his major achievements and their importance to science. The theory of relativity gets an understandably more in-depth coverage, along with photos and illustrations. The pages on his theories on light and time include illustrated explanations and an interactive test. There is also a 'Time-traveller' game demonstrating these theories.

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einsteinium

chemical symbol Es

synthesized, radioactive, metallic element of the actinide series, atomic number 99, relative atomic mass 254.09.

It was produced by the first thermonuclear explosion, in 1952, and discovered in fallout debris in the form of the isotope Es-253 (half-life 20 days). Its longest-lived isotope, Es-254, with a half-life of 276 days, allowed the element to be studied at length. It is now synthesized by bombarding lower-numbered transuranic elements in particle accelerators. It was first identified by US chemist Albert Ghiorso and his team who named it in 1955 after Albert Einstein, in honour of his theoretical studies of mass and energy.

Einthoven, Willem (1860-1927)

Dutch physiologist who was awarded a Nobel Prize for Physiology or Medicine in 1924 for his invention of the electrocardiograph. He demonstrated that certain disorders of the heart alter its electrical activity in characteristic ways.

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ejecta

in astronomy, any material thrown out of a crater due to volcanic eruption or the impact of a meteorite or other object. Ejecta from impact craters on the Moon often form long bright streaks known as rays, which in some cases can be traced for thousands of kilometres across the lunar surface.

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ejector seat

device for propelling an aircraft pilot out of the plane to parachute to safety in an emergency, invented by the British engineer James Martin (1893-1981). The first seats of 1945 were powered by a compressed spring; later seats used an explosive charge. The British company Martin-Baker, a pioneer of ejector seats, claim that by the end of 2003 their seats had saved 7028 lives.

Seats that can be ejected on takeoff and landing or at low altitude were a major breakthrough of the 1980s. They are as effective as those originally designed for parachuting from high altitudes.

Ekman spiral effect

in oceanography, theoretical description of a consequence of the Coriolis effect on ocean currents, whereby currents flow at an angle to the winds that drive them. It derives its name from the Swedish oceanographer Vagn Ekman (1874-1954).

In the northern hemisphere, surface currents are deflected to the right of the wind direction. The surface current then drives the subsurface layer at an angle to its original deflection. Consequent subsurface layers are similarly affected, so that the effect decreases with increasing depth. The result is that most water is transported at about right-angles to the wind direction. Directions are reversed in the southern hemisphere.

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eland

largest species of antelope, *Taurotragus oryx*. Pale fawn in colour, it is about 2 m/6 ft high, and both sexes have spiral horns about 45 cm/18 in long. It is found in central and southern Africa.

Elasmobranchii

subclass of class Chondrichthyes (cartilaginous fish), which includes the sharks and rays. They are characterized by having five to seven pairs of gill clefts that open separately to the exterior and are not covered by a protective fold of skin.

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elasticity

in physics, the ability of a solid to recover its shape once deforming forces are removed. An elastic material obeys Hooke's law, which states that its deformation is proportional to the applied stress up to a certain point, called the **elastic limit**; beyond this point additional stresses will deform it permanently. Elastic materials include metals and rubber; however, all materials have some degree of elasticity.

E-layer

formerly Kennelly-Heaviside layer

lower regions (90–120 km/56–75 mi) of the ionosphere, which reflect radio waves, allowing their reception around the surface of the Earth. The E-layer approaches the Earth by day and recedes from it at night.

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elder

in botany, any of a group of small trees or shrubs belonging to the honeysuckle family, native to North America, Europe, Asia, and North Africa. Some are grown as ornamentals for their showy yellow or white flower clusters and their colourful black or scarlet berries. (Genus *Sambucus*, family Caprifoliaceae.)

The American elder (*Sambucus canadensis*) reaches tree size and has blue berries. The common elder (*S. nigra*) of Europe, North Africa, and western Asia has pinnate leaves (leaflets growing either side of a stem) and heavy heads of small, sweet-scented, white flowers in early summer. These are followed by clusters of small, black, shiny berries. The scarlet-berried *S. racemosa* is found in parts of Europe, Asia, and North America.

Elder

Go to site

Immensely informative resource relating to the elder. It contains a detailed description of the plant, as well as its place in history. There are also notes on the constituents and uses of the bark, leaves, and flowers of the elder. There are even a number of recipes that make use of the elder, including elderberry chutney.

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electrical relay

an electromagnetic switch; see relay.

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electric arc

a continuous electric discharge of high current between two electrodes, giving out a brilliant light and heat. The phenomenon is exploited in the carbon-arc lamp, once widely used in film projectors. In the electric-arc furnace an arc struck between very large carbon electrodes and the metal charge provides the heating. In arc welding an electric arc provides the heat to fuse the metal. The discharges in low-pressure gases, as in neon and sodium lights, can also be broadly considered as electric arcs.

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electric cell

device in which chemical energy is converted into electrical energy; see cell, electrical.

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electric charge

property of some bodies that causes them to exert forces on each other. Two bodies both with positive or both with negative charges repel each other, whereas bodies with opposite or 'unlike' charges attract each other. Electrons possess a negative charge, and protons an equal positive charge. The SI unit of electric charge is the coulomb (symbol C).

A body can be charged by friction, induction, or chemical change, and the charge shows itself as an accumulation of electrons (negative charge) or a loss of electrons (positive charge) on an atom or body. Atoms generally have zero net charge but can gain electrons to become negative ions or lose them to become positive ions. So-called static electricity, seen in such phenomena as the charging of nylon shirts when they are pulled on or off, or in brushing hair, is in fact the gain or loss of electrons from the surface atoms. A flow of charge (such as electrons through a copper wire) constitutes an electric current; the flow of current is measured in amperes (symbol A).

Static Electricity

Go to site

Excellent site, explaining the theory simply, but thoroughly. It also includes several easy-to-do experiments to demonstrate the theory behind static electricity.

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electric current

flow of electrically charged particles through a conducting circuit due to the presence of a potential difference. The current at any point in a circuit is the amount of charge flowing per second; its SI unit is the ampere (coulomb per second).

Current carries electrical energy from a power supply, such as a battery of electrical cells, to the components of the circuit, where it is converted into other forms of energy, such as heat, light, or motion. It may be either direct current or alternating current.

heating effect

When current flows in a component possessing resistance, electrical energy is converted into heat energy. If the resistance of the component is R ohms and the current through it is I amperes, then the heat energy W (in joules) generated in a time t seconds is given by the formula: $W = I^2Rt$.

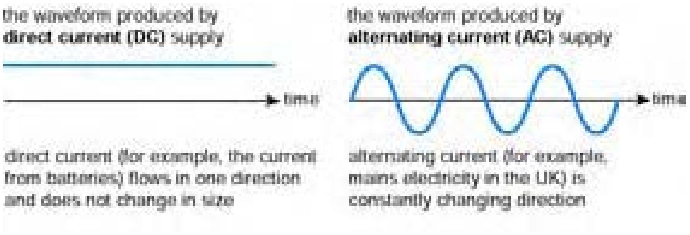
magnetic effect

A magnetic field is created around all conductors that carry a current. When a current-bearing conductor is made into a coil it forms an electromagnet with a magnetic field that is similar to that of a bar magnet, but which disappears as soon as the current is switched off. The strength of the magnetic field is directly proportional to the current in the conductor – a property that allows a small electromagnet to be used to produce a pattern of magnetism on recording tape that accurately represents the sound or data stored. The direction of the field created around a conducting wire may be predicted by using Maxwell's screw rule.

motor effect

A conductor carrying current in a magnetic field experiences a force, and is impelled to move in a direction perpendicular to both the direction of the current and the direction of the magnetic field. The direction of motion may be predicted by Fleming's left-hand rule (see Fleming's rules). The magnitude of the force experienced depends on the length of the conductor and on the strengths of the current and the magnetic field, and is greatest when the conductor is at right angles to the field. A conductor wound into a coil that can rotate between the poles of a magnet forms the basis of an electric motor.

electric current


the waveform produced by **direct current (DC)** supply
time
direct current (for example, the current from batteries) flows in one direction and does not change in size
the waveform produced by **alternating current (AC)** supply
time
alternating current (for example, mains electricity in the UK) is constantly changing direction

(Image © Research Machines plc)

The patterns produced by a direct current and an alternating current on the screen of an oscilloscope.

Physics is Phun

Go to site

Colourful physics site aiming to prove that 'physics can be fun'. There are three sections, the 'Electrodynamics' section being most useful for GCSE physics. It contains several lessons covering topics such as 'Ohm's law' and 'Electric current' plus questions to test what has been learnt.

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electric eel

South American freshwater bony fish. It grows to almost 3 m/10 ft and the electric shock produced, normally for immobilizing prey, is enough to stun an adult human. Electric eels are not true eels.

classification

Electrophorus electricus is in the order Cypriniformes, class Osteichthyes.

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electric field

in physics, a region in which a particle possessing electric charge experiences a force owing to the presence of another electric charge. The strength of an electric field, *E*, is measured in volts per metre ($V m^{-1}$). It is a type of electromagnetic field.

An electric field is formed between two metal plates that are parallel to each other and connected to a voltage supply. An electron beam moving through these plates will be deflected slightly towards the positive plate.

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electric fish

any of several unrelated fishes that have electricity-producing powers, including the South American 'electric eel'. These include *Electrophorus electricus*, which is not a true eel, and in which the lateral tail muscles are modified to form electric organs capable of generating 650 volts; the current passing from tail to head is strong enough to stun another animal. Not all electric fishes produce such strong discharges; most use weak electric fields to navigate and to detect nearby objects.

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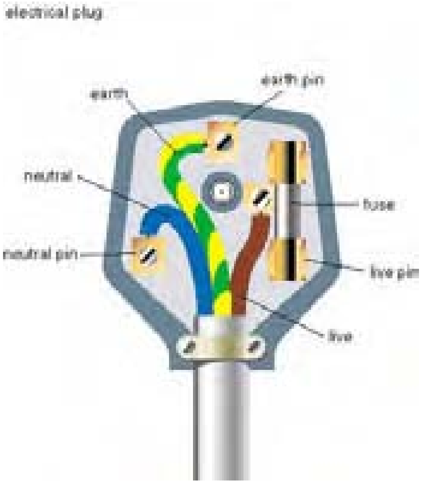
electricity

all phenomena caused by electric charge. There are two types of electricity: static and current. Electric charge is caused by an excess or deficit of electrons in a substance, and an electric current is the movement of charge through a material. Materials having equal numbers of positive and negative charges are termed neutral, as the charges balance out. Substances may be electrical conductors, such as metals, which allow the passage of electricity through them readily, or insulators, such as rubber, which are extremely poor conductors. Substances with relatively poor conductivities that increase with a rise in temperature or when light falls on the material are known as semiconductors. Electric currents also flow through the nerves of organisms. For example, the optic nerve in humans carries electric signals from the eye to the brain. Electricity cannot be seen, but the effects it produces can be clearly seen; for example, a flash of lightning, or the small sparks produced by rubbing a nylon garment.

Electricity is essential to modern society. Electrical devices are used in the home, office, and industry; this is called mains electricity, and is measured in kilowatt hours. Electrical energy is used to power devices used for communications such as fax machines, telephones, computers, and satellites.

plug, three-pin



(Image © Research Machines plc)

The wiring in an electrical plug. The colours of the wires are used universally to represent the same things: earth is green and yellow, live is brown, and neutral is blue.

Circuit

Go to site

Site with helpful graphics and in-depth case studies of series and parallel circuits. There are also interactive questions included to test the user's knowledge, with answers available online at the press of a button.

Electricity and Magnetism

Go to site

Clearly presented explanation of 'electric charge', 'electromagnetism' and other aspects relating to this area of study.

Electricity Association

Go to site

Site of the Electricity Association (EA), the 'collective voice of the major electricity companies in the UK'. It details how the electricity industry in the UK works, provides a map of the UK electricity system, explains the EA's position towards the environment, and gives a list of power stations.

National Grid

Go to site

Home page of the National Grid Company plc, the owner and operator of the high-voltage electricity transmission system in England and Wales. The introduction provides a choice of seven sections to visit: 'Company', 'Financial', 'Activities', 'Environment', 'Media', 'Library', and 'FAQs'. Each section gives an insight into the company that provides one of the largest electricity services to the UK and abroad.

Verbund: Electricity Glossary

Go to site

Glossary containing definitions of a number of terms to do with electricity. The entries are divided into three sections, 'Basic terms', 'Units of measurement', and 'Engineering', and are explained in an easy-to-understand way.

What Is Electricity?

Go to site

Humorous article aiming to answer the question 'What is electricity?' It outlines the difficulties in defining electricity, with the use of clear examples. It then describes several ways that the term electricity is used, such as to mean electrical energy, electric field, or electric charge. Many of the key words in the text are linked to useful glossary definitions. The 'Applications' section demonstrates real-life applications of physics, such as the workings of the eye. There is also a 'Hall of fame' where those who answer the most quiz questions correctly can have their names posted.

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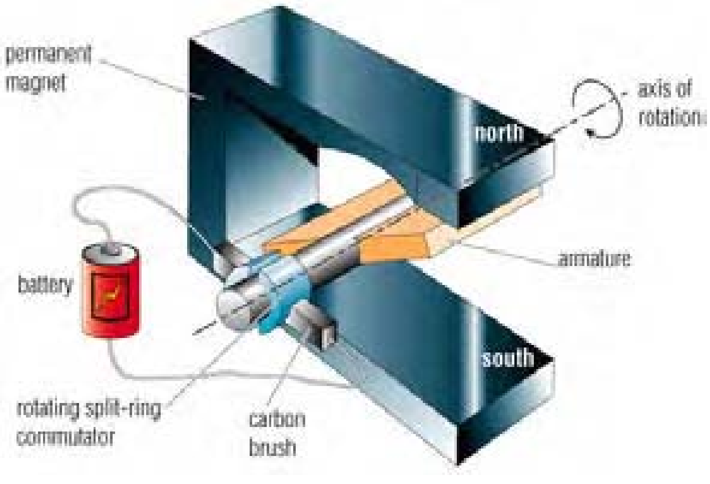
electric motor

machine that converts electrical energy into mechanical energy. There are various types, including direct-current and induction motors, most of which produce rotary motion. A linear induction motor produces linear (in a straight line) rather than rotary motion. Electric motors and generators have the same components; they differ in the way they are used.

A simple **direct-current motor** consists of a horseshoe-shaped permanent magnet with a wire-wound coil (armature) mounted so that it can rotate between the poles of the magnet. The ends of the wire are connected to a commutator. This reverses the current (from a battery) fed to the coil on each half turn, which rotates because of the mechanical force exerted on a conductor carrying a current in a magnetic field.

electric motor



(Image © Research Machines plc)

In an electric motor, magnetic fields generated by electric currents push against each other, causing a shaft (holding the armature) to rotate.

electric power

rate at which an electrical machine uses electrical energy or converts it into other forms of energy - for example, light, heat, or mechanical energy. Usually measured in watts (equivalent to joules per second), it is equal to the product of the voltage and the current flowing.

In a closed circuit the potential difference (voltage) causes electrons to flow towards the positive potential. Work is done in moving the electrons, and the rate at which this work is done is called the electrical power. If the voltage is V volts and the current is I amps, then the power, P watts, is given by $P = V \times I$

An electric lamp that passes a current of 0.4 amperes at 250 volts uses 100 watts of electrical power and converts it into light and heat - in ordinary terms it is a 100-watt lamp. An electric motor that requires 6 amperes at the same voltage consumes 1,500 watts (1.5 kilowatts), equivalent to delivering about 2 horsepower of mechanical power.

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electric ray

another name for the torpedo.

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electrocardiogram

ECG or EKG

graphic recording of the electrical changes in the heart muscle, as detected by electrodes placed on the chest. Electrocardiography is used in the diagnosis of heart disease.

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electrochemical series

or electromotive series

list of chemical elements arranged in descending order of the ease with which they can lose electrons to form cations (positive ions). An element can be displaced (displacement reaction) from a compound by any element above it in the series.

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electrochemistry

branch of science that studies chemical reactions involving electricity. The use of electricity to produce chemical effects, electrolysis, is employed in many industrial processes, such as electroplating, the manufacture of chlorine, and the extraction of aluminium. The use of chemical reactions to produce electricity is the basis of electrical cells, such as the dry cell and the Leclanché cell.

Since all chemical reactions involve changes to the electronic structure of atoms, all reactions are now recognized as electrochemical in nature. Oxidation, for example, was once defined as a process in which oxygen was combined with a substance, or hydrogen was removed from a compound; it is now defined as a process in which electrons are lost.

Electrochemistry is also the basis of new methods of destroying toxic organic pollutants. For example, electrochemical cells that operate with supercritical water (a type of supercritical fluid) have been developed to combust organic waste materials.

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electroconvulsive therapy

ECT; or electroshock therapy

treatment mainly for severe depression, given under anaesthesia and with a muscle relaxant. An electric current is passed through one or both sides of the brain to induce alterations in its electrical activity. The treatment can cause distress and loss of concentration and memory, and so there is much controversy about its use and effectiveness.

ECT was first used in 1938 but its success in treating depression lead to its excessive use for a wide range of mental illnesses against which it was ineffective. Its side effects included broken bones and severe memory loss.

The procedure in use today is much improved, using the minimum shock necessary to produce a seizure, administered under general anaesthetic with muscle relaxants to prevent spasms and fractures. It is the seizure rather than the shock itself that produces improvement. The smaller the shock administered the less damage there is to memory.

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electrocrystal diagnosis

technique developed by British biologist Harry Oldfield, based on the finding that stimulated electromagnetic fields of the human body resonate at a particular frequency which varies with individuals, and that actual or incipient disease can be pinpointed by a scanning device responsive to local deviations from the person's norm.

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electrode

any terminal by which an electric current passes in or out of a conducting substance; for example, the anode or cathode in an electrolytic cell. The anode is the positive electrode and the cathode is the negative electrode.

The terminals that emit and collect the flow of electrons in thermionic valves (electron tubes) are also called electrodes: for example, cathodes, plates (anodes), and grids.

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electrodynamics

branch of physics dealing with electric charges, electric currents, and associated forces. Quantum electrodynamics (QED) studies the interaction between charged particles and their emission and absorption of electromagnetic radiation. This subject combines quantum theory and relativity theory, making accurate predictions about subatomic processes involving charged particles such as electrons and protons.

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electroencephalogram

EEG

graphic record of the electrical discharges of the brain, as detected by electrodes placed on the scalp. The pattern of electrical activity revealed by electroencephalography is helpful in the diagnosis of some brain disorders, in particular epilepsy.

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electroencephalography

in medicine, diagnostic technique that monitors the brain's electrical discharge to determine the presence of brain disease. An electroencephalogram (EEG) is a graphical record of these changes.

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electrolysis

in archaeological conservation, a cleaning process, especially of material from underwater archaeology, involving immersing the object in a chemical solution and passing a weak current between it and a surrounding metal grille. Corrosive salts move slowly from the object (cathode) to the grille (anode), leaving the artefact clean.

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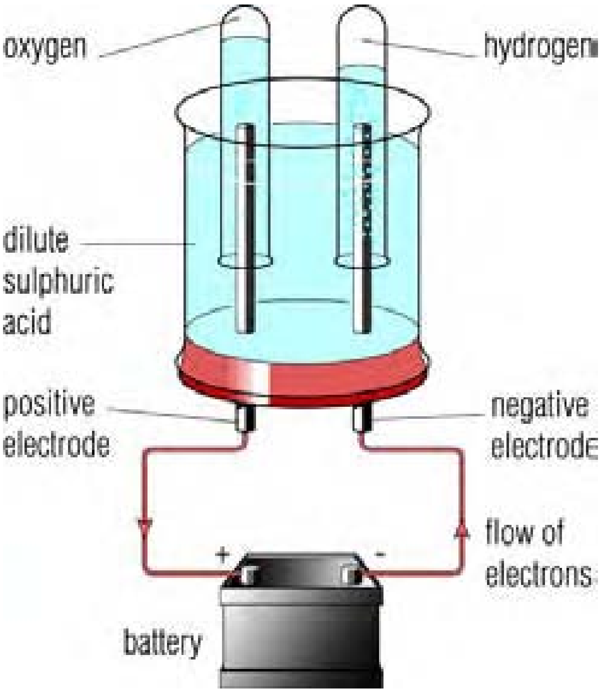
electrolysis

in chemistry, the production of chemical changes by passing an electric current through a solution or molten salt (the electrolyte), resulting in the migration of ions to the electrodes: positive ions (cations) to the negative electrode (cathode) and negative ions (anions) to the positive electrode (anode).

During electrolysis, the ions react with the electrode, either receiving or giving up electrons. The resultant atoms may be liberated as a gas, or deposited as a solid on the electrode, in amounts that are proportional to the amount of current passed, as discovered by English chemist Michael Faraday. For instance, when acidified water is electrolysed, hydrogen ions (H^+) at the cathode receive electrons to form hydrogen gas; hydroxide ions (OH^-) at the anode give up electrons to form oxygen gas and water.

One application of electrolysis is **electroplating**, in which a solution of a salt, such as silver nitrate ($AgNO_3$), is used and the object to be plated acts as the negative electrode, thus attracting silver ions (Ag^+). Electrolysis is used in many industrial processes, such as coating metals for vehicles and ships, refining bauxite into aluminium, and the chlor-alkali industry, in which brine (sodium chloride solution) is electrolysed to produce chlorine, hydrogen, and sodium hydroxide (caustic soda); it also forms the basis of a number of electrochemical analytical techniques, such as polarography.

electrolysis



(Image © Research Machines plc)

Passing an electric current through acidified water (such as diluted sulphuric acid) breaks down the water into its constituent elements - hydrogen and oxygen.

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electrolyte

solution or molten substance in which an electric current is made to flow by the movement and discharge of ions in accordance with Faraday's laws of electrolysis.

The term 'electrolyte' is frequently used to denote a substance that, when dissolved in a specified solvent, usually water, dissociates into ions to produce an electrically conducting medium.

In medicine the term is often used for the ion itself (sodium or potassium, for example). Electrolyte balance may be severely disrupted in illness or injury.

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electromagnet

coil of wire wound around a soft iron core that acts as a magnet when an electric current flows through the wire. Electromagnets have many uses: in switches, electric bells, solenoids, and metal-lifting cranes.

The strength of the electromagnet can be increased by increasing the current through the wire, changing the material of the core, or by increasing the number of turns in the wire coil. At the north pole of the electromagnet current flows anticlockwise; at the south pole flow is clockwise.

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electromagnetic field

in physics, region in which a particle with an electric charge experiences a force. If it does so only when moving, it is in a pure **magnetic field**; if it does so when stationary, it is in an **electric field**. Both can be present simultaneously. For example, a light wave consists of continually oscillating electric and magnetic fields.

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electromagnetic force

one of the four fundamental forces of nature, the other three being the gravitational force (gravity), the weak nuclear force, and the strong nuclear force. The particle that is the carrier for the electromagnetic force is the photon.

Sketches of a History of Classical Electromagnetism

Go to site

Annotated chronology of progress in electromagnetics. Key personalities are linked to biographical information. The site has a brief reading list, and links to relevant tutorials and sites with time lines.

electromagnetic induction

in electronics, the production of an electromotive force (emf) in a circuit by a change of magnetic flux through the circuit or by relative motion of the circuit and the magnetic flux. As a magnet is moved in and out of a coil of wire in a closed circuit an induced current will be produced. All dynamos and generators produce electricity using this effect. When magnetic tape is driven past the playback head (a small coil) of a tape recorder, the moving magnetic field induces an emf in the head, which is then amplified to reproduce the recorded sounds.

Electromagnetic induction takes place when the magnetic field around a conductor changes. If the magnetic field is made to change quickly, the size of the current induced is larger. A galvanometer can be used to measure the direction of the current. As a magnet is pushed into a coil, the needle on the galvanometer moves in one direction. As the magnet is removed from the coil, the needle moves in the opposite direction.

If the change of magnetic flux is due to a variation in the current flowing in the same circuit, the phenomenon is known as self-induction; if it is due to a change of current flowing in another circuit it is known as mutual induction.

Lenz's law

The direction of an electromagnetically-induced current (generated by moving a magnet near a wire or by moving a wire in a magnetic field) will be such as to oppose the motion producing it. This law is named after the German physicist Heinrich Friedrich Lenz (1804-1865), who announced it in 1833.

Faraday's laws

English scientist Michael Faraday proposed three laws of electromagnetic induction: (1) a changing magnetic field induces an electromagnetic force in a conductor; (2) the electromagnetic force is proportional to the rate of change of the field; and (3) the direction of the induced electromagnetic force depends on the orientation of the field.

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electromagnetic spectrum

complete range, over all wavelengths and frequencies, of electromagnetic waves. These include (in order of decreasing wavelength) radio and television waves, microwaves, infrared radiation, visible light, ultraviolet light, X-rays, and gamma radiation.

The colour of sunlight is made up of a whole range of colours. A glass prism can be used to split white light into separate colours that are sensitive to the human eye, ranging from red (longer wavelength) to violet (shorter wavelength). The human eye cannot detect electromagnetic radiation outside this range. Some animals, such as bees, are able to detect ultraviolet light.

electromagnetic spectrum

To remember the different categories of radiation, in order of increasing wavelength:

Cary **G**rant e**x**pects **u**nanimous **v**otes **i**n **m**ovie **r**eviews **t**onight

Cosmic, **g**amma, **X**-rays, **u**ltraviolet, **v**isible, **i**nfrared, **m**icrowave, **r**adio, **t**elevision

Electromagnetic Spectrum

Go to site

Written and designed by a physics teacher for teaching this GCSE topic. The information is supported by diagrams and images, and there is also a quiz. The topics covered are radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. This is a well-designed and useful site with printable worksheets.

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electromagnetic system of units

former system of units (emu) based on the c.g.s. system and having, as its primary unit, the unit magnetic pole. It was replaced by SI units.

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electromagnetic waves

oscillating electric and magnetic fields travelling together through space at a speed of approximately 300,000 kps/186,000 mps. Visible light is composed of electromagnetic waves. The **electromagnetic spectrum** is a family of waves that includes radio waves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. All electromagnetic waves are transverse waves. They can be reflected, refracted, diffracted, and polarized.

Radio and television waves lie at the **long wavelength-low frequency** end of the spectrum, with wavelengths longer than 10^{-4} m. Infrared radiation has wavelengths between 10^{-4} m and 7×10^{-7} m. Visible light has yet shorter wavelengths from 7×10^{-7} m to 4×10^{-7} m. Ultraviolet radiation is near the **short wavelength-high frequency** end of the spectrum, with wavelengths between 4×10^{-7} m and 10^{-8} m. X-rays have wavelengths from 10^{-8} m to 10^{-12} m. Gamma radiation has the shortest wavelengths (less than 10^{-10} m). The different wavelengths and frequencies lend specific properties to electromagnetic waves. While visible light is diffracted by a diffraction grating, X-rays can only be diffracted by crystals. Radio waves are refracted by the atmosphere; visible light is refracted by glass or water.

Electromagnetic Waves

Go to site

Great explanation of the electromagnetic spectrum. The pages are very well presented in a conversational style with large, clear text. The site makes good use of Java applets to illustrate the principles behind electromagnetism. Subsequent pages develop the subject further, examining topics such as electric force and electric force fields.

electromagnetism

in physics, the properties and interactions of magnetism and electric currents. A current flowing through a conductor produces a magnetic field around the conductor; a varying magnetic field interacting with a conductor produces a current in the conductor. This is known as the electromagnetic effect.

electromotive force

EMF

in physics, the greatest potential difference that can be generated by a source of current. This is always greater than the measured potential difference generated, due to the resistance of the wires and components, in the circuit.

electron

negatively-charged particle with negligible mass. Electrons form the outer portion of all atoms, orbiting the nucleus in groupings called shells. The first shell can hold up to two electrons; the second and third shells can hold up to eight electrons each. The electron arrangement of an element is called its **electronic configuration**; for example, the electronic configuration of the sodium atom is $Na_{(2,8,1)}$. In a neutral atom the number of electrons is equal to the number of protons in the nucleus. This electron structure is responsible for the chemical properties of the atom (see atomic structure). Electrons are a member of the class of elementary particles known as leptons.

Electrons carry a charge of 1.602177×10^{-19} coulombs and have a mass of 9.109×10^{-31} kg, which is 1/1836 times the mass of a proton. Energy can be used to remove electrons from their outer orbits in conducting materials and they can be made to flow through these materials under a potential difference. This flow is known as an electric current or electricity. A beam of electrons will undergo diffraction (scattering) and produce interference patterns in the same way as electromagnetic waves such as light; hence they may be regarded as waves as well as particles.

Look Inside the Atom

Go to site

Part of the American Institute of Physics site, this page examines J J Thomson's 1897 experiments that led to the discovery of a fundamental building block of matter, the electron. The site includes images and quotes and a section on the legacy of his discovery. Also included is a section on suggested readings and related links.

electronegativity

ease with which an atom can attract electrons to itself. Electronegative elements attract electrons, so forming negative ions.

US chemist Linus Pauling devised an electronegativity scale to indicate the relative power of attraction of elements for electrons. Fluorine, the most non-metallic element, has a value of 4.0 on this scale; oxygen, the next most non-metallic, has a value of 3.5.

In a covalent bond between two atoms of different electronegativities, the bonding electrons will be located close to the more electronegative atom, creating a dipole.

electron gun

series of electrodes, including a cathode for producing an electron beam. It plays an essential role in many electronic devices, including cathode-ray tubes (television tubes) and electron microscopes.

electronic learning

or e-learning

online training delivered to personal computers over the Internet, with the advantage that classes can be taken at any time and in any place, so that students are able to learn at their own pace. E-learning includes multimedia, search engines, electronic libraries, content portals, distance learning, and Web-enabled classrooms.

Although e-learning is not an attempt to replace classroom teaching, it has had a major effect on it, and teachers increasingly need to be properly trained to use technology in the classroom. In addition, broadband Internet access is required to make full use of rich audio-visual training content.

electronic mail

see e-mail.

electronic point of sale

EPOS

system used in retailing in which a bar code on a product is scanned at the cash till and the information relayed to the store computer. The computer will then relay back the price of the item to the cash till. The customer can then be given an itemized receipt while the computer removes the item from stock figures.

EPOS enables efficient computer stock control and reordering as well as giving a wealth of information about turnover, profitability on different lines, stock ratios, and other important financial indicators.

electronic publishing

distribution of information using computer-based media such as multimedia and hypertext in the creation of electronic 'books'. Critical technologies in the development of electronic publishing were CD-ROM, with its massive yet compact storage capabilities, and the advent of computer networking with its ability to deliver information instantaneously anywhere in the world.

By 2006, many publishers had purchased electronic publishing equipment to enable them to print books on demand, avoiding the need to keep stocks of books which might sell only a small number of copies over several years, and would otherwise go out of print. In addition, global hotel chains were purchasing similar equipment to print international business newspapers on demand via the Internet.

KidPub

Go to site

Site concerned not with underage drinking, but with publishing – with over 11,000 stories written by children around the world available to read here. What makes it special is the ability for children to submit new stories to the page, to add to the already impressive database.

Oxford Text Archive

Go to site

Major archive of electronic texts with over 2,000 titles from a wide variety of sources and in many languages. The professionally designed site offers a catalogue of texts in plain text, HTML (sorted by language), and SGML with clear indications of the availability of the texts and their size, as well as details on how to order or contribute a text. There is also some useful material on SGML, the Standard Generalized Markup Language used to encode the whole archive.

electronics

branch of science that deals with the emission of electrons from conductors and semiconductors, with the subsequent manipulation of these electrons, and with the construction of electronic devices. The first electronic device was the thermionic valve, or vacuum tube, in which electrons moved in a vacuum, and led to such inventions as radio, television, radar, and the digital computer. Replacement of valves with the comparatively tiny and reliable transistor from 1948 revolutionized electronic development. Modern electronic devices are based on minute integrated circuits (silicon chips), wafer-thin crystal slices holding tens of thousands of electronic components.

By using solid-state devices such as integrated circuits, extremely complex electronic circuits can be constructed, leading to the development of digital watches, pocket calculators, powerful microcomputers, and word processors (see word processing).

electronics

To remember whether current leads voltage or lags it in reactive circuits:

Think of 'Eli the Ice man'. In inductive ('L') circuits, voltage ('E') leads current ('I'), hence 'E L I'. In capacitive ('C') circuits, it is the other way, so 'I C E'

Electronics: key dates

1897	The electron is discovered by English physicist John Joseph Thomson.
1904	English physicist Ambrose Fleming invents the diode valve, which allows flow of electricity in one direction only.
1906	The triode electron valve, the first device to control an electric current, is invented by US physicist Lee De Forest.
1947	John Bardeen, William Shockley, and Walter Brattain invent the junction germanium transistor at the Bell Laboratories, New Jersey, USA.
1952	British physicist G W A Dunner proposes the integrated circuit.
1953	Jay Forrester of the Massachusetts Institute of Technology, USA, builds a magnetic memory smaller than existing vacuum-tube memories.
1954	The silicon transistor is developed by Gordon Teal of Texas Instruments, USA.
1958	The first integrated circuit, containing five components, is built by US electrical physicist Jack Kilby.
1959	The planar transistor, which is built up in layers, or planes, is designed by Robert Noyce of Fairchild Semiconductor Corporation, USA.
1961	Steven Hofstein designs the field-effect transistor used in integrated circuits.
1971	The first microprocessor, the Intel 4004, is designed by Ted Hoff in the USA; it contains 2,250 components and can add two four-bit numbers in 11-millionths of a second.
1974	The Intel 8080 microprocessor is launched; it contains 4,500 components and can add two eight-bit numbers in 2.5-millionths of a second.
1979	The Motorola 68000 microprocessor is introduced; it contains 70,000 components and can multiply two 16-bit numbers in 3.2-millionths of a second.
1981	The Hewlett-Packard Superchip is introduced; it contains 450,000 components and can multiply two 32-bit numbers in 1.8-millionths of a second.
1985	The Inmos T414 transputer, the first microprocessor designed for use in parallel computers, is launched.
1988	The first optical microprocessor, which uses light instead of electricity, is developed.
1989	Wafer-scale silicon memory chips are introduced: the size of a beer mat, they are able to store 200 million characters.
1990	Memory chips capable of holding 4 million bits of information begin to be mass-produced in Japan. The chips can store the equivalent of 520,000 characters, or the contents of a 16-page newspaper. Each chip contains 9 million components packed on a piece of silicon less than 15 mm long by 5 mm wide.
1992	Transistors made from high-temperature superconducting ceramics rather than semiconductors are produced in Japan by Sanyo Electric. The new transistors are ten times faster than semiconductor transistors.
1993	US firm Intel launches the Pentium 64-bit microprocessor. With two separate integer processing units that can run in parallel, it is several times faster than earlier processors.
1996	Japanese researchers complete a computer able to perform 1.08 billion floating-point operations per second.
1997	The US firm Texas Instruments introduces a digital-signal microprocessor chip that can process 1.6 billion instructions a second – about 40 times more powerful than current chips.
1997	The US company Dragon Systems releases the world's first voice recognition software program that is able to recognize and create text from normal continuous speech.
1998	Japanese scientists create an insect robot or 'cybug' by fusing the antennae of a moth onto a wheeled robot containing an electronic brain.
2002	Microchips are produced that are 90 nanometres wide – a thousand times smaller than a human hair.
2005	Blue Gene/L, made by IBM, becomes the first supercomputer capable of over 100 trillion operations per second.

Basic Soldering Guide

Go to site

Definitive guide to the art of soldering. It introduces the basics behind soldering and the types of equipment and solder available. The page is mainly text-based, and also has a handy guide on how to remove soldered joints in the correct manner.

Circuit Exchange Information

Go to site

Resource exchange for anyone making circuit boards. Recap on the basics behind the circuit board and the components needed, or read solutions to other people's circuit-based problems.

Definitions and Terminology - Electronics

Go to site

Enormous reference guide to almost any electronic term. Links to definitions or associated sites are provided for some terms. It can be browsed alphabetically, or searched by a keyword, by pressing 'Control' and 'F' on the keyboard.

Intel Education - Chips

Go to site

History of the Intel line of microprocessors (Click on microprocessors). The site takes the user on a virtual guided tour showing how the chips are made, where microprocessors are used, and how they are adapted for different purposes. Use the search facility for more detailed articles.

Resistor Colour Codes

Go to site

Quick and simple guide to identifying different types of resistor. The explanation focuses around a large diagram of a resistor, featuring labelled sections highlighting the colour bands on it. The site explains how to read the resistor code and then how to interpret it.

Rough Guide to Electronics

Go to site

Basic guide to electronics. From the basics of currents and voltages, this guide moves on to provide information on types of electrical components and what is involved in a basic oscillating circuit. This is an easy-to-follow and well-designed site.

Transistor History

Go to site

Detailed history of the transistor. It covers many of the key technological breakthroughs on the road to developing the transistor, and explains the use of transistors from the past up to the present day.

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electron microscope

instrument that produces a magnified image by using a beam of electrons instead of light rays, as in an optical microscope. An **electron lens** is an arrangement of electromagnetic coils that control and focus the beam. Electrons are not visible to the eye, so instead of an eyepiece there is a fluorescent screen or a photographic plate on which the electrons form an image. The wavelength of the electron beam is much shorter than that of light, so much greater magnification and resolution (ability to distinguish detail) can be achieved. The development of the electron microscope has made possible the observation of very minute organisms, viruses, and even large molecules.

A transmission electron microscope passes the electron beam through a very thin slice of a specimen. A scanning electron microscope looks at the exterior of a specimen. A scanning transmission electron microscope (STEM) can produce a magnification of 90 million times. See also atomic force microscope.

Electron Microscopy via the Internet

research and study at a distance

Researchers can now make use of the high voltage electron microscope at the Lawrence Berkeley Laboratory without travelling to the laboratory in California. The laboratory has created a set of interactive, online computing tools that allow scientists to manipulate the instrument, conduct experiments, and view images from their own office, via the Internet. In the first demonstration of the system, researchers 2,000 miles from Berkeley used a computer to take control of the microscope, heat an advanced alloy specimen, and observe the ensuing progression of structural changes on their computer monitor.

a fast-moving subject

Remote control of machines or scientific instruments is not new; the Hubble Space Telescope is a well-known example. Remote operation of an electron microscope, however, is especially difficult because of the slight but inevitable time delays that occur with Internet use. At the atomic level, things move fast; atoms move and shapes change quickly. This means that an electron microscope needs constant adjustment to keep it in focus and trained on the area being studied.

the time delay factor

According to Bahram Parvin, the computer scientist who leads the team at Berkeley with Michael O'Keefe, deputy head of the Berkeley National Center for Electron Microscopy, normally an operator sitting next to the microscope has to constantly adjust dials just to keep the area of the specimen under study within the field of view. Focusing also requires continuous attention. Trying to do this over the Internet, which has a time lag analogous to the time lag that occurs during an international phone call, is impossible. By the time the remote operator's commands reach the microscope, they are too late.

computer vision

To sidestep this limitation of computer networks, Parvin's team has automated the positioning and focusing of the Berkeley microscope using advanced computer vision techniques.

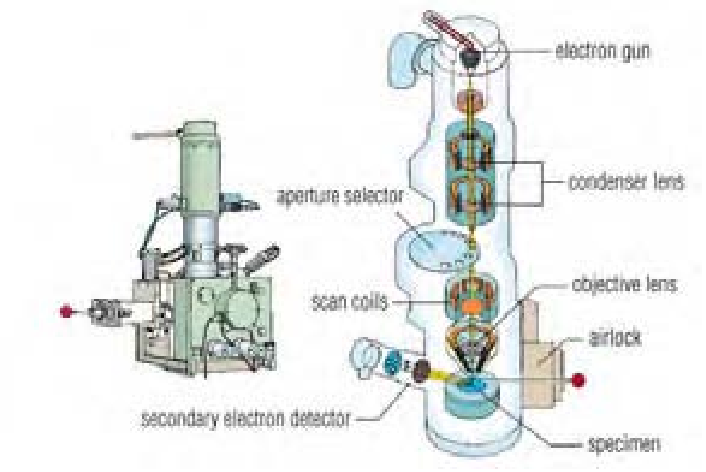
As Parvin explains, 'You start with what to a computer is an indiscriminate field. You then detect and lock onto objects of interest. This is computer vision. Very soon, from a remote location, computer vision will self-calibrate the microscope, automatically focus it, and compensate for thermal drift. Underlying this is a complex package of algorithms dealing with shape analysis, background measurements, and so on. Essentially though, we are making the microscope smarter, making it do automatically what users would normally have to do on their own'.

developments in online tools

Parvin is also developing another set of computer vision tools in collaboration with Berkeley scientists

Dan Callahan and Marcos Maestre. These not only detect objects of interest - for example, single DNA molecules - but lock onto and track them. The starting point for this technology is an algorithm that defines a shape. Parvin's team have constructed algorithms for a range of shapes, including circular, tubular, and complex objects. The team has also created a tool for drawing an outline around a uniquely-shaped object and then launching a process that finds and tracks these objects. Ultimately, Parvin hopes to integrate tracking software into a package of online tools.

electron microscope



(Image © Research Machines plc)

The scanning electron microscope. Electrons from the electron gun are focused to a fine point on the specimen surface by the lens systems. The beam is moved across the specimen by the scan coils. Secondary electrons are emitted by the specimen surface and pass through the detector, which produces an electrical signal. The signal is passed to an electronic console, and produces an image on a screen.

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electrons, delocalized

electrons that are not associated with individual atoms or identifiable chemical bonds, but are shared collectively by all the constituent atoms or ions of some chemical substances (such as metals, graphite, and aromatic compounds).

A metallic solid consists of a three-dimensional arrangement of metal ions through which the delocalized electrons are free to travel. Aromatic compounds are characterized by the sharing of delocalized electrons by several atoms within the molecule.

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electrons, localized

pair of electrons in a covalent bond that are located in the vicinity of the nuclei of the two contributing atoms. Such electrons cannot move beyond this area.

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electron spin resonance

in archaeology, a nondestructive dating method applicable to teeth, bone, heat-treated flint, ceramics, sediments, and stalagmitic concretions. It enables electrons, displaced by natural radiation and then trapped in the structure, to be measured; their number indicates the age of the specimen.

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electron volt

symbol eV

unit for measuring the energy of a charged particle (ion or electron) in terms of the energy of motion an electron would gain from a potential difference of one volt. Because it is so small, more usual units are mega-(million) and giga- (billion) electron volts (MeV and GeV).

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electrooculography

in medicine, a method of recording movements of the eyes. It is used to assess the function of the retina.

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electrophoresis

the diffusion of charged particles through a fluid under the influence of an electric field. It can be used in the biological sciences to separate molecules of different sizes, which diffuse at different rates. In industry, electrophoresis is used in paint-dipping operations to ensure that paint reaches awkward corners.

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electroplating

deposition of metals upon metallic surfaces by electrolysis for decorative and/or protective purposes. It is used in the preparation of printing plates, 'master' audio discs, and in many other processes.

A current is passed through a bath containing a solution of a salt of the plating metal, the object to be plated being the cathode (negative terminal); the anode (positive terminal) is either an inert substance or the plating metal. Among the metals most commonly used for plating are zinc, nickel, chromium, cadmium, copper, silver, and gold.

In **electropolishing**, the object to be polished is made the anode in an electrolytic solution and by carefully controlling conditions the high spots on the surface are dissolved away, leaving a high-quality stain-free surface. This technique is useful in polishing irregular stainless-steel articles.

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electropositivity

in chemistry, a measure of the ability of elements (mainly metals) to donate electrons to form positive ions. The greater the metallic character, the more electropositive the element.

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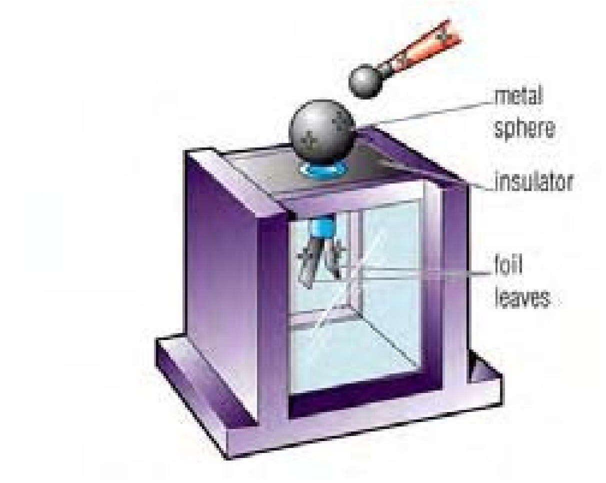
electroscope

apparatus for detecting electric charge. The simple gold-leaf electroscope consists of a vertical conducting (metal) rod ending in a pair of rectangular pieces of gold foil, mounted inside and insulated from an earthed metal case or glass jar. An electric charge applied to the end of the metal rod makes the gold leaves diverge, because they each receive a similar charge (positive or negative) via the rod and so repel each other.

The polarity of the charge can be found by bringing up another charge of known polarity and applying it to the metal rod. A like charge has no effect on the gold leaves since they remain repelled. An opposite charge neutralizes the charge on the leaves and causes them to collapse.

electroscope



(Image © Research Machines plc)

The electroscope is a simple means of detecting electric charge. The metal foil leaves diverge when a charge is applied to the metal sphere.

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electrostatics

study of stationary electric charges and their fields (not currents). See static electricity.

Charged materials behave differently if they are brought near to each other. Materials of like charge, that is both positive or both negative, will move away from each other (repelled by electrostatic force). Materials of opposite charge, that is one positive and one negative, brought close together will move towards each other (attracted by electrostatic force).

An electroscope is an instrument that detects charges on objects that have been charged by static electricity.

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electrovalent bond

another name for an ionic bond, a chemical bond in which the combining atoms lose or gain electrons to form ions.

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electrum

naturally occurring alloy of gold and silver used by early civilizations to make the first coins, about the 6th century BC.

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element

substance that cannot be split chemically into simpler substances. The atoms of a particular element all have the same number of protons in their nuclei (their proton or atomic number). Elements are classified in the periodic table of the elements. Of the known elements, 92 are known to occur naturally on Earth (those with atomic numbers 1-92). Those elements with atomic numbers above 96 do not occur in nature and must be synthesized in particle accelerators. Of the elements, 81 are stable; all the others, which include atomic numbers 43, 61, and from 84 up, are radioactive.

Elements are classified as metals, nonmetals, or metalloids (weakly metallic elements) depending on a combination of their physical and chemical properties; about 75% are metallic. Some elements occur abundantly (oxygen, aluminium); others occur moderately or rarely (chromium, neon); some, in particular the radioactive ones, are found in minute (neptunium, plutonium) or very minute (astatine, technetium) amounts. Symbols (devised by Swedish chemist Jöns Berzelius) are used to denote the elements; the symbol is usually the first letter or letters of the English or Latin name (for example, C for carbon, Ca for calcium, Fe for iron, from the Latin *ferrum*). The symbol represents one atom of the element. Two or more elements bonded together form a **compound** from which they cannot be separated by physical means. Compounds are held together by ionic or covalent bonds. The number of atoms of an element that combine to form a molecule is it **atomicity**. A molecule of oxygen (O_2) has atomicity 2; sulphur (S_8) has atomicity 8.

According to current theories, hydrogen and helium were produced in the Big Bang at the beginning of the universe. Of the other elements, those up to atomic number 26 (iron) are made by nuclear fusion within the stars. The heavier elements, such as lead and uranium, are produced when an old star explodes; as its centre collapses, the gravitational energy squashes nuclei together to make new elements.

Chemical elements

An element is a substance that cannot be split chemically into simpler substances. The atoms of a particular element all have the same number of protons in their nuclei (their atomic, or proton, number). (- = not applicable.)

Name	Symbol	Atomic number	Atomic mass (amu)[1]	Relative density[2]	Melting or fusing point (°C)
Actinium	Ac	89	227[3]	-	-
Aluminium	Al	13	26.9815	2.58	658
Americium	Am	95	243[3]	-	-
Antimony	Sb	51	121.75	6.62	629
Argon	Ar	18	39.948	gas	-188
Arsenic	As	33	74.9216	5.73	volatile, 450
Astatine	At	85	210[3]	-	-
Barium	Ba	56	137.34	3.75	850
Berkelium	Bk	97	249[3]	-	-
Beryllium	Be	4	9.0122	1.93	1,281
Bismuth	Bi	83	208.9806	9.80	268
Bohrium	Bh	107	262[3]	-	-
Boron	B	5	10.81	2.5	2,300
Bromine	Br	35	79.904	3.19	-7.3
Cadmium	Cd	48	112.40	8.64	320
Caesium	Cs	55	132.9055	1.88	26
Calcium	Ca	20	40.08	1.58	851
Californium	Cf	98	251[3]	-	-
Carbon	C	6	12.011	3.52	infusible
Cerium	Ce	58	140.12	6.68	623
Chlorine	Cl	17	35.453	gas	-102
Chromium	Cr	24	51.996	6.5	1,510
Cobalt	Co	27	58.9332	8.6	1,490
Copper	Cu	29	63.546	8.9	1,083
Curium	Cm	96	247[3]	-	-
Dubnium	Db	105	262[3]	-	-
Dysprosium	Dy	66	162.50	-	-

Einsteinium	Es	99	254^3	-	-
Erbium	Er	68	167.26	4.8	-
Europium	Eu	63	151.96	-	-
Fermium	Fm	100	253^3	-	-
Fluorine	F	9	18.9984	gas	-223
Francium	Fr	87	223^3	-	-
Gadolinium	Gd	64	157.25	-	-
Gallium	Ga	31	69.72	5.95	30
Germanium	Ge	32	72.59	5.47	958
Gold	Au	79	196.9665	19.3	1,062
Hafnium	Hf	72	178.49	12.1	2,500
Hassium	Hs	108	265^3	-	-
Helium	He	2	4.0026	gas	-272
Holmium	Ho	67	164.9303	-	-
Hydrogen	H	1	1.0080	gas	-258
Indium	In	49	114.82	7.4	155
Iodine	I	53	126.9045	4.95	114
Iridium	Ir	77	192.22	22.4	2,375
Iron	Fe	26	55.847	7.86	1,525
Krypton	Kr	36	83.80	gas	-169
Lanthanum	La	57	138.9055	6.1	810
Lawrencium	Lr	103	260^3	-	-
Lead	Pb	82	207.2	11.37	327
Lithium	Li	3	6.941	0.585	186
Lutetium	Lu	71	174.97	-	-
Magnesium	Mg	12	24.305	1.74	651
Manganese	Mn	25	54.9380	7.39	1,220
Meitnerium	Mt	109	266^3	-	-
Mendelevium	Md	101	256^3	-	-
Mercury	Hg	80	200.59	13.596	-38.9
Molybdenum	Mo	42	95.94	10.2	2,500
Neodymium	Nd	60	144.24	6.96	840
Neon	Ne	10	20.179	gas	-248.6
Neptunium	Np	93	237^3	-	-
Nickel	Ni	28	58.71	8.9	1,452
Niobium	Nb	41	92.9064	8.4	1,950
Nitrogen	N	7	14.0067	gas	-211
Nobelium	No	102	254^3	-	-
Osmium	Os	76	190.2	22.48	2,700
Oxygen	O	8	15.9994	gas	-227
Palladium	Pd	46	106.4	11.4	1,549
Phosphorus	P	15	30.9738	1.8-2.3	44
Platinum	Pt	78	195.09	21.5	1,755
Plutonium	Pu	94	242^3	-	-
Polonium	Po	84	210^3	-	-
Potassium	K	19	39.102	0.87	63
Praseodymium	Pr	59	140.9077	6.48	940
Promethium	Pm	61	145^3	-	-
Protactinium	Pa	91	231.0359	-	-
Radium	Ra	88	226.0254	6.0	700
Radon	Rn	86	222^3	gas	-150
Rhenium	Re	75	186.2	21	3,000
Rhodium	Rh	45	102.9055	12.1	1,950
Rubidium	Rb	37	85.4678	1.52	39
Ruthenium	Ru	44	101.07	12.26	2,400
Rutherfordium	Rf	104	262^3	-	-
Samarium	Sm	62	150.4	7.7	1,350
Scandium	Sc	21	44.9559	-	-
Seaborgium	Sg	106	263^3	-	-
Selenium	Se	34	78.96	4.5	170-220
Silicon	Si	14	28.086	2.0-2.4	1,370
Silver	Ag	47	107.868	10.5	960
Sodium	Na	11	22.9898	0.978	97
Strontium	Sr	38	87.62	2.54	800

Sulphur	S	16	32.06	2.07	115-119
Tantalum	Ta	73	180.9479	16.6	2,900
Technetium	Tc	43	99[3]	-	-
Tellurium	Te	52	127.60	6.0	446
Terbium	Tb	65	158.9254	-	-
Thallium	Tl	81	204.37	11.85	302
Thorium	Th	90	232.0381	11.00	1,750
Thulium	Tm	69	168.9342	-	-
Tin	Sn	50	118.69	7.3	232
Titanium	Ti	22	47.90	4.54	1,850
Tungsten	W	74	183.85	19.1	2,900-3,000
Ununbium	Uub[4]	112	277[3]	-	-
Ununhexium	Uuh[4]	116	289[3]	-	-
Ununnilium	Uun[4]	110	269[3]	-	-
Ununoctium	Uno[4]	118	293[3]	-	-
Ununquadium	Unq[4]	114	289[3]	-	-
Unununium	Uuu[4]	111	272[3]	-	-
Uranium	U	92	238.029	18.7	-
Vanadium	V	23	50.9414	5.5	1,710
Xenon	Xe	54	131.30	gas	-140
Ytterbium	Yb	70	173.04	-	-
Yttrium	Y	39	88.9059	3.8	-
Zinc	Zn	30	65.37	7.12	418
Zirconium	Zr	40	91.22	4.15	2,130

[1] Atomic mass units.

[2] Also known as specific gravity. Relative density is the density (at 20°C/68°F) of a solid or liquid relative to the maximum density of water (at 4°C/39.2°F).

[3] The number given is that for the most stable isotope of the element.

[4] Elements as yet unnamed; temporary identification assigned until a name is approved by the International Union for Pure and Applied Chemistry.

Chemical Elements.com

Go to site

Searchable, interactive version of the periodic table. This site provides clear information, pictures of atomic structure, and facts about each element.

Compounds, Elements, Mixtures

Go to site

Part of the ChemWeb Online site providing an introduction to chemistry, this page provides a definition of elements, compounds, and mixtures. There are also sections explaining atoms, ions, and molecules, as well as a searchable glossary of chemistry terms.

What is an Element?

Go to site

Simple information on elements and atomic structure, part of the BBC World Service elementary science Web site. A good starting point for revision, this page defines key concepts such as atomic number.

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elementary particle

or fundamental particle

any of those particles that combine to form atoms and all matter, the most familiar being the electron, proton, and neutron. More than 200 particles have now been identified by physicists, categorized into several classes as characterized by their mass, electric charge, spin, magnetic moment, and interaction. Although many particles were thought to be nondivisible and permanent, now most are known to be combinations of more basic particles.

Since the 1890s, inquiry has progressed from the atom to its nucleus to the hadrons that make up the nucleus to the quarks that make up the hadrons. Since the 1960s, the main interest of particle physicists has been the elucidation of hadron structure. Only a small number of the 200 known particles are nondivisible - basic and stable - those that cannot be subdivided. They include eight of the 12 leptons (the electron, the positron, and six kinds of neutrinos); the quarks (36 varieties); and the gauge bosons - the particles that carry the four fundamental forces (the photon, the graviton, eight kinds of gluons, and three kinds of weakons). All matter in the universe is now seen as being made up of various combinations and interactions of these particles.

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elements, the four

earth, air, fire, and water. The Greek philosopher Empedocles believed that these four elements made up the fundamental components of all matter and that they were destroyed and renewed through the action of love and discord.

This belief was shared by Aristotle who also claimed that the elements were mutable and contained specific qualities: cold and dry for earth, hot and wet for air, hot and dry for fire, and cold and wet for water. The transformation of the elements formed the basis of medieval alchemy, and the belief that base metals could be turned into gold. The theory of the elements prevailed until the 17th century when Robert Boyle redefined an element as a substance 'simple or unmixed, not made of other bodies' and proposed the existence of a greater number than four.

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elephant

large grazing mammal with thick, grey wrinkled skin, large ears, a long flexible trunk, and huge curving tusks. There are fingerlike projections at the end of the trunk used for grasping food and carrying it to the mouth. The trunk is also used for carrying water to the mouth. The elephant is herbivorous and, because of its huge size, much of its time must be spent feeding on leaves, shoots, bamboo, reeds, grasses, and fruits, and, where possible, cultivated crops such as maize and bananas. Elephants are the largest living land animal and usually live in herds containing between 20 and 40 females (cows), led by a mature, experienced cow. Most male (bull) elephants live alone or in small groups; young bulls remain with the herd until they reach sexual maturity. Elephants have the longest gestation period of any animal (18–23 months between conception and birth) and usually produce one calf , which takes 10–15 years to reach maturity. Their tusks, which are initially tipped with enamel but later consist entirely of ivory, continue growing throughout life. They are preceded by milk tusks, which are shed at an early age. Elephants can live up to 60 years in the wild, but those in captivity have been known to reach over 65.

classification

Elephants belong to the phylum Chordata, class Mammalia (mammals), order Proboscidea, family Elephantidae. There are two species, the African elephant(*Loxodonta africana*), and the Indian or Asian elephant (*Elephas maximus*). The African elephant is much the larger of the two species, growing to heights of 4 m/13 ft and weighing up to 8 tonnes compared with the 2.7 m/9 ft and 4 tonnes of the Indian elephant.

endangered species

Elephants are slaughtered for ivory, and this, coupled with the fact that they reproduce slowly and do not breed readily in captivity, is leading to their extinction. In Africa, overhunting caused numbers to decline rapidly during the 1980s and the elephant population of East Africa is threatened with extinction. They were placed on the Convention on International Trade in Endangered Species (CITES) list of most endangered species 1989–97, and this combined with a world ban on trade in ivory in 1990, resulted in an apparent drop in poaching. In 1997, however, at the 10th CITES convention, the elephant was downgraded to CITES Appendix II (vulnerable) and the ban on ivory exportation was lifted. The Asian elephant was also placed on the CITES endangered list.

African elephant herd

(Image © Corel)

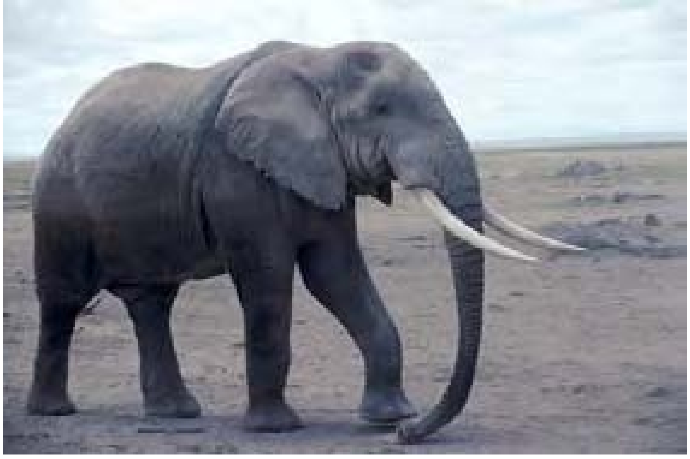
Grazing herd of African elephants, Kenya. The African elephant has been aggressively hunted for its ivory tusks and is now an endangered species.

African elephants

(Image © Corel)

Elephant crossing in Hwange National Park, Zimbabwe, southern Africa. The largest national park in the country, Hwange is thought to hold the world's largest concentration of African elephants (estimates vary between 17,000 and 30,000).

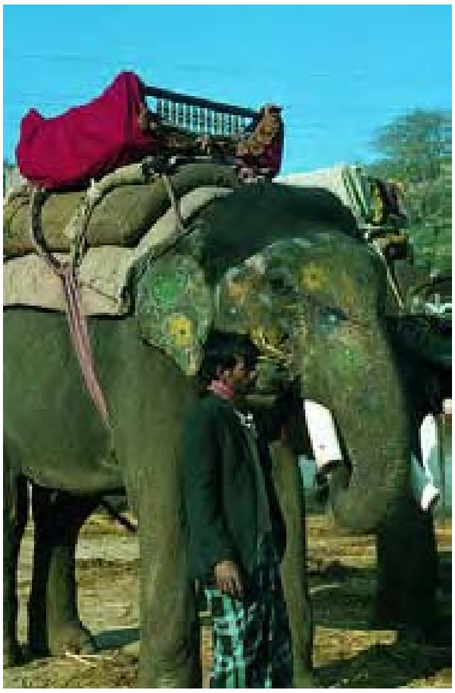
elephant

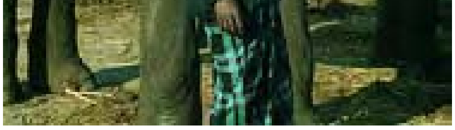


(Image © Research Machines plc)

An African bull elephant, one of 1,000 elephants living in the Amboseli Wildlife Park south of Nairobi, Kenya. This animal is clearly distinguished from the Asian elephant by its relatively large ears and sloping, rather than domed, forehead. The trunk of the African elephant is ridged rather than smooth, and there are two fingerlike projections at the tip (the Asian species has only one).

elephant





(Image © Research Machines plc)

An Indian elephant, in Amber, Rajasthan. This elephant has been decorated with chalk or paint. An annual springtime Elephant Festival, held in the nearby city of Jaipur, begins with a procession of highly decorated and lavishly attired elephants.

elephant

(Image © Research Machines plc)

An elephant calf at a watering hole in Kenya. Elephants do not reach maturity until they are 10-15 years old, during which time they remain with the herd. Males leave the herd when they become sexually mature, whereas females normally remain.

elephant

CHIVAS REGAL

(Image © Research Machines plc)

Elephant polo being played in Nepal. The World Elephant Polo Association has its headquarters at Chitwan, in the south of the country.

elephant

To distinguish between Indian and African elephants:

Indian elephants have l**i**ttle ears, **A**frican elephants have l**a**rge ears

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elephantiasis

in medicine, a condition of local enlargement and deformity, most often of a leg, though the scrotum, vulva, or breast may also be affected. The commonest form of elephantiasis is the tropical variety (lymphatic filariasis) caused by infestation by parasitic roundworms (filaria); the enlargement is due to damage of the lymphatic system which impairs immunity. In 2002 there were approximately 120 million people infected worldwide, of whom 40 million were disfigured and considered incurable. The World Health Organization (WHO) aims to eradicate the disease by 2020.

The sufferer is susceptible to infection from bacteria and fungi, entering through skin splits. The swelling reduces dramatically if the affected area is kept rigorously clean and treated with antibiotic cream, combined with rest, after drug treatment has killed all filarial worms.

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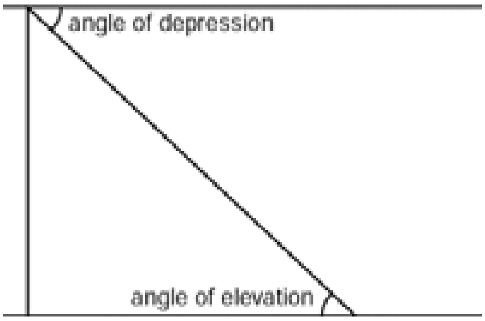
elevation, angle of

an upward angle made with the horizontal.

elevation, angle of



(Image © Research Machines plc)

The angle of elevation is the angle up from the horizontal. The angle of depression is the angle down from the horizontal.

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elevator

any mechanical device for raising or lowering people or materials. It usually consists of a platform or boxlike structure suspended by motor-driven cables with safety ratchets along the sides of the shaft. The US inventor Elisha Graves Otis developed the first passenger safety elevator in 1852, installed in 1857. This invention permitted the development of skyscrapers from the 1880s. At first steam powered the movement, but hydraulic and then electric elevators were common from the early 1900s. Elevator operators worked controls and gates within the cab until the automatic, or self-starter, was introduced.

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elk

or wapiti

North American deer *Cervus canadensis*, closely related to the red deer of Eurasia. Head and body length is about 8 ft/2.5 m, and shoulder height is about 5 ft/1.5 m. They are grayish-brown with a yellow rump patch. Males carry magnificent antlers up to 5.8 ft/1.8 m along the beam. In Europe, moose are called elk.

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elkhound

Norwegian dog resembling the husky but much smaller. Its coat is thick, with a full undercoat and the tail is bushy. Elkhounds are grey, with a darker shade on the back, and are about 50 cm/20 in high, weighing approximately 22 kg/48 lb.

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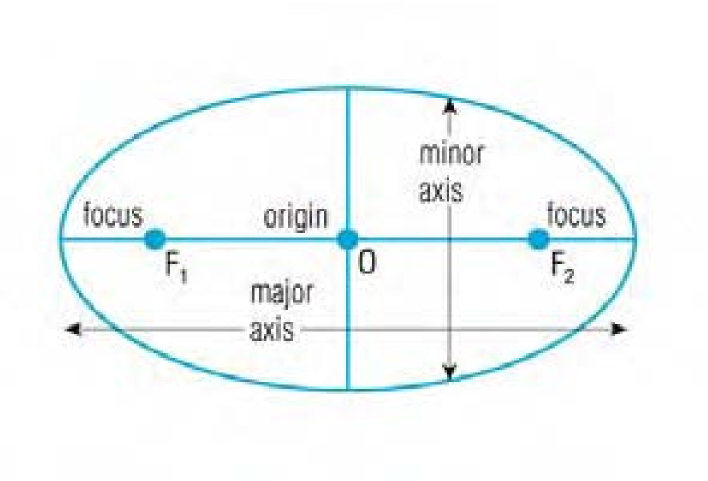
ellipse

curve joining all points (loci) around two fixed points (foci) such that the sum of the distances from those points is always constant. The diameter passing through the foci is the major axis, and the diameter bisecting this at right angles is the minor axis. An ellipse is one of a series of curves known as conic sections. A slice across a cone that is not made parallel to, and does not pass through, the base will produce an ellipse.

ellipse



(Image © Research Machines plc)

Technical terms used to describe an ellipse; for all points on the ellipse, the sum of the distances from the two foci, F_1 and F_2, is the same.

Ellipse

Go to site

Introduction to ellipses and links to associated curves. If you have a Java-enabled browser you can experiment interactively with this curve and its associates. There are also links to mathematicians who have studied the ellipse, to the ellipse's particular attributes, and to related Web sites.

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elliptical galaxy

in astronomy, one of the main classes of galaxy in the Hubble classification, characterized by a featureless elliptical profile. Unlike spiral galaxies, elliptical galaxies have very little gas or dust and no stars have recently formed within them. They range greatly in size from giant ellipticals, which are often found at the centres of clusters of galaxies and may be strong radio sources, to tiny dwarf ellipticals, containing about a million stars, which are the most common galaxies of any type. More than 60% of known galaxies are elliptical.

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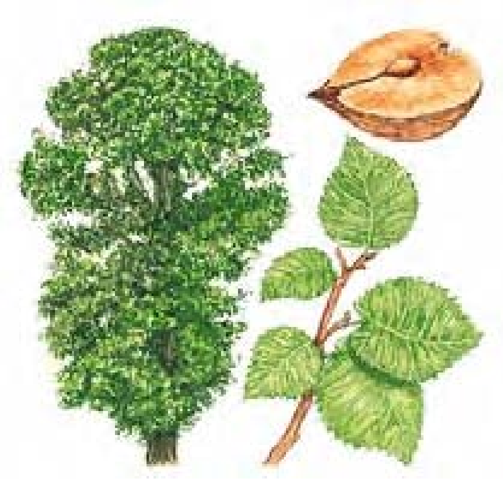
elm

any of a group of trees found in temperate regions of the northern hemisphere and in mountainous parts of the tropics. All have doubly-toothed leaf margins and clusters of small flowers. (Genus *Ulmus*, family Ulmaceae.)

Species include the wych elm (*Ulmus glabra*), native to Britain; the North American white elm (*U. americana*); and the red or slippery elm (*U. fulva*). Most elms (apart from the wych elm) reproduce not by seed but by suckering (new shoots arising from the root system). This nonsexual reproduction results in an enormous variety of forms.

The fungus disease *Ceratocystis ulmi*, known as **Dutch elm disease** because of a severe outbreak in the Netherlands in 1924, has reduced the numbers of elm trees in Europe and North America. It is carried from tree to tree by beetles. Elms were widespread throughout Europe to about 4000 BC, when they suddenly disappeared and were not common again until the 12th century. This may have been due to an earlier epidemic of Dutch elm disease. In 1997 the US National Arboretum developed a Valley Forge elm that is resistant to the disease. It is expected to be available to the public in 2000.

elm



(Image © Research Machines plc)

The English elm has the typical elm leaf, oval, toothed, and distinctly lopsided. The seed is surrounded by a yellowish petal-like wing.

Elm, Common

Go to site

Informative resource relating to the common elm. It contains a detailed description of the tree and its habitat. There are also notes on the uses and constituents of the tree, as well as information on Dutch elm disease.

El Niño

(Spanish 'the child')

marked warming of the eastern Pacific Ocean that occurs when a warm current of water moves from the western Pacific, temporarily replacing the cold Peru Current along the west coast of South America. This results in a reduction in marine plankton, the main food source in the ocean, and fish numbers decline. The atmospheric circulation in the region is also seriously disturbed, and may result in unusual climatic events, for example floods in Peru, and drought in Australia. El Niño events occur at irregular intervals of between two and seven years. It is understood that there might be a link between El Niño and global warming.

El Niño is believed to be caused by the failure of trade winds and, consequently, of the ocean currents normally driven by these winds. Warm surface waters then flow in from the east. The phenomenon can disrupt the climate of the area disastrously, and has played a part in causing famine in Indonesia, drought and bush fires in the Galapagos Islands, rainstorms in California, USA, and in South America, and the destruction of Peru's anchovy harvest and wildlife in 1982–83. El Niño contributed to algal blooms in Australia's drought-stricken rivers and an unprecedented number of typhoons in Japan in 1991. It is also thought to have caused the 1997 drought in Australia and contributed to certain ecological disasters such as bush fires in Indonesia.

El Niño Theme Page

Go to site

Wealth of scientific information about El Niño (a 'disruption of the ocean-atmosphere system in the tropical Pacific') with animated views of the monthly sea changes brought about by it, El Niño-related climate predictions, and forecasts from meteorological centres around the world. It also offers an illuminating 'Frequently asked questions' section with basic and more advanced questions as well as an interesting historical overview of the phenomenon starting from 1550.

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elongation

in astronomy, angular distance between the Sun and a planet or other Solar System object. This angle is 0° at conjunction, 90° at quadrature, and 180° at opposition.

Elton, Charles Sutherland (1900-1991)

British ecologist, a pioneer of the study of animal and plant forms in their natural environments, and of animal behaviour as part of the complex pattern of life. He defined the concept of food chains and was an early conservationist. Elton was instrumental in establishing the Nature Conservancy Council (1949), and was much concerned with the impact of introduced species on natural systems.

Charles Elton: 'Early Forms of Landholding'

Go to site

Part of the Archive for the History of Economic Thought at McMaster University, this page provides the text of Elton Sutherland's 1886 essay 'Early Forms of Landholding', in which he responds to a volume of essays by M Fustel de Coulanges concerning the history of property.

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elytra

horny wing cases characteristic of beetles. The elytra are adapted from the beetles' forewings (only the hindwings are used for flight). They fold over the back, generally meeting in the middle in a straight line, and serve to protect the hindwings and the soft posterior parts of the body.

Elytra are also to be found in earwigs.

In Hemiptera (true bugs) the forewings are hardened over half their length and are known as **hemelytra**. In Orthoptera (crickets, grasshoppers, and locusts) the forewings are greatly thickened and are known as **tegmina**.

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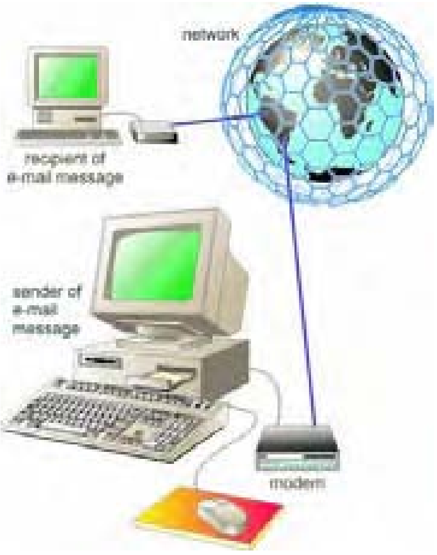
e-mail

contraction of electronic mail

messages sent electronically from computer to computer via network connections such as Ethernet or the Internet, or via telephone lines to a host system. Messages once sent are stored on the network or by the host system until the recipient picks them up. As well as text, messages may contain attached text files, artwork, or multimedia clips.

Subscribers to an e-mail system key in messages in ordinary letter form on a personal computer, and 'drop' the letters into a central computer's memory bank by means of a computer/telephone connector (a modem). The recipient 'collects' the letter by calling up the central computer and feeding a unique password into the system. Due to the high speed of delivery, e-mail is cheaper than an equivalent telephone call or fax.

e-mail system



(Image © Research Machines plc)

The basic structure of an e-mail system. A message is sent via a telephone line and stored in a central computer. The message remains there until the recipient calls up the central computer and collects the message.

BBC Web-Wise Instant Answers - E-mail

Go to site

Series of pages explaining the concept and use of e-mail. It explains how to send and receive e-mail, how to set up an account and how to send attachments. Everything is explained in clear terms, making it useful for the novice as well as those who want to revise the topic.

E-mail: An Introduction

Go to site

Beginner's guide to e-mail. There is a good introduction followed by sections on why e-mail is different from paper-based communication. The site also includes information on layout, expressing gestures and intonations, and an appendix of e-mail jargon.

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embolism

blockage of a blood vessel by an obstruction called an embolus (usually a blood clot, fat particle, or bubble of air).

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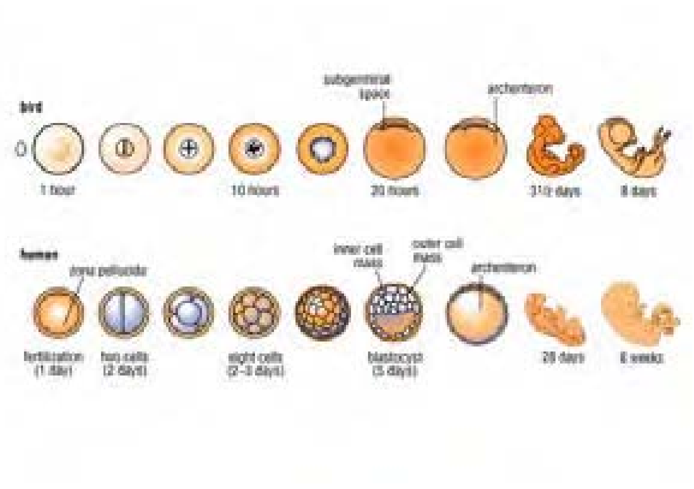
embryo

early developmental stage of an animal or a plant following fertilization of an ovum (egg cell), or activation of an ovum by parthenogenesis. In humans, the term embryo describes the fertilized egg during its first seven weeks of existence; from the eighth week onwards it is referred to as a fetus.

In animals the embryo exists either within an egg (where it is nourished by food contained in the yolk), or in mammals, in the uterus of the mother. In mammals (except marsupials) the embryo is fed through the placenta. The plant embryo is found within the seed in higher plants. It sometimes consists of only a few cells, but usually includes a root, a shoot (or primary bud), and one or two cotyledons, which nourish the growing seedling.

embryo



(Image © Research Machines plc)

The development of a bird and a human embryo. In the human, division of the fertilized egg, or ovum, begins within hours of conception. Within a week, a hollow, fluid-containing ball - a blastocyte - with a mass of cells at one end has developed. After the third week, the embryo has changed from a mass of cells into a recognizable shape. At four weeks, the embryo is 3 mm/0.1 in long, with a large bulge for the heart and small pits for the ears. At six weeks, the embryo is 1.5 cm/0.6 in long with a pulsating heart and ear flaps. By the eighth week, the embryo (now technically a fetus) is 2.5 cm/1 in long and recognizably human, with eyelids and small fingers and toes.

Odyssey of Life

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page examines the formation of embryos. It includes time-lapse video sequences of growing embryos. Two leading spokespersons of the evolution/creation debate state their opposing viewpoints regarding the age-old question 'How did we get here'? Their debate is carried out online through a series of letters in which they reply to the other's position and expand on their own. There is also an interview with the photographer of the programme in which he discusses the tricky techniques and technology required to film living embryos inside the womb.

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embryology

study of the changes undergone by an organism from its conception as a fertilized ovum (egg) to its emergence into the world at hatching or birth. It is mainly concerned with the changes in cell organization in the embryo and the way in which these lead to the structures and organs of the adult (the process of differentiation).

Applications of embryology include embryo transplants, both commercial (for example, in building up a prize dairy-cow herd quickly at low cost) and in obstetric medicine (as a method for helping couples with fertility problems to have children). See also development.

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embryo research

the study of human embryos at an early stage, in order to detect hereditary disease and genetic defects, and to develop cures for diseases.

As part of in vitro fertilization (IVF) treatment, eggs undergo fertilization and are allowed to grow to the eight-cell stage. One or two cells are then removed for analysis. Diseases that can be tested for include cystic fibrosis, Duchenne's muscular dystrophy, Lesch-Nyhan syndrome, Tay-Sachs disease, and haemophilia A.

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embryo sac

large cell within the ovule of flowering plants that represents the female gametophyte when fully developed. It typically contains eight nuclei. Fertilization occurs when one of these nuclei, the egg nucleus, fuses with a male gamete.

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emerald

clear, green gemstone variety of the mineral beryl. It occurs naturally in Colombia, the Ural Mountains in Russia, Zimbabwe, and Australia. The green colour is caused by the presence of the element chromium in the beryl.

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emery

black to greyish form of impure corundum that also contains the minerals magnetite and haematite. It is used as an abrasive.

Emery, (Walter) Bryan (1903-1971)

English archaeologist, who in 1929-34 in Nubia, North Africa, excavated the barrows at Ballana and Qustol, rich royal tombs of the mysterious X-group people (3rd to 6th centuries AD). He also surveyed the whole region 1963-64 before it was flooded as a result of the building of the Aswan High Dam.

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emetic

any substance administered to induce vomiting. Emetics are used to empty the stomach in many cases of deliberate or accidental drug overdose. The most frequently used is ipecacuanha.

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emission line

in astronomy, bright line in the spectrum of a luminous object caused by atoms or molecules emitting light at sharply defined wavelengths.

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emission spectroscopy

in analytical chemistry, a technique for determining the identity or amount present of a chemical substance by measuring the amount of electromagnetic radiation it emits at specific wavelengths; see spectroscopy.

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emotion

in psychology, a powerful feeling; a complex state of body and mind involving, in its bodily aspect, changes in the viscera (main internal organs) and in facial expression and posture, and in its mental aspect, heightened perception, excitement and, sometimes, disturbance of thought and judgement. The urge to action is felt and impulsive behaviour may result.

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emphysema

incurable lung condition characterized by disabling breathlessness. Progressive loss of the thin walls dividing the air spaces (alveoli) in the lungs reduces the area available for the exchange of oxygen and carbon dioxide, causing the lung tissue to expand. The term 'emphysema' can also refer to the presence of air in other body tissues.

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empty set

symbol ø

in mathematics, set with no elements.

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emu

flightless bird *Dromaius novaehollandiae*, family Dromaiidae, order Casuariidae, native to Australia. It stands about 1.8 m/6 ft high and has coarse brown plumage, small rudimentary wings, short feathers on the head and neck, and powerful legs, which are well adapted for running and kicking.

The female has a curious bag or pouch in the windpipe that enables her to emit a characteristic loud booming note. Emus are monogamous, and the male wholly or partially incubates the eggs.

In Western Australia emus are farmed for their meat, skins, feathers, and oil.

emu

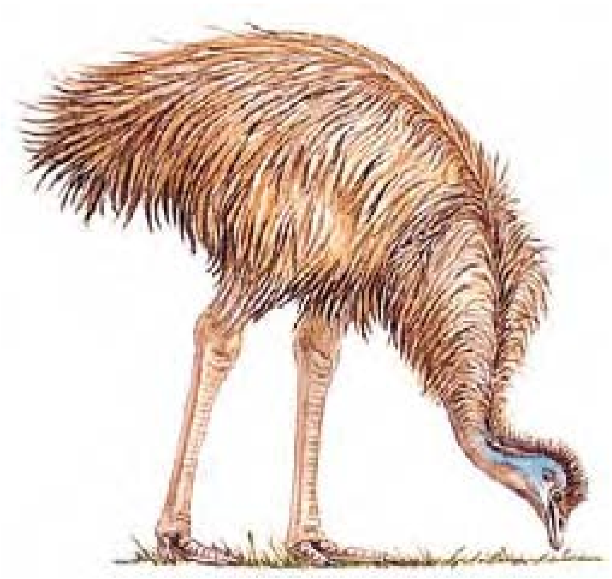
While a male emu is incubating his eggs, he cannot move from the nest to eat or drink. He must survive on his existing fat reserves for eight weeks. When the chicks are hatched they remain in their father's care for at least seven months.

emu

(Image © Corel)

An emu, photographed in Australian Capital Territory. Although they are flightless, emus can run at speeds of up to 50 kph/30 mph for short distances and swim well. They are native to mainland Australia and generally inhabit a large home range.

emu



(Image © Research Machines plc)

A flightless bird, the emu weighs 35–40 kg/80–90 lb and runs at speeds of up to 50 kph/30 mph.

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emulator

in computing, an item of software or firmware that allows one device to imitate the functioning of another. Emulator software is commonly used to allow one make of computer to run programs written for a different make of computer. This allows a user to select from a wider range of applications programs, and perhaps to save money by running programs designed for an expensive computer on a cheaper model.

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emulsifier

food additive used to keep oils dispersed and in suspension, in products such as mayonnaise and peanut butter. Egg yolk is a naturally occurring emulsifier, but most of the emulsifiers in commercial use today are synthetic chemicals.

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emulsion

stable dispersion of a liquid in another liquid - for example, oil and water in some cosmetic lotions.

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encephalin

naturally occurring chemical produced by nerve cells in the brain that has the same effect as morphine or other derivatives of opium, acting as a natural painkiller. Unlike morphine, encephalins are quickly degraded by the body, so there is no build-up of tolerance to them, and hence no addiction. Encephalins are a variety of peptides, as are endorphins, which have similar effects.

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encephalitis

inflammation of the brain, nearly always due to viral infection but it may also occur in bacterial and other infections. It varies widely in severity, from shortlived, relatively slight effects of headache, drowsiness, and fever to paralysis, coma, and death.

Childhood Infections - Encephalitis

Go to site

Useful information about encephalitis. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

Encke's Comet

comet with the shortest known orbital period, 3.3 years. It is named after German astronomer Johann Encke, who calculated its orbit in 1819 from earlier sightings.

The comet was first seen in 1786 by the French astronomer Pierre Méchain. It is the parent body of the Taurid meteor shower and a fragment of it may have hit the Earth in the Tunguska Event in 1908.

In 1913 it became the first comet to be observed throughout its entire orbit when it was photographed near its aphelion (the point in its orbit furthest from the Sun) by astronomers at Mount Wilson Observatory in California, USA.

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encryption

encoding a message so that it can only be read by the intended recipient. The mathematical calculation of encryption formulae is called cryptography.

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endangered species

plant or animal species whose numbers are so few that it is at risk of becoming extinct. Officially designated endangered species are listed by the World Conservation Union (or IUCN).

An endangered species is not a new phenomenon; extinction is an integral part of evolution. The replacement of one species by another usually involves the eradication of the less successful form, and ensures the continuance and diversification of life in all forms. However, extinctions induced by humans are thought to be destructive, causing evolutionary dead ends that do not allow for succession by a more fit species. The great majority of recent extinctions have been directly or indirectly caused by humans, most often by the loss, modification, or pollution of the organism's habitat, but also by hunting for 'sport' or for commercial purposes.

Endangered species

Species	Observation

plants	a quarter of the world's plants are threatened with extinction by the year 2010
amphibians	worldwide decline in numbers; half of New Zealand's frog species are now extinct; 25% of species threatened with extinction; 38% of US amphibians are endangered
birds	three-quarters of all bird species are declining; 11% are threatened with extinction
carnivores	almost all species of cats and bears are declining in numbers
fish	one-third of North American freshwater fish are rare or endangered; half the fish species in Lake Victoria, Africa's largest lake, are close to extinction due to predation by the introduced Nile perch; 33% of species are threatened with extinction
invertebrates	about 100 species are lost each day due to deforestation; half the freshwater snails in the southeastern USA are now extinct or threatened; 50% of crayfish and 56% of mussel species are endangered in the USA; a quarter of German invertebrates are threatened
mammals	half of Australia's mammals are threatened; 40% of mammals in France, the Netherlands, Germany, and Portugal are threatened; 25% of species are threatened with extinction
primates	two-thirds of primate species are threatened
reptiles	over 51% of reptile species are threatened; 25% with extinction

Endangered Species

Go to site

Claiming to offer 'The rarest info around', this site is packed with photos and information about endangered species and extinction rates. Sections include 'Laws that protect animals', 'Endangered species fact sheets', and 'Selected species survival plans'. There is also a separate children's site.

Endangered Species

Go to site

Good facts and pictures on species under threat from extinction. Also contains some information about the nature of historical extinctions, as well as news and links to conservation organizations around the globe.

Endangered Species Home Page

Go to site

US Fish and Wildlife site with full details of its ongoing conservation programmes. The site also contains a 'Kids' Corner', a gallery of images, and a link to the latest edition of its *Endangered Species Bulletin*.

Tiger Basics

Go to site

This page offers descriptions of the five sub-species of tiger with details of their anatomy, hunting methods, habitats, the pressures they are under, and the measures taken to protect them. There is also a 'Multimedia' section with pictures and sounds, and even a 'Tigers in the news' section.

Enders, John Franklin (1897-1985)

US virologist who was awarded a Nobel Prize for Physiology or Medicine in 1954 with Thomas Weller and Frederick Robbins for their cultivation of the polio virus in the laboratory. This led to the creation of effective vaccines against polio and measles.

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endive

cultivated annual plant, the leaves of which are used in salads and cooking. One variety has narrow, curled leaves; another has wide, smooth leaves. It is related to chicory. (*Cichorium endivia*, family Compositae.)

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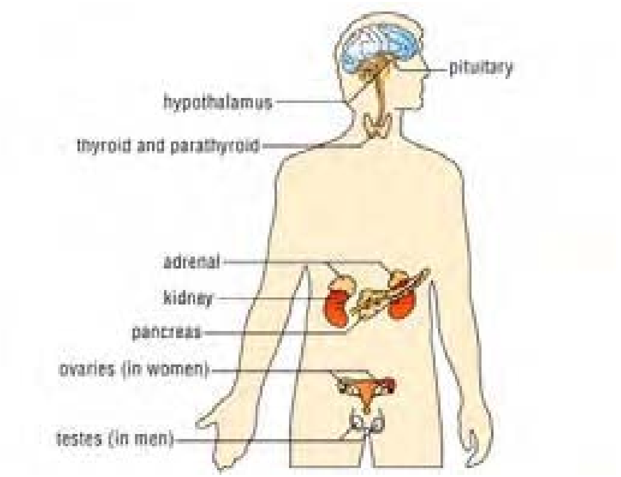
endocrine gland

gland that secretes hormones into the bloodstream to regulate body processes. Endocrine glands are most highly developed in vertebrates, but are also found in other animals, notably insects. In humans the main endocrine glands are the pituitary, thyroid, parathyroid, adrenal, pancreas, ovary, and testis.

endocrine gland



(Image © Research Machines plc)

The main human endrocrine glands. These glands produce hormones – chemical messengers – which travel in the bloodstream to stimulate certain cells.

Endocrine Disrupters

Go to site

Part of the Why Files project, published by the National Institute for Science Education (NISE) and funded by the National Science Foundation, this page investigates the harmful effects that synthetic chemicals are having on the endocrine system. The highly readable text, laid out over ten pages, includes information about the endocrine system, how 'endocrine disrupters' are adversely effecting the system, and what is being done to solve the problem. Numerous images and diagrams enhance the text throughout. You will also find a comprehensive bibliography of sources for further research.

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endolymph

fluid found in the inner ear, filling the central passage of the cochlea as well as the semicircular canals.

Sound waves travelling into the ear pass eventually through the three small bones of the middle ear and set up vibrations in the endolymph. These vibrations are detected by receptors in the cochlea, which send nerve impulses to the hearing centres of the brain.

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endometriosis

common gynaecological complaint in which patches of endometrium (the lining of the womb) are found outside the uterus.

This ectopic (abnormally positioned) tissue is present most often in the ovaries, although it may invade any pelvic or abdominal site, as well as the vagina and rectum. Endometriosis may be treated with analgesics, hormone preparations, or surgery. Between 30 and 40% of women treated for infertility are suffering from the condition.

Endometriosis

Go to site

Information about endometriosis. The facts about this common and poorly-understood disease are well presented. Methods of treatment are explained and there is a link to a site with advice on pain management and to a newsgroup for endometriosis sufferers.

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endoparasite

parasite that lives inside the body of its host.

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endoplasm

inner, liquid part of a cell's cytoplasm, as opposed to the ectoplasm.

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endoplasmic reticulum

ER

a membranous system of tubes, channels, and flattened sacs that form compartments within eukaryotic cells. It stores and transports proteins within cells and also carries various enzymes needed for the synthesis of fats. The ribosomes, or the organelles that carry out protein synthesis, are sometimes attached to parts of the ER.

Under the electron microscope, ER looks like a series of channels and vesicles, but it is in fact a large, sealed, baglike structure crumpled and folded into a convoluted mass. The interior of the 'bag', the ER lumen, stores various proteins needed elsewhere in the cell, then organizes them into transport vesicles formed by a small piece of ER membrane budding from the main membrane.

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endorphin

natural substance (a polypeptide) that modifies the action of nerve cells. Endorphins are produced by the pituitary gland and hypothalamus of vertebrates. They lower the perception of pain by reducing the transmission of signals between nerve cells.

Endorphins not only regulate pain and hunger, but are also involved in the release of sex hormones from the pituitary gland. Opiates act in a similar way to endorphins, but are not rapidly degraded by the body, as natural endorphins are, and thus have a long-lasting effect on pain perception and mood. Endorphin release is stimulated by exercise.

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endoscope

in medicine, tubular instrument inserted into a cavity in the body to investigate and treat diseases during a process known as endoscopy.

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endoscopy

examination of internal organs or tissues by an instrument allowing direct vision. An endoscope is equipped with an eyepiece, lenses, and its own light source to illuminate the field of vision. The endoscope used to examine the digestive tract is a flexible fibreoptic instrument swallowed by the patient.

There are various types of endoscope in use - some rigid, some flexible - with names prefixed by their site of application (for example, bronchoscope and laryngoscope). The value of endoscopy is in permitting diagnosis without the need for exploratory surgery. Biopsies (tissue samples) and photographs may be taken by way of the endoscope as an aid to diagnosis, or to monitor the effects of treatment. Some surgical procedures can be performed using fine instruments introduced through the endoscope. Keyhole surgery is increasingly popular as a cheaper, safer option for some conditions than conventional surgery.

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endoskeleton

internal supporting structure of vertebrates, made up of cartilage or bone. It provides support, and acts as a system of levers to which muscles are attached to provide movement. Certain parts of the skeleton (the skull and ribs) give protection to vital body organs.

Sponges are supported by a network of rigid, or semirigid, spiky structures called spicules; a bath sponge is the proteinaceous skeleton of a sponge.

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endosperm

nutritive tissue in the seeds of most flowering plants. It surrounds the embryo and is produced by an unusual process that parallels the fertilization of the ovum by a male gamete. A second male gamete from the pollen grain fuses with two female nuclei within the embryo sac. Thus endosperm cells are triploid (having three sets of chromosomes); they contain food reserves such as starch, fat, and protein that are utilized by the developing seedling.

In 'non-endospermic' seeds, absorption of these food molecules by the embryo is completed early, so that the endosperm has disappeared by the time of germination.

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endotherm

'warm-blooded', or homeothermic, animal. Endotherms have internal mechanisms for regulating their body temperatures to levels different from the environmental temperature. See homeothermy.

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endothermic reaction

chemical reaction that requires an input of energy in the form of heat for it to proceed; the energy is absorbed from the surroundings by the reactants. A sign that this is happening is if the container holding the reactants feels cold and the temperature of the reactants falls. The energy absorbed is represented by the symbol +ΔH.

The dissolving of sodium chloride in water and the process of photosynthesis are both endothermic changes. In photosynthesis the energy absorbed is in the form of light energy. In an endothermic reaction the energy needed to break the chemical bonds in the reactants is greater than the energy released when bonds are formed in the products. See energy of reaction.

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endotoxin

in biology, heat stable complex of protein and lipopolysaccharide that is produced following the death of certain bacteria. Endotoxins are typically produced by the Gram negative bacteria and can cause fever. They can also cause shock by rendering the walls of the blood vessels permeable so that fluid leaks into the tissues and blood pressure falls sharply.

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end user

user of a computer program; in particular, someone who uses a program to perform a task (such as word processing or playing a computer game), rather than someone who writes programs (a programmer).

Energiya rocket

or Energia rocket

most powerful Soviet booster rocket, first launched on 15 May 1987. Used to launch the Soviet space shuttle *Buran* in 1968, the SL-17 Energiya booster was capable, with the aid of strap-on boosters, of launching payloads of up to 190 tonnes into Earth orbit. It stood 60 m/197 ft tall and was the first Soviet rocket to use liquid-hydrogen fuel. The rocket made only two flights to orbit before being abandoned.

Energia

Go to site

Illustrated guide to the Energiya family of boosters and launch vehicles. There is detailed historical background as well as technical information.

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energy

capacity for doing work. This work may be as simple as reading a book, using a computer, or driving a car. Without energy no activity is possible. Energy can exist in many different forms. For example, potential energy (PE) is energy deriving from position; thus a stretched spring has elastic PE, and an object raised to a height above the Earth's surface, or the water in an elevated reservoir, has gravitational PE. Moving bodies possess kinetic energy (KE). Energy can be converted from one form to another, but the total quantity in a system stays the same (in accordance with the conservation of energy principle). Energy cannot be created or destroyed. For example, as an apple falls it loses gravitational PE but gains KE. Although energy is never lost, after a number of conversions it tends to finish up as the kinetic energy of random motion of molecules (of the air, for example) at relatively low temperatures. This is 'degraded' energy that is difficult to convert back to other forms.

energy sources

There are two main sources of energy: the Sun, the ultimate source; and decay of radioactive elements in the Earth. Plants use the Sun's energy and convert it into food and oxygen. The remains of plants and animals that lived millions of years ago have been converted into fossil fuels such as coal, oil, and natural gas.

energy types and transfer

For energy to be useful it has to be converted into a form that can do work. Energy occurs in many forms - for example, potential (stored energy), kinetic (movement), chemical, heat, light, electrical, sound, and nuclear energy.

A flat battery in a torch will not light the torch. If the battery is fully charged, it contains enough chemical energy to illuminate the torch bulb. When one body A does work on another body B, A transfers energy to B. The energy transferred is equal to the work done by A on B. Energy is therefore measured in joules. The rate of doing work or consuming energy is called power and is measured in watts (joules per second). Energy can be converted from any form into another. A ball resting on a slope possesses potential energy that is gradually changed into kinetic energy of rotation and translation as the ball rolls down. As a pendulum swings, energy is constantly being changed from a potential form at the highest points of the swing to kinetic energy at the lowest point. At positions in between these two extremes, the system possesses both kinetic and potential energy in varying proportions. A weightlifter changes chemical energy from the muscles into potential energy of the weight when the weight is lifted. If the weightlifter releases the weight, the potential energy is converted to kinetic energy as it falls, and this in turn is converted to heat energy and sound energy as it hits the floor. A lump of coal and a tank of petrol, together with the oxygen needed for their combustion, have chemical energy. Other sorts of energy include electrical and nuclear energy, light, and sound. However, all of these types are ultimately classifiable as either kinetic or potential energy.

resources

So-called energy resources are stores of convertible energy.
Non-renewable resources include the fossil fuels (coal, oil, and gas) and nuclear-fission 'fuels' – for example, uranium-235. The term 'fuel' is used for any material from which energy can be obtained. We use up fuel reserves such as coal and oil, and convert the energy they contain into other, useful forms. The chemical energy released by burning fuels can be used to do work.
Renewable resources, such as wind, tidal, and geothermal power, have so far been less exploited. Hydroelectric projects are well established, and wind turbines and tidal systems are being developed.

energy conservation and efficiency

All forms of energy are interconvertible by appropriate processes. Energy is transferred from one form to another, but the sum total of the energy after the conversion is always the same as the initial energy. This is the principle of conservation of energy. This principle can be illustrated by the use of energy flow diagrams, called Sankey diagrams, which show the energy transformations that take place. When a petrol engine is used to power a car, about 75% of the energy from the fuel is wasted. The total energy input equals the total energy output, but a lot of energy is wasted as heat so that the engine is only about 25% efficient. The combustion of the petrol–air mixture produces heat energy as well as kinetic energy. All forms of energy tend to be transformed into heat and cannot then readily be converted into other, useful forms of energy.

heat transfer

A difference in temperature between two objects in thermal contact leads to the transfer of energy as heat. Heat is energy transferred due to a temperature difference. Heat is transferred by the movement of particles (that possess kinetic energy) by conduction, convection, and radiation. Heat conduction involves the movement of heat through a solid material by the transfer of vibrational energy from atom to atom. For example, thermal energy is lost from a house by conduction through the walls and windows. Convection involves the transfer of energy by the movement of fluid particles. All objects radiate heat in the form of radiation of electromagnetic waves. Hotter objects emit more energy than cooler objects. Methods of reducing energy transfer as heat through the use of insulation are important because the world's fuel reserves are limited and heating homes costs a lot of money in fuel bills. Heat transfer from the home can be reduced by a variety of methods, such as loft insulation, cavity wall insulation, and double glazing. The efficiencies of insulating materials in the building industry are compared by measuring their heat-conducting properties, represented by a U-value. A low U-value indicates a good insulating material.

$E = mc^2$

Mass can be converted into energy under certain conditions, according to Einstein's theory of relativity. This conversion of mass into energy is the basis of atomic power. Einstein's special theory of relativity (1905) correlates any gain, E, in energy with a gain, m, in mass, by the equation $E = mc^2$, in which c is the speed of light. The conversion of mass into energy in accordance with this equation applies universally, although it is only in nuclear reactions that the percentage change in mass is large enough to detect.

Burning fossil fuels causes acid rain and is gradually increasing the carbon dioxide content in the atmosphere, with unknown consequences for future generations. Nuclear power stations do not release carbon dioxide but produce highly dangerous waste that must be disposed of, and pose a small but non-zero risk of a catastrophic release of radioactive material. The ultimate non-renewable but almost inexhaustible energy source would be nuclear fusion (the process by which energy is generated in the Sun), but controlled fusion is a long way off. (The hydrogen bomb is a fusion bomb.) Harnessing resources generally implies converting their energy into electrical form, because electrical energy is easy to convert to other forms and to transmit from place to place, though not to store. Almost a third of all energy consumption in Europe is by transport.

CHEMystery: Energy

Go to site

Definition of energy, what it is, and what it enables people to do. Different forms of energy are covered, such as potential and kinetic energy. Links to the topics of 'Matter and energy' and 'Law of conservation of matter and energy' are on the right-hand side of the page, and are relevant to expanding energy concepts further.

EnergyEd

Go to site

Light-hearted and educational introduction to electricity and renewable energy with the opportunity to take a virtual tour around a power station.

S-Cool!: Work, Energy, and Efficiency

Go to site

Simple, easy-on-the-eye page detailing the concepts of work, energy, and efficiency. This site includes examples, equations, and clear diagrams to aid understanding. Further links are provided to lessons in the same series.

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energy

in biology, the basis for conducting living processes. Much of life involves energy transfer. Energy is transferred from the surroundings of an organism into its body, and is also transferred within an organism's body. Energy is used by organisms to do things, such as growing or moving. When they do these things energy is transferred from one substance to another or from one place to another.

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energy, alternative

energy from sources that are renewable and ecologically safe, as opposed to sources that are non-renewable with toxic by-products, such as coal, oil, or gas (fossil fuels), and uranium (for nuclear power). The most important alternative energy source is flowing water, harnessed as hydroelectric power. Other sources include the oceans' tides and waves (see tidal power station and wave power), wind power (harnessed by windmills and wind turbines), the Sun (solar energy), and the heat trapped in the Earth's crust (geothermal energy) (see also cold fusion).

Alternative and Renewable Energy Sources

Go to site

Explains varied energy sources through real-life examples. Energy types covered are wind, solar, and wood. Each example contains detailed information on how the alternative source of energy helps save money and coal, every year. There are links to other pages on the site, such as eco-friendly housing.

Alternative Technology

Go to site

Part of an electronic teacher's guide 'Teaching for a Sustainable World: International Edition', this site also contains useful information for students.

Centre for Alternative Technology

Go to site

Dedicated to the Centre For Alternative Technology in Wales, this includes a virtual tour of the site, pictures, and maps. It also includes a quiz, a question forum, and an extensive list of educational resources.

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energy conservation

the practice and methods used to reduce energy resource consumption, usually by identification of those processes that are energy-inefficient and providing alternative solutions. The term can also used to describe the conservation of non-renewable resources such as coal, oil, and natural gas by increasing the efficiency of related processes, or finding alternatives so that existing stocks are depleted at a slower rate. Common conservation methods are insulation, optimization of processes to use minimum energy, increasing the efficiency of a process by changing the methods and/or components used, and finding alternatives that do not use nonrenewable resources. Profligate energy use by industrialized countries contributes greatly to air pollution and the greenhouse effect when it draws on nonrenewable energy sources.

Energy conservation is driven both by economic and environmental considerations. In industrial applications, inefficient energy use is both expensive and increases the negative impact the process has on the environment. This can be either by direct pollution or indirectly by requiring higher levels of energy generation from power stations, which then need to consume more nonrenewable fuels such as coal.

energy conservation

The energy used by electrical appliances, such as televisions and videos, left on standby is almost as much as that used when the appliances are running. In 1997 the amount of energy wasted in this way in the USA alone could power London for a year and costs consumers around $1 billion.

Energy Conservation: The Chimney-Stack Design

energy conservation in architecture

Low-energy buildings have been the holy grail of architects ever since energy prices rose dramatically in the 1970s. A simple approach is to combine passive solar heating with state-of-the-art insulation and triple glazing. An example of this approach is the country mansion at Wakeham, Sussex, UK.

Wakeham mansion: tradition and technology

The architectural design of Wakeham mansion combines tradition and technology. It is built in a traditional style but includes a large three-storey glass portico, supported by imposing classical columns. South-facing, the portico traps the sun's energy and provides enough warm air to heat most of the house by the application of natural convection effects called **thermo-syphoning**. Air enters the portico by a vent, is heated by the sun, and then thermo-syphoned throughout the house by a system of ducts, vents, and open doorways.

Most of the air passes first into a large central drawing room, from where it circulates to other rooms. Eventually the warm air rises through vents in the ceiling of the first floor rooms to the upper rooms and is expelled through a chimney stack at the top of the house. On hot days, the portico can be isolated from the house and the air circulation can be reversed to cool the house.

The Wakeham mansion proves that simple techniques can reduce a building's energy requirements by at least a half.

building energy management systems

Sophisticated computer-controlled 'smart' buildings can achieve even greater energy savings. Building energy management systems (BEMS) can reduce energy usage by three-quarters. Offices built for the Inland Revenue in Nottingham, UK, are one example. The complex uses 94 kilowatt-hours per square metre per year, compared to a conventional office building on the same site using 390 kWh/sq m per year.

stack effect in nature

The design of the Nottingham Inland Revenue offices is based on a natural example of good building practice. In the hot northern deserts of Western Australia, compass termites build mud towers up to three metres tall above their underground nests. Air channels link the nest, tower, and the outside air. As the tower heats up, the air inside rises, sucking cooler air through the nest. The phenomena is called **the stack effect**. The termites regulate the temperature in the nest by blocking and unblocking the air channels in the tower and nest. They are able to maintain the temperature inside the nest at 31°C, night and day, summer and winter. The outside temperature varies between 3°C and 42°C.

BEMS control Inland Revenue office blocks

The Inland Revenue office blocks have a cylindrical glass tower 17 m/56 ft high, housing the main stairway, on one corner of each block. The towers act as sun traps and the air inside is heated to create a stack effect. Air rising in the stack sucks in fresh air through the windows and grilles in the walls of the building. The roof of each tower can be raised and lowered to regulate the rising hot air and the amount of cool air sucked through the building.

The temperature within the building is monitored and regulated by a BEMS computer program which draws information from sensors in the fabric of the building. A weather station on the roof monitors wind speed and direction, rainfall, and sunshine. During a storm, BEMS closes the roof of the tower.

BEMS has other tasks, too. It starts fans to blow cold air through the offices when needed, dims the lights on sunny days, closes window blinds to prevent overheating. The system can also 'learn' about local weather conditions, varying the heating according to the amount of sunlight falling on each section of the building. Even so, the inside temperature in a naturally ventilated building varies more than in an air-conditioned one. In the Inland Revenue building, the temperature is expected to rise above 27°C for less than 22 hours each year. This is at least one degree below the outside temperature and is considered acceptable by the building's occupants.

De Montfort University

The stack effect is also used to regulate the temperature inside the Queens Building at De Montfort University in Leicester, UK, which was completed in September 1993. Each lecture theatre seats 180 people and they generate three times as much heat as people in an average office. To dissipate the heat, each theatre has two 13-m/43-ft-high brick chimneys. As hot air rises from the chimneys, cool air is drawn into the theatres through ducts under the seats. The temperature inside the theatres is predicted to rise to 27°C on only 10 days each year.

combatting sick building syndrome

Naturally ventilated buildings may have another advantage as well as energy efficiency – they may be healthier than air-conditioned buildings. Sick building syndrome (SBS) affects over half the people working in air-conditioned buildings. Symptoms include headaches and nausea. Possible causes include a build-up of pollutants and dust mites. The free circulation of air in a naturally ventilated building may prevent the build-up of pollutants and reduce SBS.

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energy of reaction

or enthalpy of reaction or heat of reaction

energy released or absorbed during a chemical reaction, part of the energy transfer that takes place. In a chemical equation it may be represented by the symbol ΔH. In a chemical reaction, the energy stored in the reacting molecules is rarely the same as that stored in the product molecules. Depending on which is the greater, energy is either released (an exothermic reaction) or absorbed (an endothermic reaction) from the surroundings. The amount of energy released or absorbed by the quantities of substances represented by the chemical equation is the energy of reaction. The principle that the total amount of energy in a given chemical reaction stays the same is known as conservation of energy.

Examples of chemical reactions that release large amounts of heat energy include the combustion of fuels and explosives. For example, when a mixture of hydrogen gas and oxygen gas in a glass jar is ignited by a spark, rapid and large amounts of heat energy are released shattering the glass jar in the process. The spark supplies the activation energy required for bond breaking to occur in the reactants, enabling the reaction to begin.

$2H_2 + O_2 \rightarrow 2H_2O$ + 115.6 kJ of energy

Some oxidation reactions take place very slowly such as the rusting of iron. The heat of the chemical reaction is immediately dissipated, and the activation energy required for rusting to take place is very large. The chemical equation describing the rusting of iron is:

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$ + 380 kJ of energy

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engine

device for converting stored energy into useful work or movement. Most engines use a fuel as their energy store. The fuel is burnt to produce heat energy - hence the name 'heat engine' - which is then converted into movement. Heat engines can be classified according to the fuel they use (petrol engine or diesel engine), or according to whether the fuel is burnt inside (internal combustion engine) or outside (steam engine) the engine, or according to whether they produce a reciprocating or a rotary motion (turbine or Wankel engine).

engine

(Image © Research Machines plc)

The first beam engines, early types of steam engine, were patented by Richard Trevithick, a Cornish mining engineer, in the first decade of the 19th century. They were used to pump water out of the mine and to bring men and ore to the surface. In recent years several engines and engine houses have been fully restored.

engine

(Image © Research Machines plc)

The Levant Beam Engine, near Pendeen in Cornwall, is more than one hundred and fifty years old. Originally used to pump water out of the tin mine below ground, and to bring ore and miners up to the surface, the engine lay idle for 60 years, before being restored to full working order in the 1990s as a tourist attraction.

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engineering

the application of science to the design, construction, and maintenance of works, machinery, roads, railways, bridges, harbour installations, engines, ships, aircraft and airports, spacecraft and space stations, and the generation, transmission, and use of electrical power. The main divisions of engineering are aerospace, chemical, civil, computer, electrical, electronic, gas, marine, materials, mechanical, mining, production, radio, and structural.

Engineering and Technology

ancient times

Our existence today is powerful evidence of our ability to invent. Were it not for the invention of simple tools made from sharp-edged stones some 2 million years ago, it is doubtful whether our relatively weak and slow ancestors would have survived for long. Such tools enabled early humans to fight off predators and to hunt for food.

As well as being surrounded by potentially hostile animals, early humans were at the mercy of the climate. It was the second of the major inventions of prehistory, a means of creating fire, that enabled them to survive the Ice Ages. *Homo erectus* was using this to live through the second Ice Age some 400,000 years ago.

These two inventions served our ancestors well for an extremely long time. Not until the foundation of Jericho, the world's first walled town, around 7000 BC does another major invention reveal itself, in the development of pottery. Behind the foundation of Jericho, were the beginnings of organized agriculture, and it was this that provided the stimulus for the development of increasingly sophisticated tools, such as the plough and the sickle. Copper appeared at around this time and the alloy made from copper and tin called bronze, appeared around 5000 BC.

the wheel

That most famous and significant of inventions of the ancient world, the wheel, first appeared around 3000 BC, in what is now the region covered by Iran and Iraq. These early wheels were solid, wooden and fixed to sleds which had previously been dragged across the ground. Although its first use was in transporting heavy loads, the wheel and axle combination later became a feature of milling devices, and irrigation systems. Sumerian and Assyrian engineers used wheel-driven water drawing devices in irrigation networks which are still in use today.

Greek influences

For several thousand years, these early inventions were enlarged and improved upon, without any major advances being made. By the time mathematician and physicist Archimedes (*c.* 287–*c.* 212 BC) was investigating the principle of the lever and producing his famous helical screw, the scene of the most significant developments had shifted from the Middle East to Greece. The measurement of time in particular remained a continuing challenge, and by the 2nd century BC, Ctesibius of Alexandria had developed the Egyptian *clepsydra* (water-clock) to give accuracy not surpassed until well into the Middle Ages.

Hero of Alexandria (*c.* AD 60) was the last of the Greek technologists, his most famous invention being of the *aeolipile*, a primitive steam turbine that gave a hint, as early as the 1st century BC, of the potency of steam as a power-source. One of the most important inventions of the classical world was the water wheel. In its simplest form, the Norse wheel, it was just a horizontal scoop wheel set in a fast-moving stream, driving the stones of a grain mill. The vertical wheel, first described in the 1st century BC by the Roman Pollio Vitruvius was far more efficient, and by the use of gearing could drive all kinds of machinery from water pumps to the hammers of a forge. It remained the main source of industrial power until the invention of the rotative steam engine at the end of the 18th century.

Roman and Chinese influences

Despite their astonishing ability in geometry, physics, and mathematics, the Greeks were unable to make the advance which transformed architecture and civil engineering: the arch. The pre-Roman Etruscans used the semicircular arch as an architectural feature, but it was the Romans who put the arch to full use. Because of its ability to spread imposed stresses more evenly, the arch allowed greater spans in buildings than the Greeks' simple pillar-and-beam arrangements. Aqueducts comprising 6 m/20 ft wide arches were possible as early as 142 BC, as evidenced by the Pons Aemilius in Italy.

Combining the structural economy of the arch with the availability of good cement the Romans set up an infrastructure and communications network that gave them a standard of living hitherto unprecedented in history. It also enabled them to extend that standard, and maintain it by its armies, over a similarly unprecedented expanse of the world.

Animals such as oxen had been used for ploughing by the ancient Egyptians and the Greeks. However, it was the Chinese who first produced an efficient animal harness, enabling animals to be used in tandem to haul great loads. The harness did not reach the West, however, until the 9th century, well after the fall of the Roman Empire. China was the birthplace of a number of other major inventions: of paper from pulp (by Ts'ai Lun around AD 100), of the magnetic compass, and of gunpowder, around 500 and 850 respectively.

the development of Western technology

It was also around this time that Northwestern Europe began its climb to ascendency in technology that it has held onto for centuries since. The poorer climate of this region, combined with the need to develop a new form of agriculture, was responsible for the emergence around the 8th century of the crop rotation methods still used today. The wind was put to use in both sea-going vessels and land-based mills. The region grew more populous and, by the 11th century, northern Europeans were moving their influence into the Mediterranean and Middle East.

As the societies grew, becoming more complex, the need for metals for housing, tools, equipment, and coinage increased concomitantly. This caused a renewed interest in the extraction and treatment of ores, which were also in increasing demand by rulers anxious to develop weapons capable of keeping their rivals at bay. Many of these rulers, notably in 15th-century Italy, employed engineers to come up with new systems for both defence and attack. Undoubtedly the most famous such engineer was Leonardo da Vinci (1452–1519), military engineer to the Duke of Milan. Among the thousands of pages of da Vinci's notes are to be found an astonishing number of prescient plans for modern-day inventions: tanks, submarines, helicopters, and a whole range of firearms.

the printing press

The Renaissance was ushered in by one of the most influential inventions in history: the development of the movable type printing press by the printer Johannes Gutenberg (*c.* 1397-1468) of Mainz, Germany. The Gutenberg Bible, the first book to be printed using this process, appeared in 1454. The English printer William Caxton set up a press in England in 1476. As well as disseminating religious knowledge over a far wider scale, the invention enabled the speeding up of the transfer of technological advances from one country to another.

steam power and the Industrial Revolution

The ever-increasing use of metals made mining the focus of much effort in the 15th century, one of the biggest problems being that of adequately draining the mines. Pumping water fast enough and in sufficient volume was also a problem facing those wanting to create more agricultural land from poorly drained areas, and to supply towns with their needs. By the mid-17th century, a number of patents had been granted to water pumps which used a new, remarkably versatile source of power: steam.

English inventor and engineer Thomas Savery (*c.* 1650-1715) demonstrated an engine for 'raising of water and occasioning motion to all sorts of mill works, by the impellant force of fire', to the Royal Society of London in 1699. A far more efficient machine, the atmospheric engine, was invented *c.* 1712 by English blacksmith Thomas Newcomen (1663-1729). It was a beam engine that could pump water from deep underground and came into use to maintain the mines of Staffordshire, Cornwall, and Newcastle in workable condition.

Iron was first smelted over 3,000 years ago, but for most of that time it was produced in the form of malleable or wrought iron. Cast iron appeared some time in the 15th century with the introduction of the blast furnace using charcoal as a fuel. Iron making was revolutionized when the English iron manufacturer Abraham Darby (1677-1717) bought a foundry at Coalbrookdale, Shropshire where he successfully used coke instead of charcoal in the furnace and perfected techniques for casting in sand. The Coalbrookdale works went on to be hugely influential, casting cylinders for the first steam engines, making the first iron rails and, most famously, demonstrating the structural possibilities of iron by building the world's first iron bridge across the River Severn in 1779.

Watt's improvements to the steam engine

Newcomen steam engines grew in popularity during the 18th century, and it was while repairing a model one used on the physics course at Glasgow University in 1763 that the young Scottish mechanical engineer James Watt (1736-1819) saw how major improvements could be made, improvements that led to Watt's condenser engine completely replacing the earlier model by 1800.

inventions that revolutionized manufacturing

Through its predominance as a manufacturing market, Britain was able to reap rich rewards but competition from overseas urged on the hunt for greater efficiency of production. Technologists were at the forefront of this effort, with English inventor John Kay's (1704-1780) invention of the flying shuttle for the weaving of textiles. Spinning was improved by the English weaver James Hargreaves' (1720-1778) spinning jenny. English industrial pioneer Richard Arkwright's (1732-1792) spinning machine was the centrepiece of the first cotton factory of 1771, and semi-automated mass production as a technique was born. The Industrial Revolution, which is arguably still under way, had begun.

The end of the 18th century saw English engineer Richard Trevithick (1771-1833) experimenting with the use of steam to provide motive power for boats, road vehicles, and locomotives on iron rails. Dogged by bad luck, his ideas did not achieve the success or acclaim they deserved, and the world had to wait longer than it should have for the full exploitation of steam in such applications. French engineers had more success initially, with Nicholas Joseph Cugnot (1725-1804) developing a three-wheeled steam-powered tractor around 1770, capable of 6 kph/3.5 mph. The Montgolfier brothers Joseph-Michael (1740-1810) and Jacques Etiènne (1745-1799) were responsible for the first sustained human flight, aboard a hot-air balloon 1763.

the first passenger railway

By the time Trevithick left England for Peru, his high-pressure engine had shown that steam was amply capable of providing a mobile power source. He returned to find his place as the greatest engineer in the new technology usurped by others. Most famous of these was English engineer George Stephenson (1781-1848), whose steam locomotives were responsible for the setting up of the first practical public railway ever built, in 1825, between Stockton and Darlington.

improved communications

The transport revolution began in the 17th century with the construction by the Frenchman Pierre-Paul Riquet (1604-1680) of the Canal du Midi in France, opened in 1681. Riquet was working as a collector of the salt tax in the Languedoc region when he became aware of the need for good transport in the area and began canal promotion in the 1660s. In the UK, 3,220 km/2,000 mi of waterway were constructed between 1760 and 1830. In France, improved roads were built by civil engineer Pierre Trésaguet (1716-1796). Britain's appalling roads were improved by Scottish civil engineer Thomas Telford (1757-1834) whose works included the suspension bridge over the Menai Staits, and the scientific approach to road construction devised by another Scottish civil engineer John McAdam (1756-1836) radically improved this aspect of Britain's infrastructure.

Steam power also found its way into ocean-going vessels. US artist, engineer, and inventor Robert Fulton (1765-1815) returned from Europe, where he had seen what steam engines were

first successful system was brought out by English physicist Charles Wheatstone (1802-1875), in which electrical signals deflected magnetized needles indicating letters of the alphabet. The development of a communication system using a code of dots and dashes to represent the letters by US artist Samuel Morse (1791-1872) proved so successful it was still in use at the end of the 20th century.

developments brought about by war

The problem of making cheap steel was solved almost simultaneously by ironmaster William Kelly (1811-1888) in the United States and English engineer and inventor Henry Bessemer (1813-1898) in Britain. The process involved blowing air through molten pig iron to drive out the carbon. The Crimea War led to English engineer and inventor William Armstrong (1847-1908) developing the wrought-iron, breech-loading gun with rifled barrel. The outbreak of the Crimean

The wars affecting the United States also assisted the development of weapons on that side of the Atlantic. The war against Mexico, which broke out in 1846, accelerated the revolution in small arms manufacture initiated by US inventor Samuel Colt (1814-1862), who had produced the first revolver in 1836. The Civil War of 1861-65 prompted US inventor Richard Gatling (1818-1903) to develop the rapid-fire gun that bears his name.

the internal combustion engine

It was around the middle of the 19th century that attention began to shift from steam to gas and other combustible materials as a means of providing motive power. As early as 1833, an engine that ran on an inflammable mixture of gas and air had been described, and a number of the fundamental principles of the fuel-powered engine had been described by the time Belgian-born French engineer and inventor Jean Lenoir (1822-1900) began building engines using the system which operated smoothly in 1860. Together, German engineers Nikolaus Otto (1832-1891) and Eugen Langen (1833-1895) managed by 1877 to solve the basic problems facing the development of the four-stroke internal combustion engine. This work led to the development of the modern motor car, and of powered flight. German engineer Gottlieb Daimler (1834-1900) was to join the pair as an engineer, leaving in 1883 to develop lighter, more efficient high-speed engines capable of driving cycles and boats, as well as automobiles.

German engineer Rudolph Diesel (1858-1913) experimented with internal combustion engines during the 1890s; by using the heat developed by compression of the fuel-air mixture, rather than a spark from an ignition system, to ignite the mixture, Diesel succeeded in producing an engine that could use cheaper fuels than the Otto cycle engines. However, the high pressures produced in the engines required the use of very heavy-gauge metal, with consequent weight-power ratio problems. Later advances in metallurgy enabled this disadvantage to be significantly reduced, with the result that the Diesel engine is still used in a wide range of vehicles today.

flight

Work in the USA, as well as in Germany, succeeded in bringing the power of the internal combustion engine to bear on the problem of powered flight. Early work on the flow of air over gliders by German engineer Otto Lilienthal (1848-1896) and others established a body of knowledge needed to supplement the work of earlier enthusiasts such as English inventor George Cayley (1773-1857), who had defined the basic aerodynamic forces acting on a wing as early as 1799.

Internal combustion engines, coupled to balloons to form airships, were in use by the turn of the century. The first flight of a heavier-than-air machine powered by a light, efficient internal combustion engine was constructed by US aeronautical engineers the Wright brothers, Orville (1871-1948) and Wilbur (1867-1912), on 17 December 1903. As well as finding a suitable engine for such a machine, the Wrights had succeeded in solving the problem of controlling the aeroplane in all three axes.

electricity as a source of power

Despite the success of the internal combustion engine in powering a wide range of machines, the use of water and steam as power sources remained important in another major field of technology: the generation of electricity. Water had been used to drive turbines of increasing efficiency for many years when English mechanical engineer Charles Parsons (1854-1931) adapted the basic design of a water turbine to enable a jet of steam to impart its kinetic energy to a series of turbine blades which then rotate. By combining this rotation with the ability of a dynamo to convert rotary motion into electric power, the electric generator was born. The first ever turbine-powered generating station was set up in 1888, using four Parsons turbines each developing 75 kW/100 hp. Direct use of the mechanical power developed by steam was made in Parson's 44 tonne/44.7 ton Turbinia, whose turbine engine developed 1.5 MW/2,000 hp, enabling it to travel at 60 kph/37 mph in 1897.

Work by the inventors and electrical engineers Joseph Swan (1828-1914) in England and Thomas Edison (1847-1931) in the United States finally resulted in the creation of a long-lasting light source powered by electricity - the filament lamp - around 1880.

While Germany and the United States were quick to use electrical power to bring about a revolution in their industrial processes, the availability of cheap labour and concentration on waning industries based on traditional raw material inhibited the adoption of electrical power in Britain. Concentration on telegraphic technology and the generation of electric illumination did have an indirect advantage, however. The invention of the two-electrode electric valve, the diode, by English electrical engineer John Fleming (1849-1945) provided a new outlet for the vacuum bulb technology. Such developments as radio communication, radar, television, and the computer all benefited from this.

radio communications

Communication over long distances without the use of cables - 'wireless' communication - had been a practical possibility from the day when the electromagnetic wave physicist Scottish physicist James Clerk Maxwell's (1831-1879) theory combining electrical and magnetic phenomena had been investigated by German physicist Heinrich Hertz (1857-1894) in 1888. Both transmitters and detectors of these radio waves were developed until Italian physicist Guglielmo Marconi (1874-1937) succeeded in transmitting messages over a few yards using electromagnetic waves in 1895. By 1901, he had succeeded in sending signals right across the Atlantic.

More sophisticated communication was made possible by US inventor Lee De Forest (1873-1961) and Canadian physicist Reginald Fessenden (1866-1932), and their invention of the triode amplifier and amplitude modulation respectively. These advances enabled speech and sound to be transmitted over very long distances, and gave birth to modern communications.

developments of the war years

World War I (1914-1918) saw the use of technology on an unprecedented scale. Although many of the advances then simply led to the deaths of hundreds of thousands of troops, many later found major applications in peacetime. An excellent example of this is provided by the development of the nitrogen fixation process to an industrial scale by German chemist Karl Bosch (1874-1940). This enabled the Germans to manufacture explosives such as TNT without relying on foreign imports of nitrogen-bearing materials, capable of being blockaded by the allies. In peacetime, the process allowed the cheap manufacture of fertilizers, equally vital to the survival of a country.

The war also had a profound effect on the aircraft industry. Starting the war as chiefly reconnaissance vehicles, the aircraft became directly involved in the fighting by the end, and mass production of tens of thousands became necessary. Governments spent money on research, accelerating advances in aerodynamics and power systems enormously. Civil aviation, begun by the Germans before the war, benefited, initially using modified military aircraft.

As with the automobile, engineers started to look at new power sources for the aircraft. The use of gas turbines was put forward in 1926, a suggestion turned into reality by English engineer and inventor Frank Whittle (1907-1996) in 1930. By combining a gas turbine with a centrifugal compressor, he created the jet engine.

space travel

The inter-war years saw considerable advances in rocket technology: an area of engineering that was to enable humans to leave the planet of their origin. The Chinese had used solid-fuelled rockets in battles as early as 1232; their direct ancestors are still to be seen strapped to the central booster of the Space Shuttle. It was Russian theoretician Konstantin Tsiolkovskii (1857-1935) who pointed out that liquid propellants had distinct advantages of power and controllability over solid fuels. The American astronautics pioneer US physicist Robert Goddard (1882-1949) succeeded in launching the first liquid-fuelled rocket in 1926. Just 35 years later, Soviet engineers used a liquid-filled booster to send the first human being into Earth orbit. Eight years after that a human being set foot on another celestial body for the first time.

entertainment

By the 1920s, a number of devices born in research laboratories had become established as massively popular forms of entertainment. The work of US inventor and businessman George Eastman (1854-1932), US electrical engineer and inventor Thomas Edison (1847-1931) and others brought photography and sound-and-motion 'movie' pictures to millions. A working system of television was devised by Scottish inventor John Logie Baird (1888-1946) and shown in 1925, while the modern electronic system later adopted as standard for television was demonstrated by Russian-born US electronics engineer Vladimir Zworykin (1889-1982) in 1929. The British Broadcasting Corporation's forebear, the British Broadcasting Company, was formed in 1922, transmitting radio programmes to the public on a national scale. In 1936, experimental television broadcasts were made by the BBC from Alexandra Palace near London.

atomic power

The growth in the use of electrical power put greater emphasis on ways of generating it cheaply. The United States in particular built many large storage dams, producing electricity by hydroelectric turbine technology. By 1920 some 40% of electricity in the USA was generated by this means. But developments in particle physics during these years were beginning to show that the fundamental constituents of matter would be capable of providing another, far more concentrated, form of energy: atomic power. By 1939 and the outbreak of World War II, a number of physicists had begun to appreciate the possibilities offered by 'chain reactions' involving the fission of unstable, chemical elements such as uranium.

the first electronic computers

The war itself again proved to be a sharp stimulus for the refinement of old ideas and the development of new ones. Radar, devised by Scottish physicist and engineer Robert Watson-Watt (1892-1973) in 1935, was developed into a national defence system against aircraft that were growing ever faster and more deadly. More sophisticated weapons and ever more complex message-encoding systems resulted in the development of early electronic computers. These were needed to rapidly sift through data and perform arithmetical operations upon it, and also to carry out numerical integrations which were particularly useful in the precise calculation of the trajectories for artillery shells. The pioneering work on mechanical computing machines by English mathematician Charles Babbage (1792-1871) in the early 1800s was transformed by the introduction of electronic devices by US electrical engineer Vannevar Bush (1890-1974) and others during the war years.

The inter-war ideas of jet and rocket propulsion were used in the development of fighter aircraft and missiles such as the 'V' (*vergeltung*) 1 and 2, powered by ram-jet and liquid fuel respectively. Most devastating of all was the use of the chain reaction of atomic energy in an uncontrolled explosive device against the Japanese in 1945. Although the use of the atomic bomb finally ended World War II, the world still lives under the threat of their use, in still more deadly form, to this day. The use of the first atomic bombs has tended to overshadow another event in the development of atomic power that took place during the war. This was the setting up of the first controlled atomic chain reaction in 1942 by a team of scientists at the University of Chicago, which paved the way for the peaceful use of atomic power to generate electricity. The first nuclear electricity was generated by the Experimental Breeder Reactor in Idaho, USA 1951. The world's first commercial scale nuclear power station entered service at Calder Hall, UK 1956.

the age of the microchip

While the demand for yet more electric power grew among industrial nations mass-producing cars, ships and aircraft, ways of reducing the complexity and power consumption of electronic devices such as computers, radios, and televisions were being sought. Most crucial of these was the invention of the transistor, by US physicists John Bardeen (1908-1991), William Shockley (1910-1989), and Walter Brattain (1902-1987) at Bell Laboratories in the USA, in 1948. These tiny semiconductor-based devices could achieve the rectification and amplification of the thermionic valves of the pre-war years at a fraction of the power consumption. The use of such devices in still smaller form allowed the miniaturization of electronic devices.

In 1958 the first integrated circuit, which contained the components of a complete circuit on a single piece of silicon, was built by US electrical engineer Jack Kilby (1923–) in the USA. The first microprocessor, a complete computer on a chip was designed by US computer engineer Ted Hoff (1937–) in 1971, containing 2,250 components. By 1990 memory chips capable of holding 4 million bits of information were being mass-produced in Japan. In 1993 the US chip manufacturer Intel introduced the Pentium microprocessor chip which was about five times more powerful than earlier processors and had 3.1 million transistors on a silicon square 15 mm/0.6 in across.

Computing power packed into smaller volumes has been the driving force of many areas of technology over the last 40 years. It made possible the era of human space flight, where keeping the mass of all components to a minimum is vital. Telecommunication satellites, such as Telstar (which in 1962 transmitted the first live television pictures across the Atlantic), weather satellites and planetary probes were all made possible as a result of the semiconductor breakthrough. New materials capable of withstanding the rigours of space were also produced, many of which found use back on Earth.

Computer-aided design and manufacture have enabled new ideas in fields from architecture to aircraft manufacture to be tried out, tested, and produced far more quickly and cheaply. The influence of the computer is felt in everyday life, from the diagnosis of disease by the CAT scanner invented by English scientist Godfrey Hounsfield (1919–2004) to the production of bank statements. The first home computers were introduced in the early 1980s. In the 1990s, tens of millions of home computers are linked to the worldwide Internet. Home computer users have also powered the market for CD-ROM, which are able to hold vast amounts of information.

communications advances

The first optical fibre cable, capable of carrying digital signals, was installed in California 1977. In 1988 the International Services Digital Network (ISDN), an international system for sending signals in digital format along optical fibres and coaxial cable, was launched in Japan. The first transoceanic optical fibre cable, capable of carrying 40,000 simultaneous telephone conversations, was laid between Europe and the USA in 1989. In 1992 videophones, made possible by advances in image compression and the development of ISDN, were introduced in the UK. The Japanese began broadcasting high-definition television in 1989. All digital high-definition television was demonstrated in the USA in 1992.

lasers

The laser was another significant development invented 1960 by US physicist Theodore Maiman (1927–), and often used in robotic welders. Holograms, or three-dimensional pictures, became practicable after the development of laser technology.

power sources for the future

Even if, between them, the robot and the computer free us from manual labour, power will still be needed in vast quantities to process the raw material from which goods are produced. There is still considerable interest in finding ways of generating cheap power. Using nuclear fission has proved only a partial answer to the question of what will replace the burning of hydrocarbons such as coal to generate electricity. Public concern about both its inherent safety and the toxic waste produced has cast a shadow over the long-term future of fission-generated electricity.

Engineers and physicists in Europe, the United States, the former Soviet Union, and Japan are currently studying the generation of power by nuclear fusion. Using hydrogen and its isotopes derived from seawater, they hope to be able to mimic the reactions that have kept the Sun burning for thousands of millions of years, although the engineering difficulties presented by trying to keep a plasma stable at a temperature of 100 million degrees are immense. In 1994 the Tokamak Fusion Test Reactor at Princeton University produced 9 megawatts of power. It needed 33 megawatts to drive it and power production lasted for only 0.4 seconds. Nevertheless, the hot plasma of deuterium and tritium was so well behaved that researchers believe output can be boosted.

Others are turning to less exotic sources of energy, such as the wind, solar energy, and tides, to find better ways of exploiting them and generating cheap, clean power. The world's largest photovoltaic power station was plugged into the power grid at Davis, California, USA, in 1993. A wind farm in California's San Bernados Mountains, uses over 4,000 wind turbines to supply electricity to the Coachella Valley in south California.

The end of the century

As the 20th century came to an end, the greatest advances were being made in information technology. Fast communication began with the facsimile or fax, transmitting documents by telephone or telex networks, and continued with e-mail. The most exciting development has been the establishment of the Internet, a worldwide information service available to all computer users. It had its origins in a system developed by the US Defense Department in 1969 to link its various research departments. The non-military network was opened up in 1984, and within ten years there were an estimated 20 million users. Originally the network offered 1.5 Mbit/s, but this had risen to 1000 Mbit/s by 1996. Research continues on ever faster processors, with such innovatory ideas as making use of the changes in quantum states at the subatomic level. Traditional civil engineering also had its triumph with the completion of a scheme first proposed in 1802, for a tunnel to link England and France. The Channel Tunnel, opened in 1994, has two tunnels for rails and a service tunnel. It is 50 km/30 mi long, and a new Anglo French border was established 40 m/130 ft below the sea.

engineering

To remember that to tighten a bolt or nut you turn it clockwise (right), and to take it off you turn it anti-clockwise (left):

Righty tighty, lefty loosie

Build it and Bust it: A Web Site Construction Zone

Go to site

Interactive structural engineering site. Learn the theory, then build and test practically any two-dimensional structure made from beam and joints online. Please note: you will need a Java-enabled browser to get the most out of this site.

Smart Materials

Go to site

Part of a larger site maintained by *Scientific American*, this page takes a look at consumer products and buildings that incorporate 'smart' materials, such as chemical switches and mechanical sensors, to increase performance and safety. The text includes hypertext links to further information, and there is also a list of related links at the bottom of the page.

English Channel

stretch of water between England and France, leading in the west to the Atlantic Ocean, and in the east via the Strait of Dover to the North Sea; it is also known as **La Manche** (French 'the sleeve') from its shape. The Channel Tunnel, opened in 1994, runs between Folkestone, Kent, England, and Sangatte, west of Calais, France.

The English Channel is 560 km/348 mi long west-east; 27 km/17 mi wide at its narrowest (Cap Gris Nez-Dover) and 177 km/110 mi wide at its widest (Ushant-Land's End). The average depth is 40-60 m/131-197 ft, reaching 120 m/394 ft at the entrance to the Strait of Dover and as much as 180 m/590 ft at Hurds Deep, 30 km/19 mi northwest of Guernsey.

English toy terrier

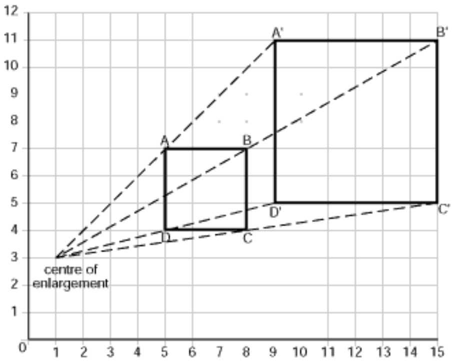
or black-and-tan terrier

breed of toy dog closely resembling the Manchester terrier but smaller and with erect ears. It weighs no more than 3.5 kg/8 lb and is 25-30 cm/10-12 in high.

enlargement

mathematical transformation that changes the size of a shape by multiplying all its proportions by the same scale factor. An enlargement may be either smaller or larger.

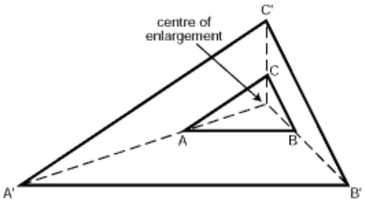
For example:



A'B'C'D' is an enlargement of ABCD. The scale factor of the enlargement is 2, because all the lengths of the shape have been doubled and the distances of points A', B', C', and D' from the centre of enlargement have also been doubled.

A scale factor greater than 1 will give a new shape that is larger than the original and a scale factor less than 1 will give a new shape that is smaller than the original, but they are both called enlargements.

To find the centre of enlargement, the corresponding points of the enlargement and the original shape should be joined, and the lines extended until they all meet. For example:



The centre of enlargement is at O and the scale factor is 3.

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enterovirus

in medicine, one of a family of small polyhedral RNA-containing viruses that enter the body through the gut and are able to penetrate the central nervous system. They include the polio virus; Coxsackie viruses that cause diseases such as herpangina and epidemic myalgia; and ECHO viruses that cause aseptic meningitis.

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entomology

study of insects.

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entropy

in thermodynamics, a parameter representing the state of disorder of a system at the atomic, ionic, or molecular level; the greater the disorder, the higher the entropy. Thus the fast-moving disordered molecules of water vapour have higher entropy than those of more ordered liquid water, which in turn have more entropy than the molecules in solid crystalline ice.

In a closed system undergoing change, entropy is a measure of the amount of energy unavailable for useful work. At absolute zero (-273.15°C/-459.67°F/0 K), when all molecular motion ceases and order is assumed to be complete, entropy is zero.

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envelope

in geometry, a curve that touches all the members of a family of lines or curves. For example, a family of three equal circles all touching each other and forming a triangular pattern (like a clover leaf) has two envelopes: a small circle that fits in the space in the middle, and a large circle that encompasses all three circles.

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environmental archaeology

subfield of archaeology aimed at identifying processes, factors, and conditions of past biological and physical environmental systems and how they relate to cultural systems.

It is a field where archaeologists and natural scientists combine their skills to reconstruct the human uses of plants and animals and how societies adapted to changing environmental conditions.

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environmental audit

another name for green audit, the inspection of a company to assess its environmental impact.

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environmental issues

matters relating to the damaging effects of human activity on the biosphere, their causes, and the search for possible solutions. The political movement that supports protection of the environment is the green movement. Since the Industrial Revolution, the demands made by both the industrialized and developing nations on the Earth's natural resources are increasingly affecting the balance of the Earth's resources. Over a period of time, some of these resources are renewable - trees can be replanted, soil nutrients can be replenished - but many resources, such as minerals and fossil fuels (coal, oil, and natural gas), are non-renewable and in danger of eventual exhaustion. In addition, humans are creating many other problems that may endanger not only their own survival, but also that of other species. For instance, deforestation and air pollution are not only damaging and radically altering many natural environments, they are also affecting the Earth's climate by adding to the greenhouse effect and global warming, while water pollution is seriously affecting aquatic life, including fish populations, as well as human health.

Environmental pollution is normally taken to mean harm done to the natural environment by human activity. In fact, some environmental pollution can have natural sources, for example volcanic activity, which can cause major air pollution or water pollution and destroy flora and fauna. In terms of environmental issues, however, environmental pollution relates to human actions, especially in connection with energy resources. The demands of the industrialized nations for energy to power machines, provide light, heat, and so on are constantly increasing. The most versatile form of energy is electricity, which can be produced from a wide variety of other energy sources, such as the fossil fuels and nuclear power (produced from uranium). These are all non-renewable resources and, in addition, their extraction, transportation, utilization, and waste products all give rise to pollutants of one form or another. The effects of these pollutants can have consequences not only for the local environment, but also at a global level.

Consumption and the Environment

consume, consume, consume

The world is undergoing a consumption revolution. Since the 1950s, the rate at which we consume energy, meat, copper, steel, and timber has doubled. Car ownership has quadrupled, while plastic use has quintupled and air travel has multiplied by a staggering 33 times.

Use of resources is not evenly spread. A fifth of the world's population are listed among the 'consumer class', but consumption at the level enjoyed by most Western middle classes is confined to a much smaller subgroup. Only a tenth of people in the USA ever fly in an aeroplane, for example. Yet this tiny group of high consumers has an impact on the environment out of all proportion with its size.

ecosystems in danger

Rapid use of nonrenewable or limited resources puts ecosystems at risk. Cocoa is grown in developing countries, but eaten mainly in the North. Africa only consumes 3% of the cocoa it produces, for example. Yet natural ecosystems are being destroyed to produce chocolate. In Sarawak, Malaysia, 3,000 sq km/1,158 sq mi of rainforest have been converted to the production of cash crops in the last five years alone.

pollution

Increased pollution also damages forests, freshwaters, and oceans. A German study calculated that, over ten years, the average car is responsible for 2,040 million cu m/72,040 million cu ft of polluted air, 26.5 tonnes/26.9 tons of rubbish, three dead trees and 30 'sick' trees through its contribution to acid rain, and 200 sq m/2,200 sq ft of tarmac and concrete.

endangered animals

Consumption is putting extra pressures on agricultural land and fisheries. Tuna fishing in Mexico kills 50-100,000 dolphins a year. Synthetic gill nets catch 60 seabird species around the world and the jackass penguin is directly threatened.

what can be done?

Despite much talk about 'overpopulation' in the underdeveloped countries, demand for the world's resources comes from the rich countries. It would be impossible for the whole of the world's population to consume at the Western level. Tackling these problems will not be easy. Conservation, recycling, and longer-life products can all help. The sensitive issue of reducing consumption among the rich has scarcely begun to be addressed, but is likely to become increasingly important in the future.

Environmental Organization Web Directory

Go to site

A site that contains thousands of links, Web sites and contact addresses from over 100 countries. This is the largest exclusively environmental directory for those interested in environmental issues and information.

Environmentally Sensitive Area

ESA

scheme introduced by the UK Ministry of Agriculture in 1984, as a result of European Community (EC) legislation, to protect some of the most beautiful areas of the UK countryside from the loss and damage caused by agricultural change. The first areas to be designated ESAs were in the Pennine Dales, the North Peak District, the Norfolk Broads, the Breckland, the Suffolk River Valleys, the Test Valley, the South Downs, the Somerset Levels and Moors, West Penwith, Cornwall, the Shropshire Borders, the Cambrian Mountains, and the Lleyn Peninsula.

The total area designated as ESAs was estimated in 2003 to be 571,520 hectares/1,278,300 acres. The scheme is voluntary, with farmers being encouraged to adapt their practices so as to enhance or maintain the natural features of the landscape and conserve wildlife habitat. A farmer who joins the scheme agrees to manage the land in this way for at least five years. In return, the Ministry of Agriculture pays the farmer a sum that reflects the financial losses incurred as a result of reconciling conservation with commercial farming.

Environmental Protection Agency

EPA

US agency set up in 1970 to control water and air quality, industrial and commercial wastes, pesticides, noise, and radiation. In its own words, it aims to protect 'the country from being degraded, and its health threatened, by a multitude of human activities initiated without regard to long-ranging effects upon the life-supporting properties, the economic uses, and the recreational value of air, land, and water'.

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environment-heredity controversy

see nature-nurture controversy.

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enzyme

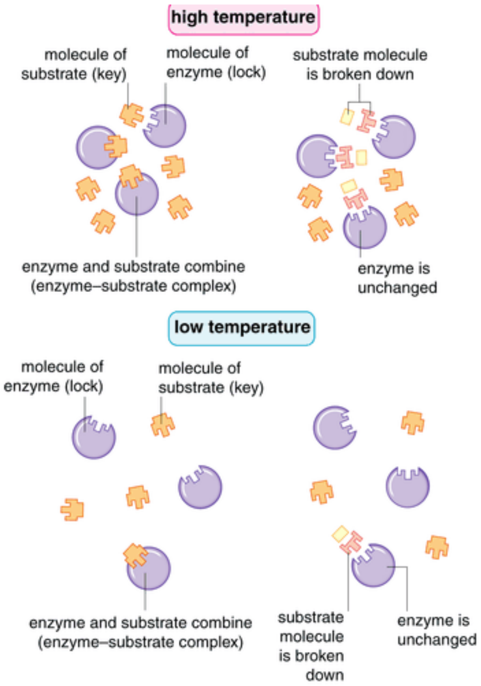
biological catalyst produced in cells, and capable of speeding up the chemical reactions necessary for life. They are large, complex proteins, usually soluble, and are highly specific, each chemical reaction requiring its own particular enzyme. The enzyme's specificity arises from its active site, an area with a shape corresponding to part of the molecule with which it reacts (the substrate). The shape of the enzyme where the chemical binds only allows the binding of that particular chemical, rather like a specific key only working a specific lock (the lock and key hypothesis). The enzyme and the substrate slot together forming an enzyme-substrate complex that allows the reaction to take place, after which the enzyme falls away unaltered.

The activity and efficiency of enzymes are influenced by various factors, including temperature and acidity (pH). Temperatures above 60°C/140°F damage (denature) the intricate structure of enzymes, inactivating them and causing reactions to stop. Each enzyme operates best - at its maximum rate - within a specific pH range and temperature, and is denatured by excessive acidity or alkalinity or extremes of temperature.

In digestion, digestive enzymes include amylases (which digest starch), lipases (which digest fats), and proteases (which digest protein). Other enzymes play a part in the conversion of food energy into ATP, the manufacture of all the molecular components of the body, the replication of DNA when a cell divides, the production of hormones, and the control of movement of substances into and out of cells.

Enzymes have many uses in medical and industrial biotechnology, from washing powders to drug production, and as research tools in molecular biology. They are involved in the making of beer, bread, cheese, and yogurt. They can be extracted from bacteria and fungi and genetic engineering now makes it possible to tailor an enzyme for a specific purpose.

enzyme


high temperature
molecule of substrate (key)
molecule of enzyme (lock)
substrate molecule is broken down
enzyme and substrate combine (enzyme–substrate complex)
enzyme is unchanged
low temperature
molecule of enzyme (lock)
molecule of substrate (key)
enzyme and substrate combine (enzyme–substrate complex)
substrate molecule is broken down
enzyme is unchanged

(Image © Research Machines plc)

Enzymes are catalysts that can help break larger molecules into smaller molecules while remaining unchanged themselves. Like a key for a lock, each enzyme is specific to one molecule. Most also function best within a narrow temperature and pH range. As the temperature rises enzymes catalyse more molecules but beyond a certain temperature most enzymes become denatured.

Eocene epoch

second epoch of the Tertiary period of geological time, roughly 56.5-35.5 million years ago. Originally considered the earliest division of the Tertiary, the name means 'early recent', referring to the early forms of mammals evolving at the time, following the extinction of the dinosaurs.

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ephedrine

drug that acts like adrenaline on the sympathetic nervous system (sympathomimetic). Once used to relieve bronchospasm in asthma, it has been superseded by safer, more specific drugs. It is contained in some cold remedies as a decongestant. Side effects include rapid heartbeat, tremor, dry mouth, and anxiety.

Ephedrine is an alkaloid, $C_{10}H_{15}NO_1$, derived from Asian gymnosperms (genus *Ephedra*) or synthesized. It is sometimes misused, and excess leads to mental confusion and increased confidence in one's own capabilities as they actually decline.

ephemeral plant

plant with a very short life cycle, sometimes as little as six to eight weeks. It may complete several generations in one growing season.

epicentre

point on the Earth's surface immediately above the seismic focus of an earthquake. Most building damage takes place at an earthquake's epicentre. The term is also sometimes used to refer to a point directly above or below a nuclear explosion ('at ground zero').

epicyclic gear

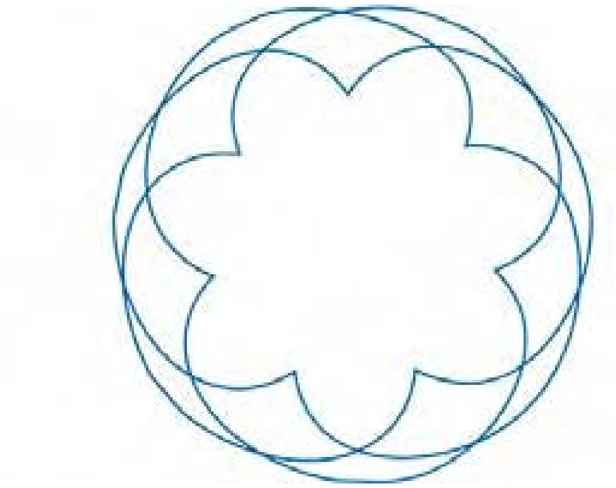
or sun-and-planet gear

gear system that consists of one or more gear wheels moving around another. Epicyclic gears are found in bicycle hub gears and in automatic gearboxes.

epicycloid

in geometry, a curve resembling a series of arches traced out by a point on the circumference of a circle that rolls around another circle of a different diameter. If the two circles have the same diameter, the curve is a cardioid.

epicycloid



(Image © Research Machines plc)

A seven-cusped epicycloid, formed by a point on the circumference of a circle (of diameter *d*) that rolls around another circle (of diameter 7*d*/3).

epidemic

outbreak of infectious disease affecting large numbers of people at the same time. A widespread epidemic that sweeps across many countries (such as the Black Death in the late Middle Ages) is known as a **pandemic**.

epidermis

outermost layer(s) of cells on an organism's body. In plants and many invertebrates such as insects, it consists of a single layer of cells. In vertebrates, it consists of several layers of cells.

The epidermis of plants and invertebrates often has an outer noncellular cuticle that protects the organism from desiccation.

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epidural anaesthetic

in medicine, procedure that induces loss of sensation in the lower part of the body. The spinal nerves are blocked in the epidural space by injection of small volumes of local anaesthetic into the tissues surrounding the spinal cord through a catheter. The catheter can be used to introduce further volumes of local anaesthetic if the block begins to wear off before the end of the procedure. Epidurals are commonly used as a method of pain relief during childbirth.

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epigeal

describing seed germination in which the cotyledons (seed leaves) are borne above the soil.

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epiglottis

small flap located behind the root of the tongue in mammals. It closes off the end of the windpipe during swallowing to prevent food from passing into it and causing choking.

The action of the epiglottis is a highly complex reflex process involving two phases. During the first stage a mouthful of chewed food is lifted by the tongue towards the top and back of the mouth. This is accompanied by the cessation of breathing and by the blocking of the nasal areas from the mouth. The second phase involves the epiglottis moving over the larynx while the food passes down into the oesophagus.

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epilepsy

medical disorder characterized by a tendency to develop fits, which are convulsions or abnormal feelings caused by abnormal electrical discharges in the cerebral hemispheres of the brain. Epilepsy can be controlled with a number of anticonvulsant drugs.

The term epilepsy covers a range of conditions from mild 'absences', involving momentary loss of awareness, to major convulsions. In some cases the abnormal electrical activity is focal (confined to one area of the brain); in others it is generalized throughout the cerebral cortex. Fits are classified according to their clinical type. They include: the **grand mal** seizure with convulsions and loss of consciousness; the fleeting absence of awareness **petit mal**, almost exclusively a disorder of childhood; **Jacksonian** seizures, originating in the motor cortex; and **temporal-lobe** fits, which may be associated with visual hallucinations and bizarre disturbances of the sense of smell.

Epilepsy affects 1-3% of the world's population. It may arise spontaneously or may be a consequence of brain surgery, organic brain disease, head injury, metabolic disease, alcoholism, or withdrawal from some drugs. Almost a third of patients have a family history of the condition.

Most epileptics have infrequent fits that have little impact on their daily lives. Epilepsy does not imply that the sufferer has any impairment of intellect, behaviour, or personality.

---

epiphyte

any plant that grows on another plant or object above the surface of the ground, and has no roots in the soil. An epiphyte does not parasitize the plant it grows on but merely uses it for support. Its nutrients are obtained from rainwater, organic debris such as leaf litter, or from the air.

The greatest diversity of epiphytes is found in tropical areas and includes many orchids. There are few specialized epiphytes in temperate regions, but mosses and lichens are often found growing epiphytically on trees. The family Bromeliaceae is predominantly epiphytic and contains the genus *Tillandsia*, several of which are sold as air plants.

---

episiotomy

incision made in the perineum (the tissue bridging the vagina and rectum) to facilitate childbirth and prevent tearing of the vagina.

Episiotomy may be necessary, mainly for women giving birth for the first time, to widen the birth outlet and prevent perineal tearing. The incision is made in the second stage of labour, as the largest part of the baby's head begins to emerge from the birth canal.

An episiotomy is quickly repaired using absorbable stitches under local anaesthetic.

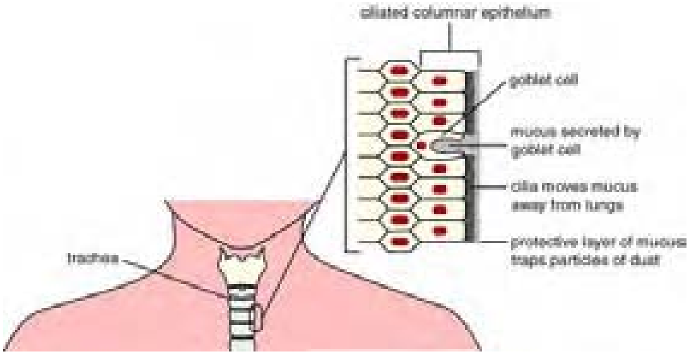
---

epithelium

in animals, tissue of closely packed cells that forms a surface or lines a cavity or tube. Epithelial cells line the inside surfaces of fluid or air-filled tubes and spaces within the body. Epithelium may be protective (as in the skin) or secretory (as in the cells lining the wall of the gut). Epithelial cells join each other side to side to make epithelial tissue. Epithelial cells are specialized cells. They protect cells below them and may also carry out special functions. For example, in the human lung epithelial cells line the alveoli (air spaces). These cells are very thin and form a large surface area in order to facilitate the absorption of oxygen and the loss of carbon dioxide during the process of gas exchange. They also make sure the alveoli remain moist at all times to keep them healthy.

The epithelial cells lining the airways leading to the lung from the mouth and nose are different. Here there are many are specialized ciliated cells. These cells have tiny hairs or cilia which beat backwards and forwards. They sweep fluid up and away from the lungs to the mouth. Any dirt or bacteria that have been inhaled are taken away from the lungs where they may cause damage. Smoking harms these ciliated cells.

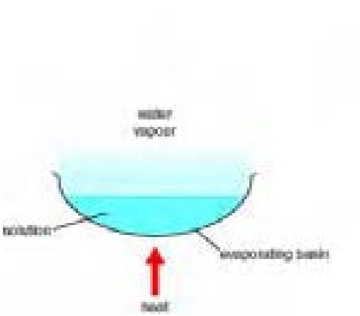
epithelium


ciliated columnar epithelium
goblet cell
mucus secreted by goblet cell
cilia moves mucus away from lungs
protective layer of mucous traps particles of dust
trachea

(Image © Research Machines plc)

Structure of a ciliated columnar epithelium, as found in the trachea. The goblet cells secrete mucus, which forms a protective mucal blanket that traps dust particles. The beating of the cilia moves the mucus away from the lungs.

evaporation



(Image © Research Machines plc)

Evaporation is a way of separating a solid that has been dissolved in a solvent. If heated (or left to stand over some days) the solvent (liquid part) evaporates as a vapour, leaving the solid as a residue.

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epoch

subdivision of a geological period in the geological time scale. Epochs are sometimes given their own names (such as the Palaeocene, Eocene, Oligocene, Miocene, and Pliocene epochs comprising the Tertiary period), or they are referred to as the late, early, or middle portions of a given period (as the Late Cretaceous or the Middle Triassic epoch).

Geological time is broken up into **geochronological units** of which epoch is just one level of division. The hierarchy of geochronological divisions is eon, era, period, epoch, age, and chron. Epochs are subdivisions of periods and ages are subdivisions of epochs. Rocks representing an epoch of geological time comprise a **series**.

epochs: ascending

To remember the different epochs, in ascending order:

Put **e**ggs **o**n **m**y **p**late **p**lease **h**oney or **P**lease **e**liminate **o**ld **m**en **p**laying **p**oker **h**onestly

Palaeocene, **E**ocene, **O**ligocene, **M**iocene, **P**liocene, **P**leistocene, **H**olocene

epochs: descending

To remember the different epochs, in descending order of age:

Heavy **p**eople **p**ut **m**ore **o**n **e**very **p**late or **H**appy **p**lump **p**regnant **m**others **o**nly **e**at **p**ickles or **H**appy **p**eople **p**lay **m**usic, **o**thers **e**at **p**izza

Holocene, **P**leistocene, **P**liocene, **M**iocene, **O**ligocene, **E**ocene, **P**aleocene

epoxy resin

synthetic resin used as an adhesive and as an ingredient in paints. Household epoxy resin adhesives come in component form as two separate tubes of chemical, one tube containing resin, the other a curing agent (hardener). The two chemicals are mixed just before application, and the mix soon sets hard.

EPROM

acronym for Erasable Programmable Read-Only Memory

computer memory device in the form of an integrated circuit (chip) that can record data and retain it indefinitely. The data can be erased by exposure to ultraviolet light, and new data recorded. Other kinds of computer memory chips are ROM (read-only memory), PROM (programmable read-only memory), and RAM (random-access memory).

Epsom salts

$MgSO_4.7H_2O$

hydrated magnesium sulphate, used as a relaxant and laxative and added to baths to soothe the skin. The name is derived from a bitter saline spring at Epsom, Surrey, UK, which contains the salt in solution.

equation

in chemistry, representation of a chemical reaction by symbols and numbers; see chemical equation. For example, the reaction of sodium hydroxide (NaOH) with hydrochloric acid (HCl) to give sodium chloride and water may be represented by:

$NaOH + HCl \rightarrow NaCl + H_2O$

equation

in mathematics, an expression that represents the equality of two expressions involving constants and/or variables, and thus usually includes an equals (=) sign. For example, the equation $A = \pi r^2$ equates the area A of a circle of radius r to the product πr^2. This is also known as the formula for the area of a circle. The algebraic equation $y = mx + c$ is the general one in coordinate geometry for a straight line and is known as a linear equation. See also algebra, quadratic equations, simultaneous equations, and graphs.

solving an equation

To solve an equation means to find the value or values of the unknown quantity that satisfy the equation; for example,

$x + 4 = 7$ is true when x is 3

The values of the unknown that make an equation true are called its solutions or roots.

In general, solving an equation depends on transforming it into a simple standard form. This can be achieved by using the following processes:

(i) adding the same quantity to each side of the equation

(ii) subtracting the same quantity from each side of the equation

(iii) multiplying each side of the equation by the same quantity (so long as it is not zero)

These processes can be used to change an equation into a simpler form but they will not alter its solution. For example, to solve the equation $7x - 4 = 3x + 8$:

subtract $3x$ from each side in order to collect the xs on the left-hand side:

$7x - 4 - 3x = 3x + 8 - 3x$ so $4x - 4 = 8$

add 4 to each side in order to collect the numbers on the right-hand side:

$4x - 4 + 4 = 8 + 4$ so $4x = 12$

divide both sides by 4 to obtain the solution:

$4x \div 4 = 12 \div 4$ so $x = 3$

polynomials

A type of equation that has been studied particularly intensively is where there is one unknown and the expression involving it is a polynomial. A polynomial equation has the form:

$$f(x) = a_nx^n + a_{n-1}x^{n-1} + \rangle + a_2x^2 + a_1x + a_0$$

where a_n, a_{n-1}, ⟩, a_0 are all constants, n is a positive integer, and $a_n \neq 0$.

The 'degree' of a polynomial equation is simply the degree of the polynomial involved. A polynomial of degree one, that is, whose highest power of x is 1, as in $2x + 1$, is called a linear polynomial;

$3x^2 + 2x + 1$ is quadratic;

$4x^3 + 3x^2 + 2x + 1$ is cubic.

indeterminate equations

An indeterminate equation is an equation for which there is an infinite set of solutions – for example, $2x = y$. A **diophantine equation** is an indeterminate equation in which both the solution and the terms must be whole numbers (after Diophantus of Alexandria, *c.* AD 250).

identity

An equation that is true for all values of the unknown is called an identity, for example $x + x = 2x$. It is denoted by ≡

Thus $(x + y)^2 \equiv x^2 + 2xy + y^2$ for all real numbers x, y.

Aerobi-graphs

Go to site

Fun look at the graph equation $y=mx+c$. See what happens to the graph when each variable is manipulated, as demonstrated by human bodies! As the graphs become more complex, so do the actions. However, the good illustrations do make this site quite slow.

Equator

or terrestrial equator

great circle whose plane is perpendicular to the Earth's axis (the line joining the poles). Its length is 40,092 km/24,902 mi, divided into 360 degrees of longitude. The Equator encircles the broadest part of the Earth, and represents 0° latitude. It divides the Earth into two halves, called the northern and the southern hemispheres.

The **celestial equator** is the circle in which the plane of the Earth's Equator intersects the celestial sphere.

---

equatorial coordinates

in astronomy, system for measuring the position of astronomical objects on the celestial sphere with reference to the plane of the Earth's Equator.

Declination (symbol δ), analogous to latitude, is measured in degrees from the Equator to the north (δ = 90°) or south (δ =-90°) celestial poles. Right ascension (symbol α), analogous to longitude, is normally measured in hours of time (α = 0 hours to 24 hours) eastward along the Equator from a fixed point known as the first point of Aries or the vernal equinox.

---

equatorial mounting

in astronomy, method of mounting a telescope to simplify the tracking of celestial objects. One axis (the polar axis) is mounted parallel to the rotation axis of the Earth so that the telescope can be turned about it to follow objects across the sky. The declination axis moves the telescope in declination and is clamped before tracking begins. Another advantage over the simpler altazimuth mounting is that the orientation of the image is fixed, permitting long-exposure photography.

Equidae

horse family in the order Perissodactyla, which includes the odd-toed hoofed animals. Besides the domestic horse, wild asses, wild horses, onagers, and zebras, there are numerous extinct species known from fossils.

All species in the family are inhabitants of flat, open country, except the mountain zebra from the hills of southern Africa. They have long legs, adapted to carry the animals at speed over firm ground; only one toe, terminating in a hoof, is present on each limb. They are all herbivorous and have keen senses to detect their enemies. Their jaws are strong and able to chew the tough grasses and herbs on which they feed in the wild state.

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equilateral

describing a geometrical figure, having all sides of equal length.

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equilibrium

in physics, an unchanging condition in which an undisturbed system can remain indefinitely in a state of balance. In a **static equilibrium**, such as an object resting on the floor, there is no motion. In a **dynamic equilibrium**, in contrast, a steady state is maintained by constant, though opposing, changes. For example, in a sealed bottle half-full of water, the constancy of the water level is a result of molecules evaporating from the surface and condensing on to it at the same rate.

---

equinox

time when the Sun is directly overhead at the Earth's Equator and consequently day and night are of equal length at all latitudes. This happens twice a year: 20 or 21 March is the spring, or vernal, equinox and 22 or 23 September is the autumn equinox.

The variation in day lengths occurs because the Earth is tilted on its axis with respect to the Sun. However, because the Earth not only rotates on its own axis but also orbits the Sun, at the equinoxes the two bodies are positioned so that the line on the Earth separating day from night passes through both of the Earth's poles.

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equivalent

having a different appearance but the same value. 3/5 and 6/10 are equivalent fractions. They both have the value 0.6.

---

era

any of the major divisions of geological time that includes several periods but is part of an eon. The eras of the current Phanerozoic in chronological order are the Palaeozoic, Mesozoic, and Cenozoic. We are living in the Recent epoch of the Quaternary period of the Cenozoic era.

Geological time is broken up into **geochronological units** of which era is just one level of division. The hierarchy of geochronological divisions is eon, era, period, epoch, age, and chron. Eras are subdivisions of eons and periods are subdivisions of eras. Rocks representing an era of geological time comprise an **erathem**.

Eratosthenes (c. 276–c. 194 BC)

Greek geographer and mathematician whose map of the ancient world was the first to contain lines of latitude and longitude, and who calculated the Earth's circumference with an error of about 10%. His mathematical achievements include a method for duplicating the cube, and for finding prime numbers (Eratosthenes' sieve).

No work of Eratosthenes survives complete. The most important that remains is on geography – a word that he virtually coined as the title of his three-volume study of the Earth (as much as he knew of it) and its measurement.

Eratosthenes' sieve

method for finding prime numbers. It involves writing in sequence all numbers from 2. Then, starting with 2, cross out every second number (but not 2 itself), thus eliminating numbers that can be divided by 2. Next, starting with 3, cross out every third number (but not 3 itself), and continue the process for 5, 7, 11, 13, and so on. The numbers that remain are primes.

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erbium

chemical symbol Er

soft, lustrous, greyish, metallic element of the lanthanide series, atomic number 68, relative atomic mass 167.26. It occurs with the element yttrium or as a minute part of various minerals. It was discovered in 1843 by Carl Mosander (1797-1858), and named after the town of Ytterby, Sweden, near which the lanthanides (rare-earth elements) were first found.

Erbium has been used since 1987 to amplify data pulses in optical fibres, enabling faster transmission. Erbium ions in the fibreglass, charged with infrared light, emit energy by amplifying the data pulse as it moves along the fibre.

erg

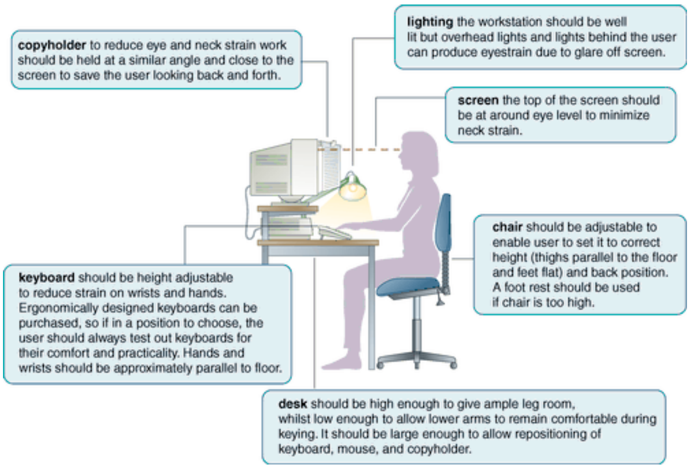
c.g.s. unit of work, replaced in the SI system by the joule. One erg of work is done by a force of one dyne moving through one centimetre.

ergonomics

study of the relationship between people and the furniture, tools, and machinery they use at work. The object is to improve work performance by removing sources of muscular stress and general fatigue: for example, by presenting data and control panels in easy-to-view form, making office furniture comfortable, and creating a generally pleasant environment.

Good ergonomic design makes computer systems easier to use and minimizes the health hazards and physical stresses of working with computers for many hours a day: it helps data entry workers to avoid conditions like repetitive strain injury (RSI), eyestrain, and back and muscle aches.

ergonomics


copyholder to reduce eye and neck strain work should be held at a similar angle and close to the screen to save the user looking back and forth.
lighting the workstation should be well lit but overhead lights and lights behind the user can produce eyestrain due to glare off screen.
screen the top of the screen should be at around eye level to minimize neck strain.
chair should be adjustable to enable user to set it to correct height (thighs parallel to the floor and feet flat) and back position. A foot rest should be used if chair is too high.
keyboard should be height adjustable to reduce strain on wrists and hands. Ergonomically designed keyboards can be purchased, so if in a position to choose, the user should always test out keyboards for their comfort and practicality. Hands and wrists should be approximately parallel to floor.
desk should be high enough to give ample leg room, whilst low enough to allow lower arms to remain comfortable during keying. It should be large enough to allow repositioning of keyboard, mouse, and copyholder.

(Image © Research Machines plc)

Careful arrangement of computer workstations and other office or home furniture can reduce the risk of eye, back, and neck strain, and repetitive strain injury, for those who use a computer a great deal. Regular breaks away from the screen are also essential.

ergosterol

substance that, under the action of the Sun's ultraviolet rays on the skin, gives rise to the production of vitamin D2 – a vitamin that helps in calcium and phosphorus metabolism, promotes bone formation, and in children prevents rickets.

Ergosterol $C_{28}H_{43}OH$ is a sterol that occurs in ergot (hence the name), yeast and other fungi, and some animal fats. The principal source of commercial ergosterol is yeast.

ergot

any of a group of parasitic fungi (especially of the genus *Claviceps*), whose brown or black grainlike masses replace the kernels of rye or other cereals. *C. purpurea* attacks the rye plant. Ergot poisoning is caused by eating infected bread, resulting in burning pains, gangrene, and convulsions.

The large grains of the fungus contain the poison ergotamine.

ergotamine

alkaloid $C_{33}H_{35}O_5N_5$ administered to treat migraine. Isolated from ergot, a fungus that colonizes rye, it relieves symptoms by causing the cranial arteries to constrict. Its use is limited by severe side effects, including nausea and abdominal pain.

---

erica

any plant of a large group that includes the heathers. There are about 500 species, distributed mainly in South Africa with some in Europe. (Genus *Erica*, family Ericaceae.)

Eridanus

sixth-largest constellation, which meanders from the celestial equator (see celestial sphere) deep into the southern hemisphere of the sky. Eridanus is represented as a river. Its brightest star is Achernar, a corruption of the Arabic for 'the end of the river'.

---

ermine

short-tailed weasel *Mustela erminea*, of the northern hemisphere, whose winter coat becomes white. In northern latitudes the coat becomes completely white, except for a black tip to the tail, but in warmer regions the back may remain brownish. The alternate Eurasian name 'stoat' is used especially during the summer, when the coat is brown. The fur is used commercially.

The ermine is an efficient predator, killing its prey (typically rodents and rabbits) by biting the back of the neck. It needs to consume the equivalent of almost a third of its body weight each day. Females are about half the size of males, and males and females live in separate territories. Ermine live in North America, Europe, and Asia; they have been introduced to New Zealand.

Eros

in astronomy, asteroid discovered in 1898 by German astronomer Gustav Witt. It was the first asteroid to be discovered that has an orbit coming within that of Mars. It passes within 22 million km/14 million mi of the Earth. It is elongated, measures 33 × 13 × 13 km/21 × 8 × 8 mi, rotates around its shortest axis every 5.3 hours, and orbits the Sun every 1.8 years.

NASA's Near-Earth Asteroid Rendezvous spacecraft went into orbit around Eros on 14 February 2000. Pictures showed the asteroid to be heavily cratered, indicating that it is probably older than was previously thought. The surface was discovered to contain aluminium, iron, magnesium, and silicon.

---

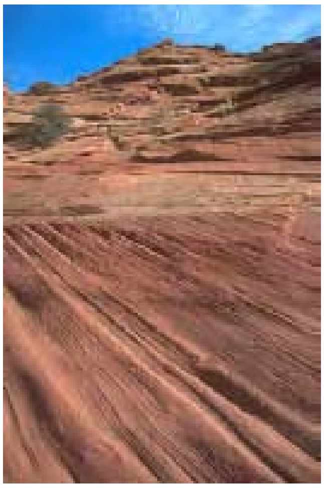
erosion

wearing away of the Earth's surface by a moving agent, caused by the breakdown and transport of particles of rock or soil. Agents of erosion include the sea, rivers, glaciers, and wind. By contrast, weathering does not involve transportation.

The most powerful forms of erosion are water, consisting of sea waves and currents, rivers, and rain; ice, in the form of glaciers; and wind, hurling sand fragments against exposed rocks and moving dunes along. People also contribute to erosion by poor farming practices and the cutting down of forests, which can lead to increased overland water run-off.

There are several processes of river erosion including hydraulic action, corrasion, attrition, and solution.

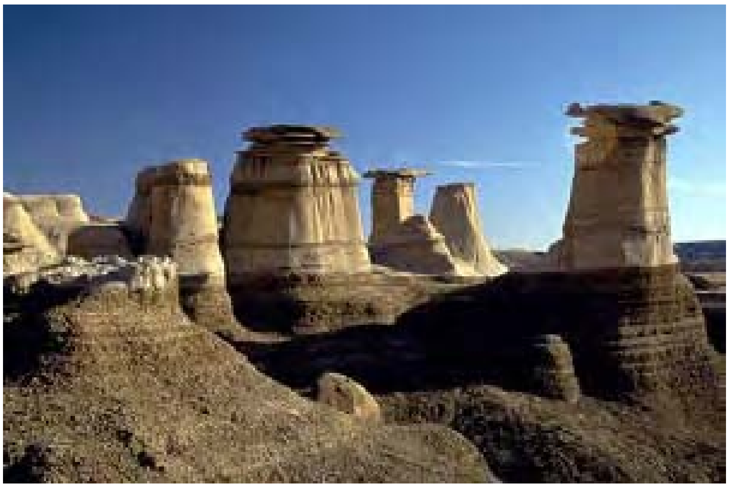
eroded sandstone



(Image © Corel)

Eroded sandstone, Utah, USA.

Hoodoos



(Image © Corel)

Hoodoos, east of Drumheller in Alberta Province, Canada. Sandstone rock has eroded into curious columns in the badlands of southern Alberta.

erosion

(Image © Corel)

A mountainous ridge in the Canadian Rocky Mountains. The slopes here have been eroded by rain and melting snow to form steep-sided gullies.

Erosion and Deposition

Go to site

Introduction to two important geological processes: erosion and deposition. The hyperlinked text explains the three stages in the process of erosion - detachment, entrainment, and transport - as well as the causes of deposition.

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erratic

in geology, a displaced rock that has been transported by a glacier or some other natural force to a site of different geological composition.

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error

in computing, a fault or mistake, either in the software or on the part of the user, that causes a program to stop running (crash) or produce unexpected results. Program errors, or bugs, are largely eliminated in the course of the programmer's initial testing procedure, but some will remain in most programs. All computer operating systems are designed to produce an **error message** (on the display screen, or in an error file or printout) whenever an error is detected, reporting that an error has taken place and, wherever possible, diagnosing its cause.

---

error

in mathematics, incorrect answer to a calculation. Also, the amount by which an incorrect answer differs from the correct one. This is usually denoted by δx for a figure whose correct value is x.

GCSE the EasyMaths Way: Mistakes

Go to site

Not just about making mistakes, this page explains the importance of error calculations and how they are neither 'wrong' nor 'right'. The key terms are highlighted in blue or red, and there are many worked examples that accompany the text.

---

error detection

in computing, the techniques that enable a program to detect incorrect data. A common method is to add a check digit to important codes, such as account numbers and product codes. The digit is chosen so that the code conforms to a rule that the program can verify. Another technique involves calculating the sum (called the hash total) of each instance of a particular item of data, and storing it at the end of the data.

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erythrocyte

another name for red blood cell.

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erythropoietin

EPO

in biology, a naturally occurring hormone, secreted mainly by the kidneys in adults and the liver in children, that stimulates production of red blood cells, which carry oxygen around the body. It is released in response to a lowered percentage of oxygen in the blood reaching the kidneys, such as in anaemic subjects. Recombinant human erythropoietin is used therapeutically to treat the anaemia associated with chronic kidney failure. A synthetic version is sometimes used illegally by athletes in endurance sports as it increases the oxygen-carrying capacity of the blood.

ESA

abbreviation for European Space Agency.

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escalator

automatic moving staircase that carries people between floors or levels. It consists of treads linked in an endless belt arranged to form strips (steps), powered by an electric motor that moves both steps and handrails at the same speed. Towards the top and bottom the steps flatten out for ease of passage. The first escalator was exhibited in Paris in 1900.

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escape velocity

minimum velocity required for a spacecraft or other object to escape from the gravitational pull of a planetary body. In the case of the Earth, the escape velocity is 11.2 kps/6.9 mps; the Moon, 2.4 kps/1.5 mps; Mars, 5 kps/3.1 mps; and Jupiter, 59.6 kps/37 mps.

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escarpment

or cuesta

large ridge created by the erosion of dipping sedimentary rocks. It has one steep side (scarp) and one gently sloping side (dip). Escarpments are common features of chalk landscapes, such as the Chiltern Hills and the North Downs in England. Certain features are associated with chalk escarpments, including dry valleys (formed on the dip slope), combes (steep-sided valleys on the scarp slope), and springs.

Escherichia coli

or colon bacillus

rod-shaped Gram-negative bacterium (see bacteria) that lives, usually harmlessly, in the colon of most warm-blooded animals. It is the commonest cause of urinary tract infections in humans. It is sometimes found in water or meat where faecal contamination has occurred and can cause severe gastric problems.

The mapping of the genome of *E. coli*, consisting of 4,403 genes, was completed in 1997. It is probably the organism about which most molecular genetics is known, and is of pre-eminent importance in recombinant DNA research.

classification

Escherichia coli is the only species in the bacterial family Enterobacteriaceae.

Escherichia coli

Five hundred *E. coli* in a line would span a full stop. The average human gut contains 100 g/3.5 oz of *E. coli*.

---

esker

narrow, steep-walled ridge, often meandering, found in formerly glaciated areas. It was originally formed beneath a glacier. It is made of sands and gravels, and represents the course of a river channel beneath the glacier. Eskers vary in height from 3 to 30 m/10 to 100 ft and can be up to 160 km/100 mi or so in length. Eskers are often used for roads as they are areas of high ground above marshy clay lowlands (glacial deposits).

ESP

abbreviation for extrasensory perception.

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esparto

species of grass native to southern Spain, southern Portugal, and the Balearics, but now widely grown in dry, sandy locations throughout the world. The plant is just over 1 m/3 ft high, producing greyish-green leaves, which are used for making paper, ropes, baskets, mats, and cables. (*Stipa tenacissima*.)

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essential amino acid

water-soluble organic molecule vital to a healthy diet because it cannot be synthesized from other food molecules; see amino acid.

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essential fatty acid

organic compound consisting of a hydrocarbon chain and important in the diet; see fatty acid.

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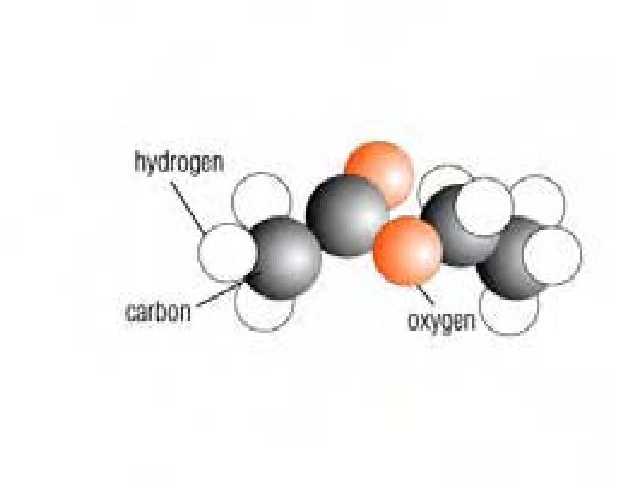
ester

organic compound formed by the reaction between an alcohol and an acid, with the elimination of water. Unlike salts, esters are covalent compounds.

ester



(Image © Research Machines plc)

Molecular model of the ester ethyl ethanoate (ethyl acetate) $CH_3CO_2CH_2CH_3$.

estuary

river mouth widening into the sea, where fresh water mixes with salt water and tidal effects are felt.

ethanal

common name acetaldehyde; CH_3CHO

one of the chief members of the group of organic compounds known as aldehydes. It is a colourless flammable liquid boiling at 20.8°C/69.6°F. Ethanal is formed by the oxidation of ethanol or ethene and is used to make many other organic chemical compounds.

ethanal trimer

common name paraldehyde; $(CH_3CHO)_3$

colourless liquid formed from ethanal (acetaldehyde). It is soluble in water.

ethane

CH_3CH_3

colourless, odourless gas, the second member of the alkane series of hydrocarbons (paraffins).

ethane-1,2-diol

technical name for glycol.

ethanoate

common name acetate; $CH_3CO_2^-$

negative ion derived from ethanoic (acetic) acid; any salt containing this ion. In photography, acetate film is a non-flammable film made of cellulose ethanoate. In textiles, it is known as acetate, and is most commonly known in the form of a synthetic fibre which can be woven or knitted to produce a variety of different fabrics including satin, moire, and taffeta. Fabrics made from acetate absorb moisture, do not shrink, and are cheaper to produce than natural fibres, but they also tend to attract dirt and can be damaged by heat. Acetate filaments are also used to make filters for cigarettes.

To produce acetate, cellulose is treated with acetic acid in a process called acetylation. This forms a thick solution which is forced through small holes and solidified, and then, through the process of spinning, continuous filaments of acetate are produced.

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ethanoic acid

common name acetic acid; CH_3CO_2H

one of the simplest carboxylic acids (fatty acids). In the pure state it is a colourless liquid with an unpleasant pungent odour; it solidifies to an icelike mass of crystals at 16.7°C/62.4°F, and hence is often called glacial ethanoic acid. In a dilute form, mixed with water, it is the acid found in vinegar. Vinegar contains 5% or more ethanoic acid, produced by fermentation.

Ethanoic acid is produced by the oxidation of ethanol. It belongs to a homologous series, or family, of organic compounds. Some other members of the series are methanoic acid, propanoic acid, and butanoic acid. They are all weak acids.

Cellulose (derived from wood or other sources) may be treated with ethanoic acid to produce a cellulose ethanoate (acetate) solution, which can be used to make plastic items by injection moulding or extruded to form synthetic textile fibres.

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ethanol

or ethyl alcohol; C_2H_5OH

alcohol found in beer, wine, cider, spirits, and other alcoholic drinks. When pure, it is a colourless liquid with a pleasant odour, miscible with water or ether; it burns in air with a pale blue flame. The vapour forms an explosive mixture with air and may be used in high-compression internal combustion engines.

It is produced naturally by the fermentation of carbohydrates by yeast cells. Industrially, it can be made by absorption of ethene and subsequent reaction with water, or by the reduction of ethanal (acetaldehyde) in the presence of a catalyst, and is widely used as a solvent.

Ethanol is used as a raw material in the manufacture of ethoxyethane (ether), trichloroethanol (chloral), and triiodomethane (iodoform). It can also be added to petrol, where it improves the performance of the engine, or be used as a fuel in its own right (as in Brazil). In August 2001 it was discovered that when ethanol is added to petrol it boosts the oxygen content, reducing the emissions of air-polluting gases. Crops such as sugar cane may be grown to provide ethanol (by fermentation) for this purpose.

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ethene

common name ethylene; C_2H_4

colourless, flammable gas, the first member of the alkene series of hydrocarbons. It is the most widely used synthetic organic chemical and is used to produce the plastics polythene (polyethylene), polychloroethene, and polyvinyl chloride (PVC). It is obtained from natural gas or coal gas, or by the dehydration of ethanol.

Ethene is produced during plant metabolism and is classified as a plant hormone. It is important in the ripening of fruit and in abscission. Small amounts of ethene are often added to the air surrounding fruit to artificially promote ripening. Tomato and marigold plants show distorted growth in concentrations as low as 0.01 parts per million. Plants also release ethene when they are under stress. German physicists invented a device in 1997 that measures stress levels in plants by measuring surrounding ethene levels.

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ether

any of a series of organic chemical compounds having an oxygen atom linking the carbon atoms of two hydrocarbon radical groups (general formula R-O-R'); also the common name for ethoxyethane $C_2H_5OC_2H_5$ (also called diethyl ether). This is used as an anaesthetic and as an external cleansing agent before surgical operations. It is also used as a solvent, and in the extraction of oils, fats, waxes, resins, and alkaloids.

Ethoxyethane is a colourless, volatile, inflammable liquid, slightly soluble in water, and miscible with ethanol. It is prepared by treatment of ethanol with excess concentrated sulphuric acid at 140°C/284°F.

History of Anaesthesia

introduction

While the need for some form of anaesthesia had been recognized since earliest times, for centuries all that was available to deaden the pain of surgery was a copious draft of alcohol. As late as 1839 a leading French surgeon predicted: 'To escape pain in surgical operations is a chimera which we cannot expect in our time.' Mercifully, he was mistaken for the first use of anaesthesia in surgery was recorded only seven years later.

early experimentation

By this time there had been some experimentation with volatile agents such as ether, chloroform and nitrous oxide. Ether, for example, enjoyed a certain notoriety arising from medical students' 'ether frolics'. But this was the substance used in what is credited as the first operation undertaken in an anaesthetized patient – in the famous 'ether dome' at Massachusetts General Hospital in Boston on October 16, 1846. Its use was demonstrated by the dentist William Thomas Green Morton (1819-68). The following day, not content with the apparatus he had used to administer the ether, Morton commissioned an improved version. Later he abandoned this, too, in favour of a simple sponge. 'This should be about the size of the open hand, or a little larger, and concave, to suit over the nose and mouth,' he wrote in the *Lancet* (June 30, 1847). 'The sponge is then thoroughly saturated with ether, applied to the nose and mouth, and, with the latter open, the patient directed to inhale as fully and freely as possible. In this way, I have found the result more sure and satisfactory, and the difficulty of inhalation very much reduced, or entirely removed. The most delicate or nervous females, or aged persons, as well as young children, are thus rapidly and almost imperceptibly narcotized...'

first use in the UK

Only a month after its Boston debut, ether anaesthesia was first used in Britain, at London's University College Hospital. In January 1847, James Young Simpson (1811-70), professor of obstetrics at Edinburgh, was the first to introduce its use for women in childbirth, initially for forceps or operative deliveries but soon also for uncomplicated cases.

effects of chloroform

However, disliking ether's 'disagreeable and very persistent smell', Simpson soon began casting around for an alternative and decided to try chloroform. In November 1847, to the consternation of his household, he and two junior colleagues were accidentally exposed to chloroform when a bottle was knocked over at his house in Queen Street. He later wrote: 'The first night we took chloroform, Dr Duncan, Dr Keith and I all tried it simultaneously and were under the table in a minute or two.'

anaesthesia during childbirth

The first obstetric delivery under chloroform took place the day after this mishap and, ten days later, Simpson published his first pamphlet on its use. A forceful figure, he insisted that liberal administration of chloroform on the corner of a towel or handkerchief was harmless. Not surprisingly, however, since it had gone from first testing to clinical use within the space of little more than a week, the safety of chloroform as an anaesthetic agent was never established. In fact the first UK death from chloroform anaesthesia took place only three months after its introduction. Elsewhere, once its toxicity became apparent, chloroform fell out of favour. Predictably its use was banned at Massachusetts General, the birthplace of ether anaesthesia. But in Britain Simpson had done such a good job of publicizing chloroform that its popularity grew regardless. Here controversy centred not on safety but on the morality of using anaesthesia at all to relieve the pain of childbirth. There were those who pointed to its apparent biblical proscription – 'In pain shalt thou bear offspring.' However, the role of anaesthesia in childbirth was confirmed when, on April 7 1853, the well-known London physician John Snow held out a chloroform-soaked handkerchief to assist the birth of Queen Victoria's ninth child, Prince Leopold. The Queen subsequently noted in her diary: 'Dr Snow administered that blessed chloroform and the effect was soothing, quieting and delightful beyond measure.' Despite a rising death toll (and the appointment of various commissions to investigate the action of chloroform), the drug remained in use until well into the new century.

nitrous oxide

Meanwhile a third volatile agent, nitrous oxide, had surfaced at around the same time as ether and chloroform. Its pain-killing properties were discovered in 1800 by the British chemist Humphry Davy (1778-1829), who foresaw that 'it may probably be used with advantage in surgical operations'. In 1845, nitrous oxide was first used for pain relief, also at Massachusetts General Hospital, in what proved to be a disastrous demonstration by another dentist, Horace Wells (1815-48). Then it was lost to view for more than two decades. Nitrous oxide – popularly known as 'laughing gas' because of the excitement it induces – was finally adopted as an anaesthetic agent by way of its use by travelling salesmen. One of these, Gardner Quincy Colton (1814-98), founder of the New York Dental Institute, demonstrated use of the gas at the 1867 International Exhibition in Paris. It was taken up by an influential US dental surgeon, Thomas Wiltberger (1823-97), who in due course introduced it to British dentists. Nitrous oxide is still used as an inhalation agent in surgery today.

further experimentation

There were to be further colourful chapters in the development of safe, effective anaesthesia, including the loss of a few surgical patients to exploding gases. Also memorable was the era of 'twilight sleep' in obstetrics, when a light state of scopolamine-morphine narcosis was used to ease pain and eradicate unpleasant recollections. The main effect of this, in addition to prolonging labour and expunging any memory on the part of the mother of her child's birth, was to produce babies almost too dopey to breathe.

anaesthesia in surgery

While some specialist training was initiated in the 1930s, it was only after World War II – a century after the first use of anaesthesia in surgery – that the speciality really came into its own. Today it is the biggest UK medical speciality, practised with a precision unimaginable in the early days under the 'ether dome'.

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ether (or aether)

in the history of science, a hypothetical medium permeating all of space. The concept originated with the Greeks, and has been revived on several occasions to explain the properties and propagation of light. It was supposed that light and other electromagnetic radiation - even in outer space - needed a medium, the ether, in which to travel. The idea was abandoned with the acceptance of relativity.

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ethnoarchaeology

the study of human behaviour and the material culture of living societies, in order to see how materials enter the archaeological record, and thus to provide hypotheses explaining the production, use, and disposal patterns of ancient material culture.

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ethnobotany

study of the relationship between human beings and plants. It combines knowledge of botany, chemistry, and anthropology. Many pharmaceutical companies, universities, and government health agencies have contracted ethnobotanists to conduct research among indigenous peoples, especially in the Amazon, to discover the traditional use of medicinal plants which can lead to the development of new drugs.

Ethnobotanical research is a cheaper way to develop new drugs than random testing of plants. The world's plant species, some of which may contain potential cures for diseases, are rapidly vanishing and there is a rush to learn as much as possible about indigenous plant-use before they disappear. Because the potential for profit exists upon discovery of an active plant compound, and due to the historical appropriation of indigenous resources, there has also been much discussion about the ethics of ethnobotanical research. For many indigenous peoples, the plants are considered sacred and their use is often religious in nature and unrelated to their active properties. Attempts have also been made to protect indigenous knowledge of plants as intellectual property and to compensate the people for revealing their knowledge.

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ethnography

study of living cultures, using anthropological techniques like participant observation (where the anthropologist lives in the society being studied) and a reliance on informants. Ethnography has provided much data of use to archaeologists as analogies.

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ethnology

study of contemporary peoples, concentrating on their geography and culture, as distinct from their social systems. Ethnologists make a comparative analysis of data from different cultures to understand how cultures work and why they change, with a view to deriving general principles about human society.

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ethology

comparative study of animal behaviour in its natural setting. Ethology is concerned with the causal mechanisms (both the stimuli that elicit behaviour and the physiological mechanisms controlling it), as well as the development of behaviour, its function, and its evolutionary history.

Ethology was pioneered during the 1930s by the Austrians Konrad Lorenz and Karl von Frisch who, with the Dutch zoologist Nikolaas Tinbergen, received the Nobel prize in 1973. Ethologists believe that the significance of an animal's behaviour can be understood only in its natural context, and emphasize the importance of field studies and an evolutionary perspective. A development within ethology is sociobiology, the study of the evolutionary function of social behaviour.

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ethyl alcohol

common name for ethanol.

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ethylene

common name for ethene.

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ethylene glycol

alternative name for glycol.

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ethyne

common name acetylene; CHCH

colourless inflammable gas produced by mixing calcium carbide and water. It is the simplest member of the alkyne series of hydrocarbons. It is used in the manufacture of the synthetic rubber neoprene, and in oxyacetylene welding and cutting.

Ethyne was discovered by English chemist Edmund Davy in 1836 and was used in early gas lamps, where it was produced by the reaction between water and calcium carbide. Its combustion provides more heat, relatively, than almost any other fuel known (its calorific value is five times that of hydrogen). This means that the gas gives an intensely hot flame; hence its use in oxyacetylene torches.

etiolation

in botany, a form of growth seen in plants receiving insufficient light. It is characterized by long, weak stems, small leaves, and a pale yellowish colour (chlorosis) due to a lack of chlorophyll. The rapid increase in height enables a plant that is surrounded by others to quickly reach a source of light, after which a return to normal growth usually occurs.

Etruscan art

the art of the inhabitants of Etruria, central Italy, a civilization that flourished 8th–2nd centuries BC. The Etruscans produced sculpture, painting, pottery, metalwork, and jewellery. Etruscan terracotta coffins (sarcophagi), carved with reliefs and topped with portraits of the dead reclining on one elbow, were to influence the later Romans and early Christians.

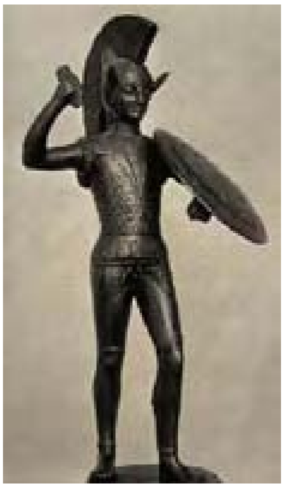
painting

Most examples of Etruscan painting come from excavated tombs, whose frescoes depict scenes of everyday life, mythology, and mortuary rites, typically in bright colours and a vigorous, animated style. Scenes of feasting, dancing, swimming, fishing, and playing evoke a confident people who enjoyed life to the full, and who even in death depicted themselves in a joyous and festive manner. The decline of their civilization, in the shadow of Rome's expansion, is reflected in their later art, which loses its original *joie de vivre* and becomes sombre.

influences

Influences from archaic Greece and the Middle East are evident, as are those from the preceding Iron Age Villanovan culture, but the full flowering of Etruscan art represents a unique synthesis of existing traditions and artistic innovation, which was to have a profound influence on the development of Western art.

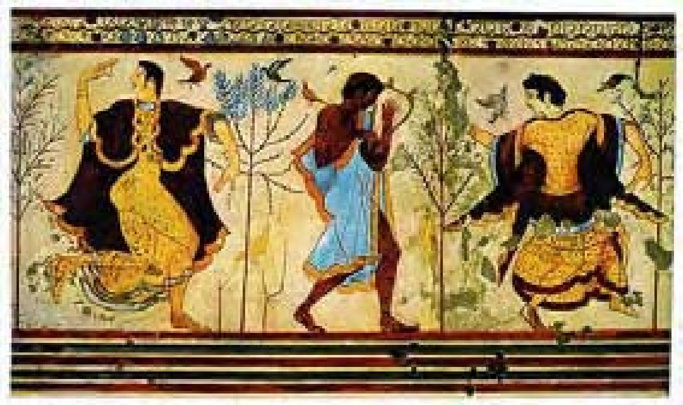
Etruscan art



(Image © Philip Sauvain Picture Collection)

A bronze statuette of an Etruscan warrior, from about 500 BC. Etruscan art, which included painting, pottery, metalwork, and jewellery as well as sculpture, had a great influence on the development of later Western art.

Etruscan art



(Image © Billie Love)

Dancers and a harpist on an Etruscan fresco from Tarquinia, Italy. This fresco was found on the wall of a tomb and dates from *c.* 465 BC. Tarquinia was a principal city of the Etruscan people, who inhabited parts of modern day Tuscany and Umbria from the 8th to the 2nd centuries BC.

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eucalyptus

any tree of a group belonging to the myrtle family, native to Australia, where they are commonly known as gumtrees. About 90% of Australian timber belongs to the eucalyptus genus, which contains about 500 species. The trees have dark hardwood timber which is used for heavy construction work such as railway and bridge building. They are mostly tall, aromatic, evergreen trees with pendant leaves and white, pink, or red flowers. (Genus *Eucalyptus*, family Myrtaceae.)

Compounds isolated from eucalyptus leaves were found in 1996 to be highly effective in killing *Streptococcus mutans*, the bacteria found in the mouth that cause dental decay.

eucalyptus

The tallest tree ever measured was an Australian eucalyptus (*Eucalyptus regnans*), reported in 1872. It was 132 m/435 ft tall.

Eucalyptus

Go to site

Informative resource relating to the eucalyptus tree. It contains a detailed description of the tree and its habitat. There are also notes on the constituents of the tree, as well as information on the possible medicinal uses of the eucalyptus, which include acting as an antiseptic.

Euclid (c. 330-c. 260 BC)

Greek mathematician who wrote the *Stoicheia/Elements* in 13 books, nine of which deal with plane and solid geometry and four with number theory. His great achievement lay in the systematic arrangement of previous mathematical discoveries and a methodology based on axioms, definitions, and theorems.

Euclid's works, and the style in which they were presented, formed the basis for all mathematical thought and expression for the next 2,000 years. He used two main styles of presentation: the synthetic (in which one proceeds from the known to the unknown via logical steps) and the analytical (in which one posits the unknown and works towards it from the known, again via logical steps). Both methods were based on axioms (statements assumed to be true), and from which mathematical propositions, or theorems, were deduced.

In the *Elements*, Euclid incorporated and developed the work of previous mathematicians as well as including his own many innovations. He was rigorous about the actual detail of the mathematical work, attempting to provide proofs for every one of the theorems. The first six books deal with plane geometry (points, lines, triangles, squares, parallelograms, circles, and so on), and includes hypotheses such as Pythagoras' theorem, which Euclid generalized, and the theorem that only one line can be drawn through a given point parallel to another line.

Books 7 to 9 are concerned with arithmetic and number theory, including Euclid's proof that there are an infinite number of prime numbers. In book 10 Euclid treats irrational numbers, and books 11 to 13 discuss solid geometry, ending with the five Platonic solids (the tetrahedron, octahedron, cube, icosahedron, and dodecahedron).

Introduction to the Works of Euclid

Go to site

Thorough introduction to the principles of Euclidean geometry. There is an emphasis on the *Elements*, but other works associated with, or attributed to, Euclid are discussed. The little that is known of the life of the mathematician is presented. There are a number of sources of further information.

Eudoxus (c. 408-c. 353 BC)

also known as Eudoxus of Cnidus

Greek mathematician and astronomer. He devised the first system to account for the motions of celestial bodies, believing them to be carried around the Earth on sets of spheres. Work attributed to Eudoxus includes methods to calculate the area of a circle and to derive the volume of a pyramid or a cone.

Probably Eudoxus regarded the celestial spheres as a mathematical device for ease of computation rather than as physically real, but the idea was taken up by Aristotle and became entrenched in astronomical thought until the time of the 16th-century Danish astronomer Tycho Brahe.

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eugenics

(Greek eugenes 'well-born')

study of ways in which the physical and mental characteristics of the human race may be improved. The eugenic principle was abused by the Nazi Party in Germany during the 1930s and early 1940s to justify the attempted extermination of entire social and ethnic groups and the establishment of selective breeding programmes. Modern eugenics is concerned mainly with the elimination of genetic disease.

The term was coined by the English scientist Francis Galton in 1883, and the concept was originally developed in the late 19th century with a view to improving human intelligence and behaviour.

In 1986 Singapore became the first democratic country to adopt an openly eugenic policy by guaranteeing pay increases to female university graduates when they give birth to a child, while offering grants towards house purchases for nongraduate married women on condition that they are sterilized after the first or second child. In China in June 1995, a law was passed making it illegal for carriers of certain genetic diseases to marry unless they agree to sterilization or long-term contraception. All couples wishing to marry must undergo genetic screening.

Euglena

genus of single-celled organisms in the protozoan phylum Sarcomastigophora that live in fresh water. They are usually oval or cigar-shaped, less than 0.5 mm/0.2 in long, and have a nucleus, green pigment in chloroplasts, a contractile vacuole, a light-sensitive eyespot, and one or two flagella, with which they swim. A few species are colourless or red.

classification

Euglena are members of the order Euglenida in class Phytomastigophora, subphylum Mastigophora, phylum Sarcomastigophora.

This organism combines animal and plant characteristics. Its plantlike characteristics include the chloroplasts and its consequent ability to photosynthesize, and the rigid cellulose wall of some species. Its main animal characteristic is its motility, but it can also absorb food from its environment, and many species have a flexible body covering.

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eukaryote

in biology, one of the three major groupings (domains) into which all life on Earth is divided. Eukaryotes are distinct from the other domains, the archaea and the bacteria (which in the obsolete systematics were combined under the name of prokaryotes) to a comparable extent and are believed to have evolved from ancestors that included genetic traits of both. Eukaryotes are the only one of the three domains that evolved multicellular organisms, but there are single-cell eukaryotes (such as yeast) as well.

The cells of eukaryotes possess a clearly defined nucleus, bounded by a membrane, within which DNA is formed into distinct chromosomes. Eukaryotic cells also contain mitochondria, chloroplasts, and other structures (organelles) that, together with a defined nucleus, are lacking in the cells of prokaryotes. Typically, eukaryotic cells are ten times larger in each dimension than bacteria and archaea.

Euler, Leonhard (1707-1783)

Swiss mathematician. He developed the theory of differential equations and the calculus of variations, and worked in astronomy and optics. He also enlarged mathematical notation.

Euler developed spherical trigonometry and demonstrated the significance of the coefficients of trigonometric expansions; **Euler's number** (e, as it is now called) has various useful theoretical properties and is used in the summation of particular series.

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eureka

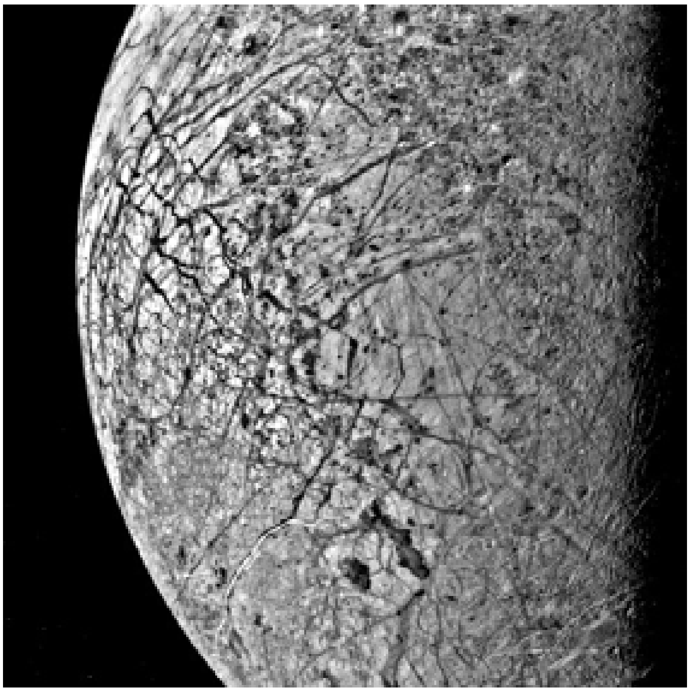
in chemistry, alternative name for the copper-nickel alloy constantan, which is used in electrical equipment.

Europa

in astronomy, fourth-largest moon of the planet Jupiter, diameter 3,140 km/1,950 mi, orbiting 671,000 km/417,000 mi from the planet every 3.55 days. It is a rocky body, probably with an iron core, covered by ice.

NASA's Galileo spacecraft began circling Europa in February 1997. One of the first discoveries from the data it sent back was that the 'cracks' covering the surface of the moon are in fact low ridges. These features lend credence to the idea that Europa possesses a hidden subsurface ocean.

Europa



(Image © NASA)

The surface of Europa, here imaged by the Voyager 2 probe in 1979, is criss-crossed by a complex network of low ridges.

Europa

Go to site

Comprehensive latest information on Jupiter's moon. There is a full discussion of evidence that Europa may have liquid water under its frozen surface. There are also a number of colour images of Europa.

European Southern Observatory

ESO

observatory operated jointly by Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland, and the United Kingdom, with headquarters near Munich, Germany. Its telescopes are at three locations in Chile. A 3.6-m/142-in reflector, opened in 1976, and the 3.5-m/138-in New Technology Telescope, opened in 1989, are at La Silla. The Very Large Telescope (VLT) is on Mount Paranal and consists of four 8-m/26-ft reflectors mounted independently but capable of working in combination. The 'first light' of the first 8-m/26-ft telescope occurred in May 1998. The VLT became fully operational in 2001. The APEX submillimetre radio telescope and ALMA, an array of 64 antennae, are located at Llano de Chajnantor. The ESO receives more than 1,300 proposals annually to use its telescopes.

European Southern Observatory

Go to site

Reports from the intergovernmental European observatory. The site's contents include a description of its observing facilities, press releases, scientific reports, and images of space.

European Space Agency

ESA

organization of 16 European countries that engages in space research and technology. It was founded in 1975, with headquarters in Paris, France. The participating countries are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the UK.

ESA astronauts have participated in numerous space activities including missions on the *Mir* space station and the *International Space Station* (*ISS*). The ESA has developed the Ariane rockets (used to launch most ESA satellites), the *Spacelab* scientific workshop, the Giotto space probe, and various scientific and communications satellites. It also created components for the *ISS*, including a robotic arm. The ESA's European Remote-Sensing Satellite ERS-2 was launched in 1995 to work in tandem with ERS-1 (launched in 1991 and retired in 2000), improving measurements of global ozone. The ESA's Envisat satellite was launched on 28 February 2002. Its Mars Express, launched in June 2003, has discovered water ice and methane on that planet. Current and planned projects include: the *Venus Express* (launched November 2005); a probe to Mercury; and space telescopes, including the Herschel Space Observatory.

European Space Agency

Go to site

Introduction to the European Space Agency, using the format of an informative and colourful slide show detailing the history of the ESA and its current projects and future developments. Included are a large gallery of still images showing past space explorations, plus a video archive.

German Aerospace Center

Go to site

News of DLR's recent activities. The site's Space Forum comprises a multimedia archive with pictures and video clips of mission highlights and features a very good Earth-observation gallery.

europium

chemical symbol Eu

soft, greyish, metallic element of the lanthanide series, atomic number 63, relative atomic mass 151.96. It is used in lasers and as the red phosphor in colour televisions; its compounds are used to make control rods for nuclear reactors. It was named in 1901 by French chemist Eugène Demarçay (1852-1904) after the continent of Europe, where it was first found.

eusociality

form of social life found in insects such as honey bees and termites, in which the colony is made up of special castes (for example, workers, drones, and reproductives) whose membership is biologically determined. The worker castes do not usually reproduce. Only one mammal, the naked mole rat, has a social organization of this type. A eusocial shrimp was discovered in 1996 living in the coral reefs of Belize. *Synalpheus regalis* lives in colonies of up to 300 individuals, all the offspring of a single reproductive female. See also social behaviour.

Eustachian tube

small air-filled canal connecting the middle ear with the back of the throat. It is found in all land vertebrates and equalizes the pressure on both sides of the eardrum.

Eustachio, Bartolommeo (1520-1574)

Italian anatomist, the discoverer of the Eustachian tube, leading from the middle ear to the pharynx, and of the Eustachian valve in the right auricles of the heart.

eustatic change

global rise or fall in sea level caused by a change in the amount of water in the oceans (by contrast, isostatic adjustment involves a rising or sinking of the land, which causes a local change in sea level). During the last ice age, global sea level was lower than today because water became 'locked-up' in the form of ice and snow, and less water reached the oceans.

Eutelsat

acronym for **European Telecommunications Satellite Organization**.

euthanasia

in medicine, 'mercy killing' of someone with a severe and incurable condition or illness. Euthanasia is a highly controversial issue on medical and ethical grounds. A patient's right to refuse life-prolonging treatment is recognized in several countries.

In November 2000, the Netherlands became the first country to legalize euthanasia. In the UK, despite a number of test cases in 2003, all forms of euthanasia are illegal and considered as criminal acts.

Euthanasia

the search for immortality

Death has always been the great mystery, handed out by the gods or by fate. Humans have tried to tame death in two main ways. On the one hand, attempts have been made to prolong life or create earthly immortality, for example, alchemy centred on the quest for the elixir of life.

The 13th-century monk, Roger Bacon (1214-1292), claimed that Christian medicine would surpass pagan science by conquering ageing. The Venetian architect, Luigi Cornaro (1475-1566), wrote a popular book to demonstrate how the pursuit of temperance would extend the lifespan up to 120 years. Francis Bacon and the philosophers of the Enlightenment expressed the hope that the advancement of science would produce the indefinite prolongation of life. Benjamin Franklin (1706-1790) boldly declared senescence to be not a natural process but a 'disease' to be cured, predicting that longevity might reach a thousand years or more. Marie Jean Condorcet (1743-1794), Erasmus Darwin (1731-1802), and William Godwin (1756-1836) speculated about virtually immortal life.

the ideal death

On the other hand, some have aimed at taming death by controlling its manner. Within traditional Christian culture, a good death (as prescribed by the *ars moriendi*, the art of dying well), was a Christian death: expiring in a state of grace, denouncing Satan, praying to the Lord, repenting one's sins, and (for Catholics) taking the sacraments. From the 18th century, the ideal death became more secular; and at this point the concept of euthanasia became relevant. In its original meaning, 'euthanasia' did not specifically mean the positive termination of life to end suffering (mercy killing) but referred to any means of bringing about an easy death.

dying gracefully

Preferences were increasingly expressed in the Enlightenment, not for the dramatic Christian deathbed (with its emotional calling on God and denouncing Satan), but for a quiet and peaceful death. Dying, it was argued, should be like sleep. A serene death would demonstrate an untroubled conscience and crown a life well lived. This tallied with later Romantic notions of death's beauty, particularly among those who died young.

the 19th-century view

In the new conception of euthanasia popular in the 19th century, the doctor's task was to ensure a gentle death, by careful management and judicious application of opiates to dull pain and induce decease. According to the wishes of family or patient, the family doctor doubtless often became the agent of informal (and illegal) euthanasia.

controversial issues

Thus there was a move toward an informal (and often unspoken) acceptance of euthanasia, whose existence social niceties compelled people to deny. This situation has continued, but has been rendered more complex and problematic in recent times. Adolf Hitler's (1899-1945) 'final solution' - of genocide for the Jews and mass extermination of the mentally ill, Romanies, and other victimized groups - twisted the concept of euthanasia for diabolical ends. Nazi genocide has created suspicion that any general legalization of euthanasia might be the thin end of the wedge, which in due course would lead to public euthanasia procedures for 'problem' or expensive people like the very old, poor, and senile.

problems for the medical profession

Death now increasingly occurs in public institutions, notably hospitals. This may render the conduct of humane euthanasia more difficult, as physicians and nursing staff involved in such informal practices may be justifiably afraid that they thereby risk exposure and legal prosecution, particularly by Christian pressure groups, such as Life, who on transcendental grounds oppose mercy killing. Medical staff who put patients out of their dying agonies are from time to time subject to prosecutions, mainly brought by religious fundamentalists.

dilemmas raised by medical advance

Yet the conditions of modern death have led to growing support for euthanasia, subject to proper safeguards. Thanks to high-tech life-support systems, it is now relatively easy to keep 'heart-dead' and even 'brain-dead' patients artificially alive. There is a growing feeling of repugnance at the 'cruelty' of the meaningless prolongation of the life of those who no longer have the possibility of consciousness, or who can feel only pain, incapacity, and the wish to be spared further agony.

living wills

Hence, pressure has come about for the establishment of acceptable procedures for mercy killing, in circumstances in which it is clearly desired by the dying. One such device is the 'living will', a kind of assisted suicide. Euthanasia under such circumstances can be reconciled with the professional ethics of the physician. It can be argued that, while it is the doctor's duty to save life, that duty does not run so far as to protract life by artificial means in any circumstances whatsoever. It may not be a duty of the doctor to provide resuscitation for a patient almost certain not to survive the effort.

no easy answers

The advance of modern medicine has thus created deep and novel dilemmas. Should a brain-dead patient be kept alive? Should a patient near death from excruciating cancer be resuscitated? Is it permissible to withhold medication from deeply malformed newborns? No categorical answers are available.
Voluntary euthanasia is obviously open to abuse. But the more that medicine is able to manage life, the more it must find responsible ways of managing death.

Euthanasia

Go to site

Euthanasia ('The intentional termination of life by another at the explicit request of the person who dies') is covered in great detail in this Web page. The issues and ideas expressed on this site are ordered into various sections such as: 'Meanings of terms', 'Beliefs about suicide and euthanasia', 'The verbal battle over euthanasia', 'Ethical aspects of euthanasia', and 'Religious aspects of euthanasia', and aim to give a balanced view of the debate. Click on a heading in the contents section to go to specific information.

Eutheria

former division of class Mammalia, comprising all mammals with a placenta.

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eutrophication

excessive enrichment of rivers, lakes, and shallow sea areas, primarily by municipal sewage, by sewage itself, and by the nitrates and phosphates from fertilizers used in agriculture. These encourage the growth of algae and bacteria which use up the oxygen in the water, making it uninhabitable for fish and other animal life. In this way eutrophication is responsible for a particular type of water pollution.

The dissolved fertilizers cause the rapid growth of water plants, especially green algae, which can clog up waterways and prevent light reaching plants below the surface. As the algae die, aerobic bacteria bring about decay, using up oxygen in the water as they do so. Anaerobic bacteria take over and convert part of the dead matter into smelly decay products. Slowly a layer of dead plant material builds up on the bottom of the lake or river. Deprived of oxygen, fish and other life forms die and decay, leaving putrid, poisonous water.

Evans, Arthur John (1851-1941)

English archaeologist. His excavations at Knossos on Crete uncovered a vast palace complex, and resulted in the discovery of various Minoan scripts. He proved the existence of a Bronze Age civilization that predated the Mycenean, and named it Minoan after Minos, the legendary king of Knossos.

From 1889, his excavations covered 35 years and also revealed evidence of an earlier Neolithic (New Stone Age) culture. The chief publications detailing his Cretan discoveries are *Scripta Minoa* (two volumes, 1909 and 1952), and four volumes on *The Palace of Minos* (1921-36). An earlier work, *Essay on the Classification of Minoan Civilization*, set out a chronological scheme of Aegean archaeology which, though long accepted, has since come under dispute.

Evans, Walker (1903-1975)

US photographer. He is best known for his documentary photographs of people in the rural American South during the Great Depression. Many of his photographs appeared in James Agee's book *Let Us Now Praise Famous Men* (1941).

Evans, Walker

Go to site

Tribute to the US photographer who established the documentary photo essay. In addition to biographical details, there are many of the haunting images of southern sharecroppers in the Great Depression which made Evans's reputation.

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evaporation

process in which a liquid turns to a vapour without its temperature reaching boiling point. Evaporation is the change of state that occurs when a liquid turns into a gas. In a liquid the particles are close together, with forces holding them together, yet able to move about. Some particles in a liquid have more energy than others. Even when a liquid is below its boiling point, some particles have enough energy to escape and form a gas. Evaporation is greater when temperatures and wind speeds are high, and the air is dry. It is why puddles dry up in the sun, and clothes dry faster in dry, windy weather.

A liquid left to stand in a saucer eventually evaporates because, at any time, a proportion of its molecules will be fast enough (have enough kinetic energy) to escape from the attractive intermolecular forces at the liquid surface into the atmosphere. The temperature of the liquid tends to fall because the evaporating molecules remove energy from the liquid. The rate of evaporation rises with increased temperature because as the mean kinetic energy of the liquid's molecules rises, so will the number possessing enough energy to escape.

A fall in the temperature of the liquid, known as the **cooling effect**, accompanies evaporation because as the faster molecules escape from the surface, the mean energy of the remaining molecules falls. The effect may be noticed when sweat evaporates from the skin. It plays a part in temperature control of the human body.

evaporite

sedimentary deposit precipitated on evaporation of salt water.

With a progressive evaporation of seawater, the most common salts are deposited in a definite sequence: calcite (calcium carbonate), gypsum (hydrous calcium sulphate), halite (sodium chloride), and finally salts of potassium and magnesium.

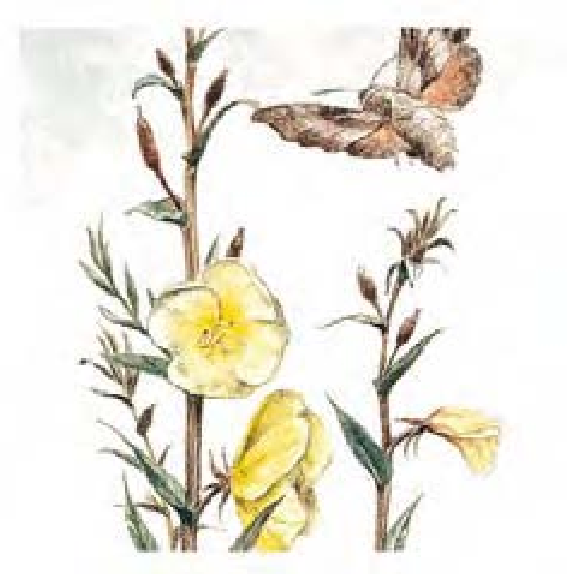
Calcite precipitates when seawater is reduced to half its original volume, gypsum precipitates when the seawater body is reduced to one-fifth, and halite when the volume is reduced to one-tenth. Thus the natural occurrence of chemically precipitated calcium carbonate is common, of gypsum fairly common, and of halite less common.

Because of the concentrations of different dissolved salts in seawater, halite accounts for about 95% of the chlorides precipitated if evaporation is complete. More unusual evaporite minerals include borates (for example borax, hydrous sodium borate) and sulphates (for example glauberite, a combined sulphate of sodium and calcium).

evening primrose

any of a group of plants that typically have pale yellow flowers which open in the evening. About 50 species are native to North America, several of which now also grow in Europe. Some are cultivated for their oil, which is rich in gamma-linoleic acid (GLA). The body converts GLA into substances which resemble hormones, and **evening primrose oil** is beneficial in relieving the symptoms of premenstrual tension. It is also used in treating such ailments as eczema and chronic fatigue syndrome. (Genus *Oenothera*, family Onagraceae.)

evening primrose



(Image © Research Machines plc)

The evening primrose belongs to a large family of flowering shrubs and plants, many of which bear four-petalled yellow flowers. The evening primrose opens its blooms at night and is pollinated by moths. Oil from the pressed seeds of one species of evening primrose is a source of gamma-linoleic acid which may be used medicinally for a variety of ailments including the reduction of high cholesterol.

event-driven

in computing, computer system that does not do anything until events are detected, such as mouse-clicks. Microsoft Windows is an event-driven operating environment.

evergreen

in botany, a plant such as pine, spruce, or holly, that bears its leaves all year round. Most conifers are evergreen. Plants that shed their leaves in autumn or during a dry season are described as deciduous.

Evershed, John (1864-1956)

English astronomer who made solar observations. In 1909 he discovered the radial movements of gases in sunspots (the **Evershed effect**). He also gave his name to a spectroheliograph, the Evershed spectroscope.

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evolution

slow gradual process of change from one form to another, as in the evolution of the universe from its formation to its present state, or in the evolution of life on Earth. In biology, it is the process by which life has developed by stages from single-celled organisms into the multiplicity of animal and plant life, extinct and existing, that inhabits the Earth. The development of the concept of evolution is usually associated with the English naturalist Charles Darwin who attributed the main role in evolutionary change to natural selection acting on randomly occurring variations. These variations in species are now known to be adaptations produced by spontaneous changes or mutations in the genetic material of organisms. In short, evolution is the change in the genetic makeup of a population of organisms from one generation to another. Evidence shows that many species of organisms do not stay the same over generations. The most dramatic evidence of this comes from fossils.

Evolution occurs via the following processes of natural selection: individual organisms within a particular species may show a wide range of variation because of differences in their genes; predation, disease, and competition cause individuals to die; individuals with characteristics most suited to the environment are more likely to survive and breed successfully; and the genes that have enabled these individuals to survive are then passed on to the next generation, and if the environment is changing, the result is that some genes are more abundant in the next generation and the organism has evolved.

Evolutionary change can be slow, as shown in part of the fossil record. However, it can be quite fast. If a population is reduced to a very small number, evolutionary changes can be seen over a few generations. Because micro-organisms have very short life cycles, evolutionary change in micro-organisms can be rapid. Micro-organisms can evolve resistance to a new antibiotic only a few years after the drug is first used. As a result of evolution from common ancestors, we are able to use classification of organisms to suggest evolutionary origins.

Coelacanth: the Fish Out of Time

Go to site

Site about the coelacanth, the 400 million-year-old 'living fossil' fish thought to have become extinct with the dinosaurs but found alive and well in 1938. It contains a mine of information on coelacanth biology, habitat, and behaviour, and reports on current efforts to preserve this unique species. A virtual swimming coelacanth is an additional fun feature.

Evolutionist, The

Go to site

Online magazine devoted to evolutionary ideas which includes features, interviews, and comment. It currently includes an article on the recent political interest in Darwinism and a column on the limits of evolutionary theory.

Evolution Theory and Science

Go to site

Explore the theory of evolution through the 'Time line of evolutionary thought' which outlines the major developments and key figures in evolutionary theory. This site also contains a section called 'Dinosaur discoveries' that explains the uncovering of dinosaur remains, complete with illustrations.

Journey into Phylogenetic Systematics

Go to site

Online exhibition about evolutionary theory with a specific emphasis on phylogenetic systematics: the way that biologists reconstruct the pattern of events that has led to the distribution and diversity of life. The site provides an introduction to the philosophy, methodology, and implication of cladistic analysis, with a separate section on the need for cladistics. Many of the scientific terms are included in an illuminating glossary.

Live A Life Page

Go to site

Fascinating page that brings together interactive programs to simulate ecological and evolutionary processes. Included is an adaptation of Richard Dawkins's Biomorphs program, described in *The Blind Watchmaker*, which enables the user to select 'morphs' for certain qualities and watch as their offspring evolve.

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evolutionary stable strategy

ESS

in sociobiology, an assemblage of behavioural or physical characters (collectively termed a 'strategy') of a population that is resistant to replacement by any forms bearing new traits, because the new traits will not be capable of successful reproduction.

ESS analysis is based on game theory and can be applied both to genetically determined physical characters (such as horn length), and to learned behavioural responses (for example, whether to fight or retreat from an opponent). An ESS may be conditional on the context, as in the rule 'fight if the opponent is smaller, but retreat if the opponent is larger'.

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excavation

or dig

in archaeology, the systematic recovery of data through the exposure of buried sites and artefacts. Excavation is destructive, and is therefore accompanied by a comprehensive recording of all material found and its three-dimensional locations (its context). As much material and information as possible must be recovered from any dig. A full record of all the techniques employed in the excavation itself must also be made, so that future archaeologists will be able to evaluate the results of the work accurately.

Besides being destructive, excavation is also costly. For both these reasons, it should be used only as a last resort. It can be partial, with only a sample of the site investigated, or total. Samples are chosen either intuitively, in which case excavators investigate those areas they feel will be most productive, or statistically, in which case the sample is drawn using various statistical techniques, so as to ensure that it is representative.

An important goal of excavation is a full understanding of a site's stratigraphy; that is, the vertical layering of a site.

These layers or levels can be defined naturally (for example, soil changes), culturally (for example, different occupation levels), or arbitrarily (for example, 10 cm/4 in levels). Excavation can also be done horizontally, to uncover larger areas of a particular layer and reveal the spatial relationships between artefacts and features in that layer. This is known as open-area excavation and is used especially where single-period deposits lie close to the surface, and the time dimension is represented by lateral movement rather than by the placing of one building on top of the preceding one.

Most excavators employ a flexible combination of vertical and horizontal digging adapting to the nature of their site and the questions they are seeking to answer.

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excavator

machine designed for digging in the ground, or for earth-moving in general. Diggers with hydraulically powered digging arms are widely used on building sites. They may run on wheels or on caterpillar tracks. The largest excavators are the draglines used in mining to strip away earth covering the coal or mineral deposit.

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exclusion principle

in physics, a principle of atomic structure originated by Austrian-born US physicist Wolfgang Pauli. It states that no two electrons in a single atom may have the same set of quantum numbers.

Hence, it is impossible to pack together certain elementary particles, such as electrons, beyond a certain critical density, otherwise they would share the same location and quantum number. A white dwarf star, which consists of electrons and other elementary particles, is thus prevented from contracting further by the exclusion principle and never collapses. Elementary particles in the class fermions obey the exclusion principle whilst those in the class bosons do not.

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excretion

in biology, the removal of the waste products of metabolism from living organisms. In plants and simple animals, waste products are removed by diffusion. Plants, for example, excrete O_2, a product of photosynthesis. In mammals, waste products are removed by specialized excretory organs, principally the kidneys, which excrete urea. Water and metabolic wastes are also excreted in the faeces and, in humans, through the sweat glands in the skin; carbon dioxide and water are removed via the lungs. The liver excretes bile pigments.

excretory organs

To remember the excretory organs of the body:

Skill

Skin, **k**idneys, **i**ntestines, **l**iver, **l**ungs

exfoliation

in biology, the separation of pieces of dead bone or skin in layers.

exobiology

study of life forms that may possibly exist elsewhere in the universe and of the effects of extraterrestrial environments on Earth organisms. Techniques include space probe experiments designed to detect organic molecules, and the monitoring of radio waves from other star systems, as part of the search for extraterrestrial intelligence SETI.

exocrine gland

gland that discharges secretions, usually through a tube or a duct, onto a surface. Examples include sweat glands which release sweat on to the skin, and digestive glands which release digestive juices onto the walls of the intestine. Some animals also have endocrine glands (ductless glands) that release hormones directly into the bloodstream.

exoskeleton

hardened external skeleton of insects, spiders, crabs, and other arthropods. It provides attachment for muscles and protection for the internal organs, as well as support. To permit growth it is periodically shed in a process called ecdysis.

exosphere

uppermost layer of the atmosphere. It is an ill-defined zone above the thermosphere, beginning at about 700 km/435 mi and fading off into the vacuum of space. The gases are extremely thin, with hydrogen as the main constituent.

exothermic reaction

chemical reaction during which heat is given out (see energy of reaction).

For example, burning sulphur in air to give sulphur dioxide is an exothermic reaction.

$2S + O_2 \rightarrow SO_2$

expand

in algebra, to multiply out. For example, $ac + bc + ad + bd$ is the expanded form of $(a+b)(c+d)$.

expansion

in physics, the increase in size of a constant mass of substance caused by, for example, increasing its temperature (thermal expansion) or its internal pressure. The **expansivity**, or coefficient of thermal expansion, of a material is its expansion (per unit volume, area, or length) per degree rise in temperature.

expectorant

any substance, often added to cough mixture, to encourage secretion of mucus in the airways to make it easier to cough up. It is debatable whether expectorants have an effect on lung secretions.

experiment

in science, a practical test designed with the intention that its results will be relevant to a particular theory or set of theories. Although some experiments may be used merely for gathering more information about a topic that is already well understood, others may be of crucial importance in confirming a new theory or in undermining long-held beliefs.

The manner in which experiments are performed, and the relation between the design of an experiment and its value, are therefore of central importance. In general, an experiment is of most value when the factors that might affect the results (variables) are carefully controlled; for this reason most experiments take place in a well-managed environment such as a laboratory or clinic.

Exploratorium

Go to site

Very well-designed site based on the hands-on science museum in San Francisco. Several of the museum's exhibits are recreated here, including a page on the science of ice hockey and a virtual dissection of a cow's eye. There is practical information about the museum and help for teachers, but most of the pages are interactive: full of images and audio clips to augment the text.

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experimental archaeology

the controlled replication of ancient technologies and behaviour in order to provide hypotheses that can be tested by actual archaeological data. Experiments can range in size from the reproduction of ancient tools in order to learn about their processes of manufacture and use, and their effectiveness, to the construction of whole villages and ancient subsistence practices in long-term experiments.

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experimental psychology

application of scientific methods to the study of mental processes and behaviour.

This covers a wide range of fields of study, including: **human and animal learning**, in which learning theories describe how new behaviours are acquired and modified; **cognition**, the study of a number of functions, such as perception, attention, memory, and language; and **physiological psychology**, which relates the study of cognition to different regions of the brain.
Artificial intelligence refers to the computer simulation of cognitive processes, such as language and problem-solving.

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expert system

computer program for giving advice (such as diagnosing an illness or interpreting the law) that incorporates knowledge derived from human expertise. A kind of knowledge-based system, it contains rules that can be applied to find the solution to a problem. It is a form of artificial intelligence.

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explanation

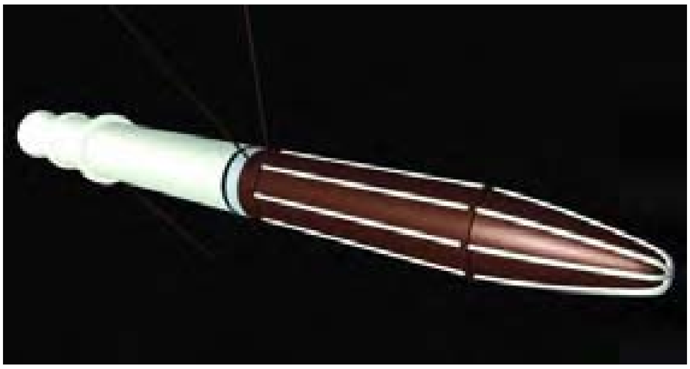
in science, an attempt to make clear the cause of any natural event by reference to physical laws and to observations.

The extent to which any explanation can be said to be true is one of the chief concerns of philosophy, partly because observations may be wrongly interpreted, partly because explanations should help us predict how nature will behave. Although it may be reasonable to expect that a physical law will hold in the future, that expectation is problematic in that it relies on induction, a much criticized feature of human thought; in fact no explanation, however 'scientific', can be held to be true for all time, and thus the difference between a scientific and a common-sense explanation remains the subject of intense philosophical debate.

Explorer

series of US scientific satellites. Explorer 1, launched on 31 January 1958, was the first US satellite in orbit and discovered the Van Allen radiation belts around the Earth. Explorer 42 in 1970 was the first satellite to study X-rays from space, and Explorer 48 in 1972 was the first to study gamma rays from space. Explorer 83 was the Swift gamma-ray astronomy spacecraft, launched in November 2004.

Explorer



(Image © Research Machines plc)

The US satellite Explorer was designed and built by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology, under the guidance of US electrical engineer William Pickering. It was 1.54 m/60.75 in in length and 15 cm/6 in in diameter.

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explosive

any material capable of a sudden release of energy and the rapid formation of a large volume of gas, leading, when compressed, to the development of a high-pressure wave (blast).

types of explosive

Combustion and explosion differ essentially only in rate of reaction, and many explosives (called **low explosives**) are capable of undergoing relatively slow combustion under suitable conditions. **High explosives** produce uncontrollable blasts. The first low explosive was gunpowder; the first high explosive was nitroglycerine.

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exponent

or index

in mathematics, a superscript number that indicates the number of times a term is multiplied by itself; for example $x^2 = x \times x$, $4^3 = 4 \times 4 \times 4$.

Exponents obey certain rules. Terms that contain them are multiplied together by adding the exponents; for example, $x^2 \times x^5 = x^7$. Division of such terms is done by subtracting the exponents; for example, $y^5 \div y^3 = y^2$. Any number with the exponent 0 is equal to 1; for example, $x^0 = 1$ and $99^0 = 1$.

See index notation.

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exponential

in mathematics, descriptive of a function in which the variable quantity is an exponent (a number indicating the power to which another number or expression is raised).

Exponential functions and series involve the constant e = 2.71828.... . Scottish mathematician John Napier devised natural logarithms in 1614 with e as the base.

Exponential functions are basic mathematical functions, written as e^x or exp x. The expression e^x has five definitions, two of which are: (i) e^x is the solution of the differential equation $dx/dt = x$ ($x = 1$ if $t = 0$); (ii) e^x is the limiting sum of the infinite series $1 + x + (x^2/2!) + (x^3/3!) + \ldots + (x^n/n!)$.

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export file

in computing, a file stored by the computer in a standard format so that it can be accessed by other programs, possibly running on different makes of computer.

For example, a word-processing program running on an Apple Macintosh computer may have a facility to save a file on a floppy disk in a format that can be read by a word-processing program running on an IBM PC-compatible computer. When the file is being read by the second program or computer, it is often referred to as an **import file**.

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exposure meter

instrument used in photography for indicating the correct exposure - the length of time the camera shutter should be open under given light conditions. Meters use substances such as cadmium sulphide and selenium as light sensors. These materials change electrically when light strikes them, the change being proportional to the intensity of the incident light. Many cameras have a built-in exposure meter that sets the camera controls automatically as the light conditions change.

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expression

in mathematics, a phrase written in symbols. For example, $2x^2 + 3x + 5$ is a quadratic (containing a term or terms raised to the second power but no higher) expression. Equations consist of expressions written around an equals sign.

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extensive agriculture

farming system where the area of the farm is large but there are low inputs (such as labour or fertilizers). Extensive farming generally gives rise to lower yields per hectare than intensive agriculture. For example, in East Anglia, intensive use of land may give wheat yields as high as 53 tonnes per hectare, whereas an extensive wheat farm on the Canadian prairies may produce an average of 8.8 tonnes per hectare.

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extensor

a muscle that straightens a limb.

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extinction

in biology, the complete disappearance of a species from the planet. Extinctions occur when a species becomes unfit for survival in its natural habitat usually to be replaced by another, better-suited species. An organism becomes ill-suited for survival because its environment is changed or because its relationship to other organisms is altered. For example, a predator's fitness for survival depends upon the availability of its prey.

past extinctions

Mass extinctions are episodes during which large numbers of species have become extinct virtually simultaneously in the distant past, the best known being that of the dinosaurs, other large reptiles, and various marine invertebrates about 65 million years ago between the end of the Cretaceous period and the beginning of the Tertiary period, the latter known as the **K-T extinction**.

There have been several others in the more distant past. There is disagreement about the causes, but one of several major catastrophes have been blamed, including meteorite impact, volcanic eruption, massive lava flows, and significant global warming. Another mass extinction occurred about 10,000 years ago when many giant species of mammal died out. This is known as the 'Pleistocene overkill' because their disappearance was probably hastened by the hunting activities of prehistoric humans. The greatest mass extinction occurred about 250 million years ago, marking the Permian-Triassic boundary (see geological time), when up to 96% of all living species became extinct.

Extinction: A Race against Time

the increasing speed to extinction

About a million different living species have been identified so far. Recent studies in tropical forests - where biodiversity is greatest - suggest the true figure is nearer 30 million. Most are animals, and most of those are insects. Because the tropical forests are threatened, at least half the animal species could become extinct in in the 21st century alone.

There have been at least five 'mass extinctions' in our planet's history; the last removed the dinosaurs 65 million years ago. The present wave of extinction is on a similar scale, but hundreds of times faster.

conflicting approaches

There is conflict within the conservation movement over what is to be done about this. Some believe that *habitats* (the places where animals and plants live) should be conserved; others prefer to concentrate upon individual *species*. Both approaches have strengths and weaknesses, and they must operate in harmony.

Habitat protection has obvious advantages. Many species benefit if land is preserved. Animals need somewhere to live; unless the habitat is preserved it may not be worth saving the individual animal. Habitat protection *seems* cheap; for example, tropical forest can often be purchased for only a few dollars per hectare. Only by habitat protection can we save more than a handful of the world's animals.

But there are difficulties. Even when a protected area is designated a 'national park', its animals may not be safe. All five remaining species of rhinoceros are heavily protected in the wild, but are threatened by poaching. Early in 1991 Zimbabwe had 1,500 black rhinos - the world's largest population. Patrols of game wardens shoot poachers on sight. Yet by late 1992, 1,000 of the 1,500 had been poached. In many national parks worldwide, the habitat is threatened by the local farmers' need to graze their cattle.

requirements for viability

Computer models and field studies show that wild populations need several hundred individuals to be viable. Smaller populations will eventually go extinct in the wild, because of accidents to key breeding individuals, or epidemics. The big predators need vast areas. One tiger may command hundreds of square kilometres; a viable population needs an area as big as Wales or Holland.

Only one of the world's five remaining subspecies of tiger - a population of Bengals in India - occupies an area large enough to be viable. All the rest (Indo-Chinese, Sumatran, Chinese, and Siberian) seem bound to die out. Three other subspecies have gone extinct in the past 100 years - the latest, the Javan, in the 1970s.

Ecologists now emphasize the concept of *mosaic*. All animals need different things from their habitat, and a failure of supply of any one is disastrous. Giant pandas feed mainly on bamboo, but give birth in old hollow trees - of which there is a shortage. Birds commonly roost in one place, but feed in special areas far away.

Nature reserves must either contain all essentials for an animal's life, or else allow access to such areas elsewhere. For many animals in a reserve, these conditions are not fulfilled. Hence year by year, after reserves are created, species go extinct: a process called *species relaxation*. The remaining fauna and flora may be a poor shadow of the original.

Interest is increasing in *captive breeding*, carried out mainly by the world's 800 zoos. Their task is formidable; each captive species should include several hundred individuals. Zoos maintain such numbers through *cooperative breeding*, organized regionally and coordinated by the Captive Breeding Specialist Group or the World Conservation Union, based in Minneapolis, Minnesota. Each programme is underpinned by a studbook, showing which individuals are related to which.

Breeding for conservation is different from breeding for livestock improvement. Livestock breeders breed *uniform* creatures by selecting animals conforming to some prescribed ideal. Conservation breeders maintain *maximum genetic diversity* by encouraging every individual to breed, including those reluctant to breed in captivity; by equalizing family size, so one generation's genes are all represented in the next; and by swapping individuals between zoos to prevent inbreeding.

Cooperative breeding programmes are rapidly diversifying; by the year 2000 there should be several hundred. They can only make a small impression on the 15 million endangered species, but they can contribute greatly to particular groups of animals, especially the land vertebrates - mammals, birds, reptiles, and amphibians. These include most of the world's largest animals, with the greatest impact on their habitats.

There are 24,000 species of land vertebrate, of which 2,000 probably require captive breeding to survive. Zoos could save all 2,000, which would be a great contribution.

conclusion

Captive breeding is not intended to establish 'museum' populations, but to provide a temporary 'lifeboat'. Things are hard for wild animals, but over the next few decades, despite the growing human population, it should be possible to establish more and safer national parks. The Arabian oryx, California condor, black-footed ferret, red wolf, and Mauritius kestrel are among the creatures so far saved from extinction by captive breeding and returned to the wild. In the future, we can expect to see many more.

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extracellular matrix

strong material naturally occurring in animals and plants, made up of protein and long-chain sugars (polysaccharides) in which cells are embedded. It is often called a 'biological glue', and forms part of connective tissues such as bone and skin.

The cell walls of plants and bacteria, and the exoskeletons of insects and other arthropods, are also formed by types of extracellular matrix.

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extrasensory perception

ESP

any form of perception beyond and distinct from the known sensory processes. The main forms of ESP are clairvoyance (intuitive perception or vision of events and situations without using the senses); precognition (the ability to foresee events); and telepathy or thought transference (communication between people without using any known visible, tangible, or audible medium). Verification by scientific study has yet to be achieved.

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extroversion

or extraversion

personality dimension described by the psychologists Carl Jung and, later, Hans Eysenck. The typical extrovert is sociable, impulsive, and carefree. The opposite of extroversion is introversion.

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extrusion

common method of shaping metals, plastics, and other materials. The materials, usually hot, are forced through a hole in a metal die and take its cross-sectional shape. Rods, tubes, and sheets may be made in this way.

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extrusive rock

or volcanic rock

igneous rock formed on the surface of the Earth by volcanic activity (as opposed to intrusive, or plutonic, rocks that solidify below the Earth's surface). Magma (molten rock) erupted from volcanoes cools and solidifies quickly on the surface. The crystals that form do not have time to grow very large, so most extrusive rocks are finely grained. The term includes fine-grained crystalline or glassy rocks formed from hot lava quenched at or near Earth's surface, and those made of welded fragments of ash and glass ejected into the air during a volcanic eruption. The formation of extrusive igneous rock is part of the rock cycle.

Large amounts of extrusive rock called basalt form at the Earth's ocean ridges from lava that fills the void formed when two tectonic plates spread apart. Explosive volcanoes that deposit pyroclastics generally occur where one tectonic plate descends beneath another. Andesite is often formed by explosive volcanoes. Magmas that give rise to pyroclastic extrusive rocks are explosive because they are viscous. The island of Montserrat, West Indies, is an example of an explosive volcano that spews pyroclastics of andesite composition. Magmas that produce crystalline or glassy volcanic rocks upon cooling are less viscous. The low viscosity allows the extruding lava to flow easily. Fluid-like lavas that flow from the volcanoes of the Hawaiian Islands have low viscosity and cool to form basalt.

volcanic vent

(Image © Corel)

Volcanic vent in the crater floor of Kilauea, Hawaii, USA.

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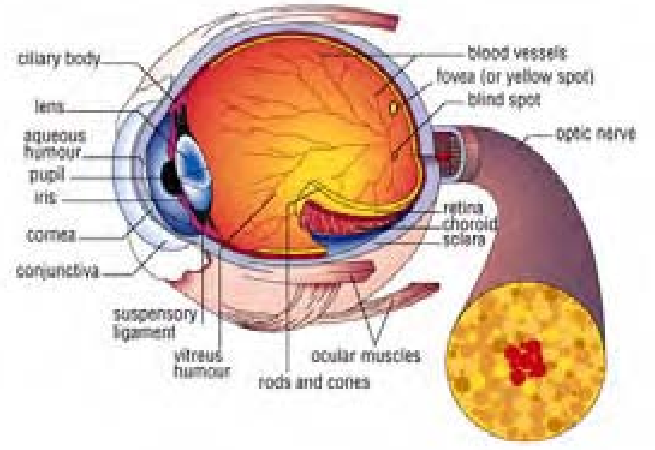
eye

organ of vision. In the human eye, the light is focused by the combined action of the curved cornea, the internal fluids, and the lens. The insect eye is compound – made up of many separate facets, known as ommatidia, each of which collects light and directs it separately to a receptor to build up an image. Invertebrates have much simpler eyes, with no lenses. Among molluscs, cephalopods have complex eyes similar to those of vertebrates. The mantis shrimp's eyes contain ten colour pigments with which to perceive colour; some flies and fish have five, while the human eye has only three.

The human eye is a roughly spherical structure contained in a bony socket. Light enters it through the cornea, a transparent region at the front of the tough outer sclera and passes through the circular opening (pupil) in the iris (the coloured part of the eye). The muscular iris controls the size of the pupil and hence the amount of light entering the eye. Light then passes through the lens, which is held in position by suspensory ligaments and ciliary muscles. The ciliary muscles act on the lens (the rounded transparent structure behind the iris) to change its shape, allowing images of objects nearby and at a distance to be focused on the retina at the back of the eye. The retina is packed with light-sensitive cells (rods and cones). Rods work well in conditions of low light but are unable to sense colour. Cones work well in bright light and are responsible for colour vision. The part of the retina on which lies the precise point at which the image is focused contains mainly cones. The rods and cones in the retina send impulses to the brain along sensory neurons in the optic nerve.

eye



(Image © Research Machines plc)

The human eye. The retina of the eye contains about 137 million light-sensitive cells in an area of about 650 sq mm/1 sq in. There are 130 million rod cells for black and white vision and 7 million cone cells for colour vision. The optic nerve contains about 1 million nerve fibres. The focusing muscles of the eye adjust about 100,000 times a day. To exercise the leg muscles to the same extent would need an 80 km/50 mi walk.

Eye

Go to site

Thorough information on the physical structures of the eye, from the University of Pennsylvania, USA. The page is divided into sections covering the main parts of the eye, such as the retina, cornea, iris, pupil, and lens.

eyebright

any of a group of annual plants belonging to the figwort family. They are 2-30 cm/1-12 in high and have whitish flowers streaked with purple. The name indicates their traditional use as an eye-medicine. (Genus *Euphrasia*, family Scrophulariaceae.)

Eyebright

Go to site

Informative resource relating to the eyebright plant. It contains a detailed description of the tree, its habitat, and even its history. There are also notes on the constituents of the plant, as well as information on the possible medicinal uses of eyebright, which include treating bronchial colds and eye ailments.

eye, defects of the

abnormalities of the eye that impair vision. Glass or plastic lenses, in the form of spectacles or contact lenses, are the usual means of correction. Common optical defects are short-sightedness or myopia; farsightedness or hypermetropia; lack of accommodation or presbyopia; and astigmatism. Other eye defects include colour blindness.

eyeglasses

pair of lenses fitted in a frame and worn in front of the eyes to correct or assist defective vision. Common defects of the eye corrected by such lenses are nearsightedness (myopia), corrected by using concave (spherical) lenses, farsightedness (hypermetropia), corrected by using convex (spherical) lenses, and astigmatism, corrected by using cylindrical lenses.

Spherical and cylindrical lenses may be combined in one lens. Bifocal spectacles correct vision both at a distance and for reading by combining two lenses of different curvatures in one piece of glass. Varifocal glasses have the same effect without any visible line between the two types of lens.

Eyeglasses are said to have been invented in the 13th century by a Florentine monk. Few people found the need for eyeglasses until printing was invented, when the demand for them increased rapidly. Using photosensitive glass, lenses can be produced that darken in glare and lighten in ordinary light conditions. Lightweight plastic lenses are also common. The alternative to eyeglasses is contact lenses.

°F

symbol for degrees Fahrenheit.

F

in physics, symbol for farad, the SI unit of capacitance equal to that of a capacitor with a potential difference of 1 volt between plates carrying a charge of 1 coulomb.

'f/64' group

group of US photographers, including Edward Weston, Ansel Adams, and Imogen Cunningham, formed 1932. The sharp focus and clarity of their black and white pictures was achieved by setting the lens aperture to f/64.

Fabre, (Jean) Henri (Casimir) (1823-1915)

French entomologist whose studies of wasps, bees, and other insects, particularly their anatomy and behaviour, have become classics.

fabric

textile that has been constructed by weaving, knitting, or felting. Fabrics are constructed from a wide range of different yarns and fibres ranging from natural fibre such as cotton, silk, linen, and wool, to synthetic fibre such as nylon, polyester, acetate, acrylic, lycra, and rayon.

Each type of fibre can be made into a range of different fabrics. For example, cotton fibre is used to make organdie, jersey, lace, and denim. For rayon fibre, the fabric range includes velvet, taffeta, and flannel.

Fabricius, Hieronymus (1537-1619)

Italian Geronimo Fabrizio; also known as Girolamo Fabrizio

Italian anatomist and embryologist. From 1574 he made detailed studies of the veins and blood flow and discovered the existence of one-way valves that direct the blood towards the heart. He also studied the development of chick embryos.

Fabricius also investigated the mechanics of respiration, the action of muscles, the anatomy of the larynx (about which he was the first to give a full description) and the eye (he was the first to correctly describe the location of the lens and the first to demonstrate that the pupil changes size).

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facies

body of rock strata possessing unifying characteristics usually indicative of the environment in which the rocks were formed. The term is also used to describe the environment of formation itself or unifying features of the rocks that comprise the facies.

Features that define a facies can include collections of fossils, sequences of rock layers, or the occurrence of specific minerals. Sedimentary rocks deposited at the same time, but representing different facies belong to a single **chronostratigraphic unit** (see stratigraphy). But these same rocks may belong to different **lithostratigraphic units**. For example, beach sand is deposited at the same time that mud is deposited further offshore. The beach sand eventually turns to sandstone while the mud turns to shale. The resulting sandstone and shale **strata** comprise two different facies, one representing the beach environment and the other the offshore environment, formed at the same time; the sandstone and shale belong to the same chronostratigraphic unit but distinct lithostratigraphic units.

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facsimile transmission

full name for fax or telefax.

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factor

in algebra, certain kinds of polynomials (expressions consisting of several or many terms) can be factorized using their common factors. Brackets are put into an expression, and the common factor is sought. For example, the factors of $2a^2 + 6ab$ are $2a$ and $a + 3b$, since $2a^2 + 6ab = 2a(a + 3b)$. This rearrangement is called **factorization**.

---

factor

number that divides into another number exactly. It is also known as a divisor. For example, the factors of 24 are 1, 2, 4, 8, 12, and 24; and the factors of 64 are 1, 2, 4, 8, 16, 32, and 64. The highest factor of both 24 and 64 is 8. This is known as the highest common factor (HCF) of the two numbers.

The largest number to be factorized to date has 167 digits: it was split into its 80- and 87-digit factors in 1997 by US mathematicians, after 100,000 hours of computing.

See also prime number and prime factor.

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factorial

of a positive number, the product of all the whole numbers (integers) inclusive between 1 and the number itself. A factorial is indicated by the symbol '!'. Thus 6! = 1 × 2 × 3 × 4 × 5 × 6 = 720. Factorial zero, 0!, is defined as 1.

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factory farming

intensive rearing of poultry or other animals for food. These are usually fed on high-protein foodstuffs in confined quarters. Chickens for eggs and meat, and calves for veal are commonly factory farmed. Some countries restrict the use of antibiotics and growth hormones as aids to factory farming because they can persist in the flesh of the animals after they are slaughtered. The emphasis is on productive yield rather than animal welfare, so conditions for the animals are often very poor. For this reason, many people object to factory farming on moral as well as health grounds.

Egg-laying hens are housed in 'batteries' of cages arranged in long rows. If caged singly, they lay fewer eggs, so there are often four to a cage with a floor area of only 2,400 sq cm/372 sq in. In the course of a year, battery hens average 261 eggs each, whereas for free-range chickens the figure is 199.

European Union's agriculture ministers agreed in June 1999 to end all battery egg production across the EU from 2012.

faeces

remains of food and other waste material eliminated from the digestive tract of animals by way of the anus. Faeces consist of quantities of fibrous material, bacteria and other micro-organisms, rubbed-off lining of the digestive tract, bile fluids, undigested food, minerals, and water.

Fahrenheit, Gabriel Daniel (1686-1736)

Polish-born Dutch physicist who invented the first accurate thermometer in 1724 and devised the Fahrenheit temperature scale. Using his thermometer, Fahrenheit was able to determine the boiling points of liquids and found that they vary with atmospheric pressure.

Fahrenheit scale

temperature scale invented in 1714 by Gabriel Fahrenheit that was commonly used in English-speaking countries until the 1970s, after which the Celsius scale was generally adopted, in line with the rest of the world. In the Fahrenheit scale, intervals are measured in degrees (°F); °F = (°C × 9/5) + 32.

Fahrenheit took as the zero point the lowest temperature he could achieve anywhere in the laboratory, and, as the other fixed point, body temperature, which he set at 96°F. On this scale, water freezes at 32°F and boils at 212°F.

fainting

sudden, temporary loss of consciousness caused by reduced blood supply to the brain. It may be due to emotional shock or physical factors, such as pooling of blood in the legs from standing still for long periods.

falcon

any bird of prey of the genus *Falco*, family Falconidae, order Falconiformes. Falcons are the smallest of the hawks (15-60 cm/6-24 in). They have short curved beaks with one tooth in the upper mandible; the wings are long and pointed, and the toes elongated. They nest in high places and kill their prey on the wing by 'stooping' (swooping down at high speed). They include the peregrine and kestrel.

The peregrine falcon *F. peregrinus*, up to about 50 cm/1.8 ft long, has become re-established in North America and Britain after near extinction (by pesticides, gamekeepers, and egg collectors). When stooping on its intended prey, it is the fastest creature in the world, timed at 240 kph/150 mph.

Fallopian tube

or oviduct

in mammals, one of two tubes that carry eggs from the ovaries to the uterus. An egg is fertilized by sperm in the Fallopian tubes, which are lined with cells whose cilia move the egg towards the uterus.

Fallopius, Gabriel (1523-1562)

Italian Gabriele Falloppio

Italian anatomist who discovered the Fallopian tubes, which he described as 'trumpets of the uterus', and named the vagina. As well as the reproductive system, he studied the anatomy of the brain and eyes, and gave the first accurate description of the inner ear.

fallout

harmful radioactive material released into the atmosphere in the debris of a nuclear explosion and descending to the surface of the Earth. Such material can enter the food chain, cause radiation sickness, and last for hundreds of thousands of years (see half-life).

fallow

land ploughed and tilled, but left unsown for a season to allow it to recuperate. In Europe, it is associated with the medieval three-field system. It is used in some modern crop rotations and in countries that do not have access to fertilizers to maintain soil fertility.

fallow deer

one of two species of deer. Fallow deer are characterized by the expansion of the upper part of their antlers in palmate form. Usually they stand about 1 m/3.3 ft high, and have small heads, large ears, and rather long tails. In colour they are fawn, with a number of large white spots, or they may be yellowish-brown or, more rarely, dark brown.

The commonest species *Dama dama* is a native of North Africa and the countries bordering the Mediterranean, but was introduced into Britain at an early period. *D. mesopotamica* is a native of the mountains of Iran.

classification

The fallow deer is in genus *Dama* in the Cervidae family of the mammalian order Artiodactyla.

false-colour imagery

graphic technique that displays images in false (not true-to-life) colours so as to enhance certain features. It is widely used in displaying electronic images taken by spacecraft; for example, Earth-survey satellites such as *Landsat*. Any colours can be selected by a computer processing the received data.

falsificationism

in philosophy of science, the belief that a scientific theory must be under constant scrutiny and that its merit lies only in how well it stands up to rigorous testing. It was first expounded by philosopher Karl Popper in his *Logic of Scientific Discovery* (1934).

Such thinking also implies that a theory can be held to be scientific only if it makes predictions that are clearly testable. Critics of this belief acknowledge the strict logic of this process, but doubt whether the whole of scientific method can be subsumed into so narrow a programme. Philosophers and historians such as Thomas Kuhn and Paul Feyerabend have attempted to use the history of science to show that scientific progress has resulted from a more complicated methodology than Popper suggests.

family

in biological classification, a group of related genera (see genus). Family names are not printed in italic (unlike genus and species names), and by convention they all have the ending -idae (animals) or -aceae (plants and fungi). For example, the genera of hummingbirds are grouped in the hummingbird family, Trochilidae. Related families are grouped together in an order.

family planning

deliberate control of human population growth by various means (contraceptives, sterilization, and abortion), in order to reduce the birth rate. The majority of developing nations now have governments that support some sort of family planning programme.

Since the early 1950s India has taken the lead among developing nations to control its population growth, with government-sponsored programmes. However, in April 2001, it became the second country after China to have a population of over 1 billion. In China, there is a one-child policy, and couples lose large financial benefits if they have a second child.

The average number of pregnancies per woman is two in the industrialized countries, where 71% use birth control, compared with six or seven pregnancies per woman in the developing world.

family planning, China

(Image © Corel)

Poster publicizing the government's one family one child policy in Chengdu, Sichuan Province, China. Under this policy families are offered incentives to have only one child in order to slow the population increase.

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farad

symbol F

SI unit of electrical capacitance (how much electric charge a capacitor can store for a given voltage). One farad is a capacitance of one coulomb per volt. For practical purposes the microfarad (one millionth of a farad, symbol μF) is more commonly used.

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faraday

unit of electrical charge equal to the charge on one mole of electrons. Its value is 9.648×10^4 coulombs.

Faraday, Michael (1791-1867)

English chemist and physicist. In 1821 he began experimenting with electromagnetism, and discovered electromagnetic induction (the production of a continuous supply of electricity using magnetic fields). He made the first dynamo, the first electric motor, the first transformer, and developed the first electric generator. He also pointed out that the energy of a magnet is in the field around it and not in the magnet itself. In chemistry, Faraday isolated benzene from gas oils, demonstrated the use of platinum as a catalyst, and developed the laws of electrolysis in 1834.

Faraday created the technique and apparatus used for electrolysis (the production of chemical changes by passing electric current through an aqueous solution), and coined the terms anode, cathode, cation, anion, electrode, and electrolyte.

In 1846 he carried out work on polarized light. Using powerful electromagnetism Faraday was able to show that the electromagnetic field could change the plane of polarization in the light to rotate. The greater the strength of the magnetic field, the greater the angle of rotation in the plane of polarization. Faraday also worked on the different responses of substances to a magnetic field, describing objects that were attracted as paramagnetic, and objects that were repulsed as diamagnetic.

Faraday

(Image © Billie Love)

English physicist and chemist Michael Faraday, one of the most prominent experimentalists of the 19th century. Largely self-educated, Faraday is best known for his discoveries about the relationship between electricity and magnetism, published in the series *Experimental Researches on Electricity* (1839-55), which formed the basis of the theory of electromagnetic behaviour.

Faraday's constant

symbol F

constant representing the electric charge carried on one mole of electrons. It is found by multiplying Avogadro's constant by the charge carried on a single electron, and is equal to 9.648×10^4 coulombs per mole.

One **faraday** is this constant used as a unit. The constant is used to calculate the electric charge needed to discharge a particular quantity of ions during electrolysis.

Faraday's laws

three laws of electromagnetic induction, and two laws of electrolysis, all proposed originally by English physicist Michael Faraday. The laws of induction are: (1) a changing magnetic field induces an electromagnetic force in a conductor; (2) the electromagnetic force is proportional to the rate of change of the field; and (3) the direction of the induced electromagnetic force depends on the orientation of the field. The laws of electrolysis are: (1) the amount of chemical change during electrolysis is proportional to the charge passing through the liquid; and (2) the amount of chemical change produced in a substance by a given amount of electricity is proportional to the electrochemical equivalent of that substance.

farming

business of cultivating land. Different approaches to farming can be classified in several ways: according to crop or animal combinations, for example arable farming or pastoral farming; according to the dominant product group, for example dairy farming or market gardening; or according to the overall approach or techniques used, for example organic farming or shifting cultivation.

farming

(Image © Research Machines plc)

Farming near Ayvalik, on the Aegean coast of Turkey. Approximately half of Turkey's land area is used for agricultural purposes, and the most productive parts of this land lie along the Aegean coast. Here, small farmers and large landholders produce high-value crops such as cotton, olives, grapes, and raisins.

farming

(Image © Research Machines plc)

Farmers, eastern Turkey. Half of the land area in Turkey is devoted to agriculture, and most farmers cultivate fairly small plots of land of less than 25 acres/11 ha. Produce includes grapes, olives, citrus fruits, tobacco, and cotton, as well as grains such as wheat, barley, and corn.

Farm Income in the UK

Source: Department for Environment, Food, and Rural Affairs (DEFRA) © Crown copyright

Data are absolute levels of cash income per farm at current prices.

Farm type[1]	Cash income (£/farm)						
	1998/99	1999/00	2000/01	2001/02[2]	2002/03	2003/04	2004/05
Dairy	30,200	28,200	28,700	49,800	31,600	42,700	45,000
Cattle and sheep (hill)	19,200	16,300	17,700	19,300	24,300	23,000	24,100
Cattle and sheep (lowland)	12,700	12,500	11,200	12,600	17,000	15,800	15,800
Cereals	45,600	51,800	38,700	39,000	45,400	63,400	54,200
General cropping	70,900	50,800	53,900	59,200	55,200	89,000	80,900
Specialist Pigs	-5,300	19,400	52,300	47,000	42,600	47,600	46,400
Specialist Poultry	50,400	27,200	45,300	48,700	110,300	67,200	103,400
Mixed	40,400	36,000	33,300	34,400	28,900	43,200	43,400
Horticulture	38,300	35,800	37,000	50,100	50,900	56,500	53,600
All types	36,700	33,800	31,900	39,600	37,300	48,700	46,700

[1] Full-time farms only.

[2] Excluding farms subjected to compulsory foot-and-mouth disease cull.

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farsightedness

alternative name for hypermetropia, a vision defect.

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fast breeder

or breeder reactor

alternative name for fast reactor, a type of nuclear reactor.

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fasting

the practice of voluntarily going without food. It can be undertaken as a religious observance, a sign of mourning, a political protest (hunger strike), or for slimming purposes.

Fasting or abstinence from certain types of food or beverages occurs in most religious traditions. It is seen as an act of self-discipline that increases spiritual awareness by lessening dependence on the material world. In the Roman Catholic Church, fasting is seen as a penitential rite, a means to express repentance for sin. The most commonly observed Christian fasting is in Lent, from Ash Wednesday to Easter Sunday, and recalls the 40 days Jesus spent in the wilderness. Roman Catholics and Orthodox Christians usually fast before taking Communion and monastic communities observe regular weekly fasts. Devout Muslims go without food or water between sunrise and sunset during the month of Ramadan. Jews fast for Yom Kippur (the Day of Atonement), and before several other festivals. Many devout Hindus observe a weekly day of partial or total fast.

Total abstinence from food for a limited period is prescribed by some naturopaths to eliminate body toxins or make available for recuperative purposes the energy normally used by the digestive system. Prolonged fasting can be dangerous. The liver breaks up its fat stores, releasing harmful by-products called ketones, which results in a condition called ketosis, which develops within three days. An early symptom is a smell of pear drops on the breath. Other symptoms include nausea, vomiting, fatigue, dizziness, severe depression, and irritability. Eventually, the muscles and other body tissues become wasted, and death results.

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fast reactor

or fast breeder reactor

nuclear reactor that makes use of fast neutrons to bring about fission. Unlike other reactors used by the nuclear-power industry, it has little or no moderator, to slow down neutrons. The reactor core is surrounded by a 'blanket' of uranium carbide. During operation, some of this uranium is converted into plutonium, which can be extracted and later used as fuel.

Fast breeder reactors can extract about 60 times the amount of energy from uranium that thermal reactors do. In the 1950s, when uranium stocks were thought to be dwindling, the fast breeder was considered to be the reactor of the future. Now, however, when new uranium reserves have been found and because of various technical difficulties in their construction, development of the fast breeder has slowed in most parts of the world.

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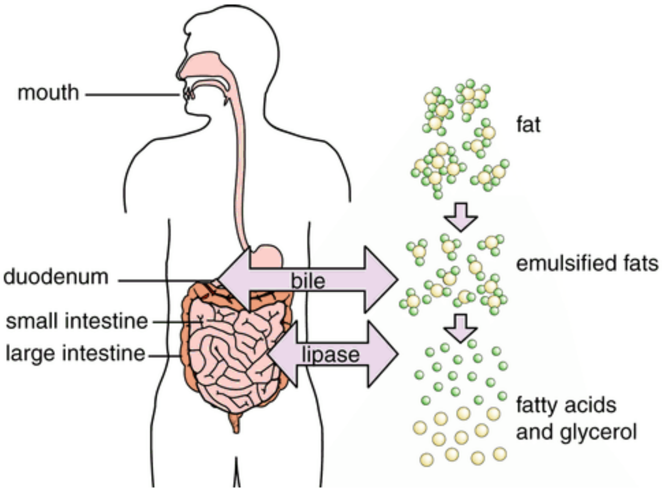
fat

in the broadest sense, a mixture of lipids - chiefly triglycerides (lipids containing three fatty acid molecules linked to a molecule of glycerol). More specifically, the term refers to a lipid mixture that is solid at room temperature (20°C/68°F); lipid mixtures that are liquid at room temperature are called oils. The higher the proportion of saturated fatty acids in a mixture, the harder the fat. Fats and oils (lipids) are compounds made up of glycerol and fatty acids. Fats are insoluble in water. Boiling fats in strong alkali forms soaps (saponification).

Fats are essential constituents of food for many animals, with a calorific value twice that of carbohydrates. However, eating too much fat, especially fat of animal origin, has been linked with heart disease in humans, where excess fat is deposited in the walls of arteries and may cause heart attacks. In many animals and plants, excess carbohydrates and proteins are converted into fats for storage. Mammals and other vertebrates store fats in specialized connective tissues (adipose tissues), which not only act as energy reserves but also insulate the body and cushion its organs.

As a nutrient, fat serves five purposes: it is a source of energy (9 kcal/g); makes the diet palatable; provides basic building blocks for cell structure; provides essential fatty acids (linoleic and linolenic); and acts as a carrier for fat-soluble vitamins (A, D, E, and K). Indeed, fatty tissue in the body stores fat-soluble vitamins. Foods rich in fat are butter, lard, and margarine. Products high in monounsaturated or polyunsaturated fats are thought to be less likely to contribute to cardiovascular disease.

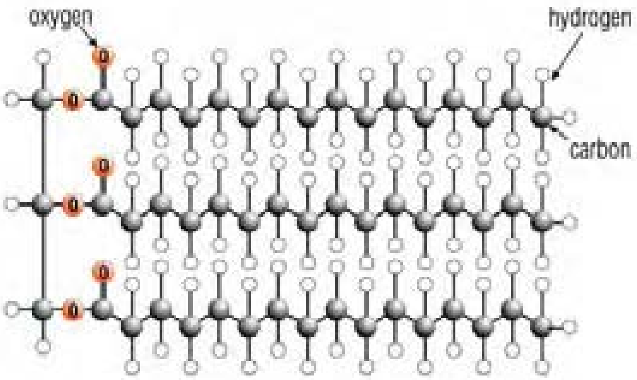
fat



(Image © Research Machines plc)

The digestion of fat. Fat is broken down into fatty acids and glycerol by bile (secreted by the gall bladder) and the enzyme lipase (secreted by the small intestine).

fat



(Image © Research Machines plc)

The molecular structure of typical fat. The molecule consists of three fatty acid molecules linked to a molecule of glycerol.

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fat hen

plant belonging to the goosefoot family, widespread in temperate regions. It grows up to 1 m/3 ft tall and has lance- or diamond-shaped leaves and compact heads of small inconspicuous flowers. Now considered a weed, fat hen was once valued for its fatty seeds and edible leaves. (*Chenopodium album*, family Chenopodiaceae.)

Skylarks favour the plant fat hen, and rely on its seeds during autumn and winter. UK ecologists, in autumn 2000, concluded that herbicide-resistant GM crops, which would lead to the wiping out of fat hen on farm land, would also lead to a reduction of 80% in the number of skylarks, whose numbers have already been reduced by half since the 1960s.

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fathom

(Anglo-Saxon faethm 'to embrace')

in mining, seafaring, and handling timber, a unit of depth measurement (1.83 m/6 ft) used prior to metrication; it approximates to the distance between an adult man's hands when the arms are outstretched.

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fatigue

in muscle, reduced response brought about by the accumulation of lactic acid in muscle tissue due to excessive cellular activity.

fatigue

in medicine, general weariness, possibly due to lack of sleep, too little exercise, and poor nutrition. It is also a symptom of certain diseases, such as anaemia, hypothyroidism, or myasthenia gravis. See also chronic fatigue syndrome.

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fatty acid

or carboxylic acid

organic compound consisting of a hydrocarbon chain of an even number of carbon atoms, with a carboxyl group (—COOH) at one end. The covalent bonds between the carbon atoms may be single or double; where a double bond occurs the carbon atoms concerned carry one instead of two hydrogen atoms. Chains with only single bonds have all the hydrogen they can carry, so they are said to be saturated with hydrogen. Chains with one or more double bonds are said to be unsaturated (see polyunsaturate). Fatty acids are produced in the small intestine when fat is digested.

Saturated fatty acids include palmitic and stearic acids; unsaturated fatty acids include oleic (one double bond), linoleic (two double bonds), and linolenic (three double bonds). Linoleic acid accounts for more than one third of some margarines. Supermarket brands that say they are high in polyunsaturates may contain as much as 39%. Fatty acids are generally found combined with glycerol in lipids such as triglycerides.

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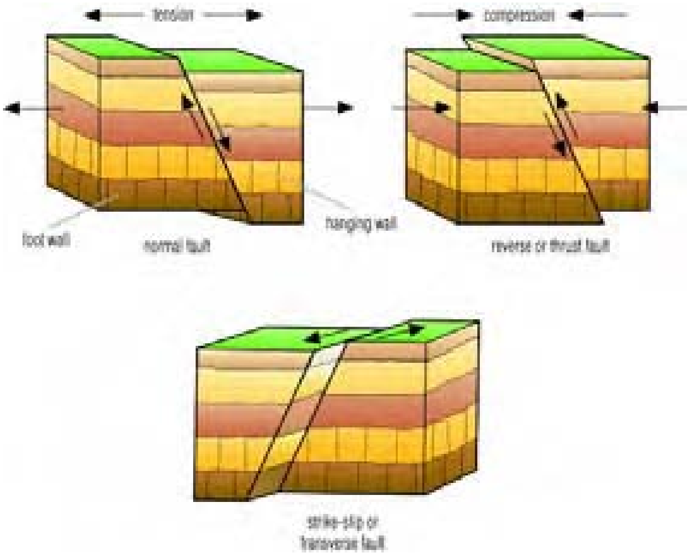
fault

fracture in the Earth's crust, on either side of which rocks have moved past each other. Faults may occur where rocks are being pushed together (compression) or pulled apart (tension) by plate tectonics, movements of the plates of the Earth's crust. When large forces build up quickly in rocks, they become brittle and break; folds result from a more gradual compression. Faults involve displacements, or offsets, ranging from the microscopic scale to hundreds of kilometres. Large offsets along a fault are the result of the accumulation of many small movements (metres or less) over long periods of time. Large movements cause detectable earthquakes, such as those experienced along the San Andreas Fault in California, USA.

Faults produce lines of weakness on the Earth's surface (along their strike) that are often exploited by processes of weathering and erosion. Coastal caves and geos (narrow inlets) often form along faults and, on a larger scale, rivers may follow the line of a fault. The Great Glen Fault in Scotland is an excellent example of a fault, and Loch Ness on this fault is an example of a fault-line feature.

fault



(Image © Research Machines plc)

Faults are caused by the movement of rock layers, producing such features as block mountains and rift valleys. A normal fault is caused by a tension or stretching force acting in the rock layers. A reverse fault is caused by compression forces. Faults can continue to move for thousands or millions of years.

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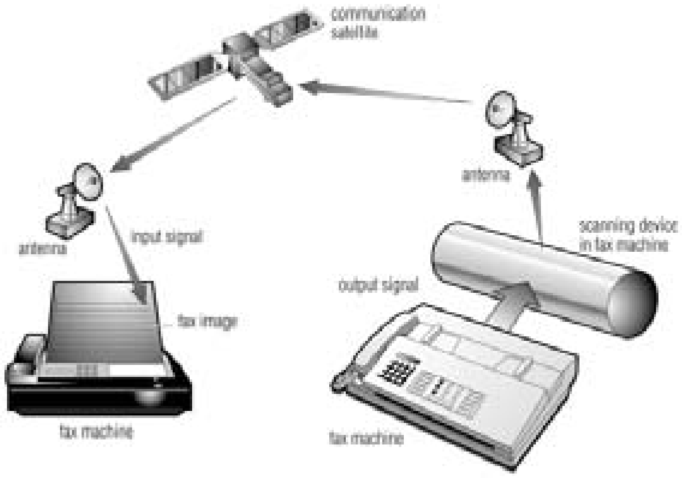
fax

or facsimile transmission or telefax

transmission of images over a telecommunications link, usually the telephone network. When placed on a fax machine, the original image is scanned by a transmitting device and converted into coded signals, which travel via the telephone lines to the receiving fax machine, where an image is created that is a copy of the original. Photographs as well as printed text and drawings can be sent.

fax



(Image © Research Machines plc)

How facsimile messages are transmitted from one remote fax machine to another, with the aid of communications satellite technology.

feather

rigid outgrowth of the outer layer of the skin of birds, made of the protein keratin. Feathers provide insulation and facilitate flight. There are several types, including long quill feathers on the wings and tail, fluffy down feathers for retaining body heat, and contour feathers covering the body. The colouring of feathers is often important in camouflage or in courtship and other displays. Feathers are normally replaced at least once a year.

There is an enormous variation between species in the number of feathers; for example a whistling swan has over 25,000 contour feathers, whereas a ruby-throated hummingbird has less than 950.

Feathers generally consist of two main parts, axis and barbs, the former of which is divided into the quill, which is bare and hollow, and the shaft, which bears the barbs. The quill is embedded in the skin, and has at its base a small hole through which the nourishment passes during the growth of the feather. The barbs which constitute the vane are lath-shaped and taper to a point, and each one supports a series of outgrowths known as barbules, so that each barb is like a tiny feather. Adjacent barbs are linked to each other by hooks on the barbules.

feather star

any of an unattached, free-swimming group of sea lilies, order Comatulida. The arms are branched into numerous projections (hence 'feather' star), and grow from a small cup-shaped body. Below the body are appendages that can hold on to a surface, but the feather star is not permanently attached.

fecundity

potential rate at which an organism reproduces, as distinct from its ability to reproduce (fertility). In vertebrates, it is usually measured as the number of offspring produced by a female each year. Specifically, it refers to the quantity of gametes (usually eggs) produced per female over a given time.

feedback

general principle whereby the results produced in an ongoing reaction become factors in modifying or changing the reaction; it is the principle used in self-regulating control systems, from a simple thermostat and steam-engine governor to automatic computer-controlled machine tools. A fully computerized control system, in which there is no operator intervention, is called a **closed-loop feedback** system. A system that also responds to control signals from an operator is called an **open-loop feedback** system.

In self-regulating systems, information about what *is* happening in a system (such as level of temperature, engine speed, or size of workpiece) is fed back to a controlling device, which compares it with what *should* be happening. If the two are different, the device takes suitable action (such as switching on a heater, allowing more steam to the engine, or resetting the tools). The idea that the Earth is a self-regulating system, with feedback operating to keep nature in balance, is a central feature of the Gaia hypothesis.

Fehling's test

chemical test to determine whether an organic substance is a reducing agent (substance that donates electrons to other substances in a chemical reaction). It is usually used to detect reducing sugars (monosaccharides, such as glucose, and the disaccharides maltose and lactose) and aldehydes.

If the test substance is heated with a freshly prepared solution containing copper(II) sulphate, sodium hydroxide and sodium potassium tartrate, the production of a brick-red precipitate indicates the presence of a reducing agent.

The test was devised by German chemist Herman von Fehling.

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feldspar

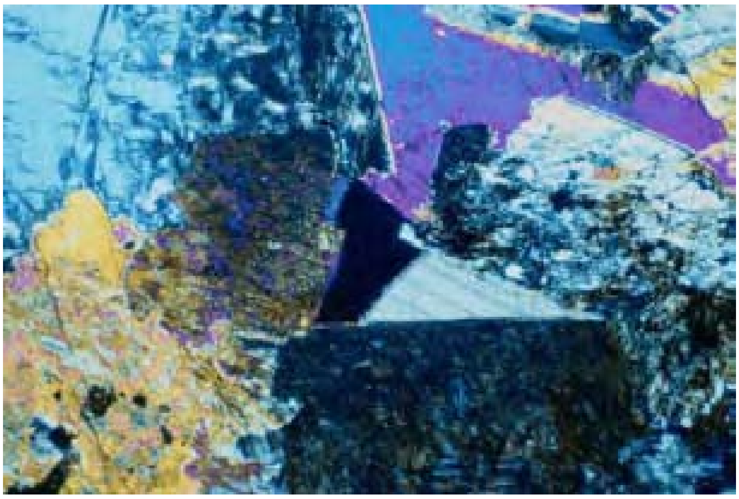
any of a group of silicate minerals. Feldspars are the most abundant mineral type in the Earth's crust. They are the chief constituents of igneous rock and are present in most metamorphic and sedimentary rocks. All feldspars contain silicon, aluminium, and oxygen, linked together to form a framework. Spaces within this framework structure are occupied by sodium, potassium, calcium, or occasionally barium, in various proportions. Feldspars form white, grey, or pink crystals and rank 6 on the Mohs scale of hardness.

The four extreme compositions of feldspar are represented by the minerals **orthoclase**, $KAlSi_3O_8$; **albite**, $NaAlSi_3O_8$; **anorthite**, $CaAl_2Si_2O_8$; and **celsian**, $BaAl_2Si_2O_8$.

Plagioclase feldspars contain variable amounts of sodium (as in albite) and calcium (as in anorthite) with a negligible potassium content.
Alkali feldspars (including orthoclase) have a high potassium content, less sodium, and little calcium.

The type known as moonstone has a pearl-like effect and is used in jewellery. Approximately 4,000 tonnes of feldspar are used in the ceramics industry annually.

feldspar



(Image © Corel)

Close-up of a feldspar mineral. Feldspars are a group of rock-forming minerals that constitute almost 60% of the earth's crust.

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feldspathoid

any of a group of silicate minerals resembling feldspars but containing less silica. Examples are nepheline ($NaAlSiO_4$ with a little potassium) and leucite ($KAlSi_2O_6$). Feldspathoids occur in igneous rocks that have relatively high proportions of sodium and potassium. Such rocks may also contain alkali feldspar, but they do not generally contain quartz because any free silica would have combined with the feldspathoid to produce more feldspar instead.

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felsic rock

a plutonic rock composed chiefly of light-coloured minerals, such as quartz, feldspar, and mica. It is derived from feldspar, lenad (meaning feldspathoid), and silica. The term felsic also applies to light-coloured minerals as a group, especially quartz, feldspar, and feldspathoids.

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femur

or thigh-bone

also the upper bone in the hind limb of a four-limbed vertebrate.

---

fennec

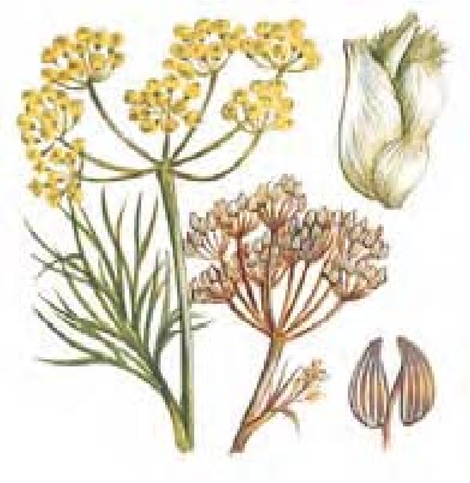
small nocturnal desert foxFennecus zerda found in North Africa and Arabia. It has a head and body only 40 cm/1.3 ft long, and its enormous ears act as radiators to lose excess heat. It eats insects and small animals.

---

fennel

any of several varieties of a perennial plant with feathery green leaves, belonging to the carrot family. Fennels have an aniseed (liquorice) flavour, and the leaves and seeds are used in seasoning. The thickened leafstalks of sweet fennel (*F. vulgare dulce*) are eaten as a vegetable. (*Foeniculum vulgare*, family Umbelliferae.)

fennel



(Image © Research Machines plc)

Fennel is a native of the Mediterranean shores. It is one of the largest herbs, growing to a height of 1.5 m/5 ft.

Fenton, Roger (1819-1869)

English photographer. He is best known for his comprehensive documentation of the Crimean War in 1855. He was a founder member of the Photographic Society (later the Royal Photographic Society) in London in 1853 but completely gave up photography in 1860.

Fermat, Pierre de (1601-1665)

French mathematician who, with Blaise Pascal, founded the theory of probability and the modern theory of numbers. Fermat also made contributions to analytical geometry. In 1657 Fermat published a series of problems as challenges to other mathematicians, in the form of theorems to be proved.

Fermat's last theorem states that equations of the form $x^n + y^n = z^n$ where x, y, z, and n are all integers have no solutions if $n > 2$. Fermat scribbled the theorem in the margin of a mathematics textbook and noted that he could have shown it to be true had he enough space in which to write the proof. The theorem remained unproven for 300 years (and therefore, strictly speaking, constituted a conjecture rather than a theorem). In 1993, Andrew Wiles, the English mathematician of Princeton University, USA, announced a proof; this turned out to be premature, but he put forward a revised proof in 1994. Fermat's last theorem was finally laid to rest in June 1997 when Wiles collected the Wolfskehl prize (the legacy bequeathed in the 19th century for the problem's solution).

Fermat, Pierre de

Go to site

Extensive biography of the French mathematical genius Pierre de Fermat. The site contains a description of his contributions to mathematics, including his last theorem and also much of his other works which were of more direct value to mathematics. Also included are the first page of his book *Ad Locos Planos et Solidos Isagoge* and an extract from his book *Maxima et Minima* (1679). Several references for further reading are also listed, and the Web site also features several portraits of Fermat.

Fermat's Last Theorem

Go to site

Account of Fermat's last theorem and of the many attempts made to prove it. It is extensively hyperlinked to related mathematicians and also includes a list of 17 references for further reading.

Fermat's principle

in physics, the principle that a ray of light, or other radiation, moves between two points along the path that takes the minimum time. The principle is named after French mathematician Pierre de Fermat, who used it to deduce the laws of reflection and refraction.

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fermentation

breakdown of sugars by bacteria and yeasts using a method of respiration without oxygen (anaerobic). The enzymes in yeast break down glucose to give two products: ethanol (alcohol) and carbon dioxide. Fermentation processes have long been utilized in baking bread, making beer and wine, and producing cheese, yogurt, soy sauce, and many other foodstuffs.

In bread baking, the bubbles of carbon dioxide trapped in the dough make the bread rise. In the brewing process, complex sugars, such as sucrose, are first broken down by yeast into simple sugars, such as glucose. Glucose is then further decomposed into ethanol and carbon dioxide. The ethanol produced is the alcohol in alcoholic drinks, such as beer and wine; the carbon dioxide puts bubbles into beers and champagne.

The word equation for fermentation is: glucose → ethanol + carbon dioxide. The symbol equation is:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

Many antibiotics are produced by fermentation; it is one of the processes that can cause food spoilage.

Fermi, Enrico (1901-1954)

Italian-born US physicist who was awarded the Nobel Prize for Physics in 1938 for his proof of the existence of new radioactive elements produced by bombardment with neutrons, and his discovery of nuclear reactions produced by low-energy neutrons. This research was the basis for studies leading to the atomic bomb and nuclear energy. Fermi built the first nuclear reactor in 1942 at Chicago University and later took part in the Manhattan Project to construct an atom bomb. His theoretical work included the study of the weak nuclear force, one of the fundamental forces of nature, and beta decay.

neutron bombardment and the Nobel Prize

Following the work of the Joliot-Curies, who discovered artificial radioactivity in 1934 using alpha particle bombardment, Fermi began producing new radioactive isotopes by neutron bombardment. Unlike the alpha particle, which is positively charged, the neutron is uncharged. Fermi realized that less energy would be wasted when a bombarding neutron encounters a positively charged target nucleus. He also found that a block of paraffin wax or a jacket of water around the neutron source produced slow, or 'thermal', neutrons. Slow neutrons are more effective at producing artificial radioactive elements because they remain longer near the target nucleus and have a greater chance of being absorbed. He did, however, misinterpret the results of experiments involving neutron bombardment of uranium, failing to recognize that nuclear fission had occurred. Instead, he maintained that the bombardment produced two new transuranic elements. It was left to Lise Meitner and Otto Frisch to explain nuclear fission in 1938.

nuclear reactors and the atomic bomb

In the USA, Fermi continued the work on the fission of uranium (initiated by neutrons) by building the first nuclear reactor, then called an **atomic pile**, because it had a moderator consisting of a pile of purified graphite blocks (to slow the neutrons) with holes drilled in them to take rods of enriched uranium. Other neutron-absorbing rods of cadmium, called control rods, could be lowered into or withdrawn from the pile to limit the number of slow neutrons available to initiate the fission of uranium. The reactor was built on the squash court of Chicago University. On the afternoon of 2 December 1942, the control rods were withdrawn for the first time and a self-sustaining nuclear chain reaction began. Two years later, the USA, through a team led by Arthur Compton and Fermi, had constructed an atomic bomb, in which the same reaction occurred but was uncontrolled, resulting in a nuclear explosion.

beta decay and the neutrino

Fermi's experimental work on beta decay in radioactive materials provided further evidence for the existence of the neutrino, predicted by Austrian physicist Wolfgang Pauli.

Fermilab

acronym for FERMI National Accelerator LABoratory

US centre for particle physics at Batavia, Illinois, near Chicago. It is named after Italian-born US physicist Enrico Fermi. Fermilab was opened in 1972, and is the home of the Tevatron, which will be the world's most powerful particle accelerator until the inauguration of the Large Hadron Collider (LHC).

The Tevatron, which began operation in 1983, is 6.4 km/4 mi in circumference and was originally called the Energy Doubler. It was constructed using 1,000 superconducting magnets and incorporated the largest cooling system ever built to keep these magnets at their low operational temperatures. This cryogenic system was designated an International Historic Mechanical Engineering Landmark by The American Society of Mechanical Engineers.

In 1998, Fermilab added a 3.2 km/2 mi Main Injector accelerator as part of a decade-long programme of upgrades in preparation for Collider Run II, the next generation of particle experiments at the Tevatron. Collider Run II began in March 2003.

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fermion

in physics, a subatomic particle whose spin can only take values that are half-odd-integers, such as 1/2 or 3/2. Fermions may be classified as leptons - particles that do not experience the strong nuclear force, such as the electron - and hadrons - particles that are subject to the strong nuclear force, such as the proton, neutron, mesons, and so on. All elementary particles are either fermions or bosons.

The exclusion principle, formulated by Austrian-US physicist Wolfgang Pauli in 1925, asserts that no two fermions in the same system (such as an atom) can possess the same position, energy state, spin, or other quantized property.

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fermium

chemical symbol Fm

synthesized, radioactive, metallic element of the actinide series, atomic number 100, relative atomic mass 257.10. Ten isotopes are known, the longest-lived of which, Fm-257, has a half-life of 80 days. Fermium has been produced only in minute quantities in particle accelerators.

It was discovered in 1952 in the debris of the first thermonuclear explosion. The element was named in 1955 in honour of Italian-US physicist Enrico Fermi.

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fern

plant of the class Filicineae, related to gymnosperms and angiosperms; however, ferns reproduce by spores and not seed. Most are perennial, spreading by low-growing roots. The leaves, known as fronds, vary widely in size and shape. Some taller types, such as tree-ferns, grow in the tropics. There are over 7,000 species.

Common forms include polypody (*Polypodium*); shield fern (*Polystichum*); maidenhair (*Adiantum capillus-veneris*); and bracken (*Pteridium*), a common weed.

---

ferret

domesticated variety of the Old World polecat.

About 35 cm/1.2 ft long, it usually has yellowish-white fur and pink eyes, but may be the dark brown colour of a wild polecat.

Ferrets may breed with wild polecats. They have been used since ancient times to hunt rabbits and rats.

Ferret Central

Go to site

Huge source of information on ferrets. There is an interesting account of people's long relationship with this domesticated polecat. There is comprehensive advice on all aspects of keeping a ferret (including several articles on litter training). Other contents include photos, latest updates of ferret events around the world, and links to the World Ferret Union and other ferret sites.

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ferrimagnetism

form of magnetism in which adjacent molecular magnets are aligned anti-parallel, but have unequal strength, producing a strong overall magnetization. Ferrimagnetism is found in certain inorganic substances, such as ferrites.

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ferrite

ceramic ferrimagnetic material. Ferrites are iron oxides to which small quantities of transition metal oxides (such as cobalt and nickel oxides) have been added. They are used in transformer cores, radio antennae, and, formerly, in computer memories.

ferro-alloy

alloy of iron with a high proportion of elements such as manganese, silicon, chromium, and molybdenum. Ferro-alloys are used in the manufacture of alloy steels. Each alloy is generally named after the added metal - for example, ferrochromium.

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ferroelectric material

ceramic dielectric material that, like ferromagnetic materials, has a domain structure that makes it exhibit magnetism and usually the piezoelectric effect. An example is Rochelle salt (potassium sodium tartrate tetrahydrate, $KNaC_4H_4O_6.4H_2O$).

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ferromagnetism

form of magnetism that can be acquired in an external magnetic field and usually retained in its absence, so that ferromagnetic materials are used to make permanent magnets. A ferromagnetic material may therefore be said to have a high magnetic permeability and susceptibility (which depends upon temperature). Examples are iron, cobalt, nickel, and their alloys.

Ultimately, ferromagnetism is caused by spinning electrons in the atoms of the material, which act as tiny weak magnets. They align parallel to each other within small regions of the material to form domains, or areas of stronger magnetism. In an unmagnetized material, the domains are aligned at random so there is no overall magnetic effect. If a magnetic field is applied to that material, the domains align to point in the same direction, producing a strong overall magnetic effect. Permanent magnetism arises if the domains remain aligned after the external field is removed. Ferromagnetic materials exhibit hysteresis.

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fertility

organism's ability to reproduce, as distinct from the rate at which it reproduces (fecundity). Individuals that can reproduce are fertile. Individuals that cannot reproduce are infertile. Individuals become infertile (unable to reproduce) when they cannot generate gametes (eggs or sperm) or when their gametes cannot yield a viable embryo after fertilization. Common causes of infertility are: low sperm numbers in the male; blocked oviducts; infrequent ovulation (release of gamete) in the female; consequence of infections in the female reproductive tract; and genetic makeup.

---

fertility drug

any of a range of drugs taken to increase a female's fertility, developed in Sweden in the mid-1950s. They increase the chances of a multiple birth.

The most familiar is gonadotrophin, which is made from hormone extracts taken from the human pituitary gland: follicle-stimulating hormone and luteinizing hormone. It stimulates ovulation in women.

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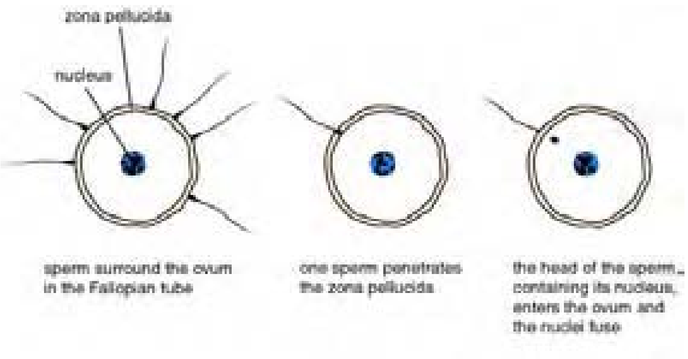
fertilization

in sexual reproduction, the union of two gametes (sex cells, often called egg or ovum, and sperm) to produce a zygote, which combines the genetic material contributed by each parent. In self-fertilization the male and female gametes come from the same plant; in cross-fertilization they come from different plants. Self-fertilization rarely occurs in animals; usually even hermaphrodite animals cross-fertilize each other.

The fusion of gametes combines the genetic material contributed by each parent. To avoid doubling the amount of inherited information every generation, each gamete contains only half the amount of inherited information - it is haploid. This is achieved by halving the number of chromosomes when gametes are being produced. When the gametes fuse the full amount of information is restored (diploid state). Gametes are therefore produced by a specialized form of cell division, known as meiosis, which is only used for this purpose. This type of cell division has ways of mixing genes before the gametes are produced. This promotes variation (see natural selection) by producing gametes with different combinations of genes.

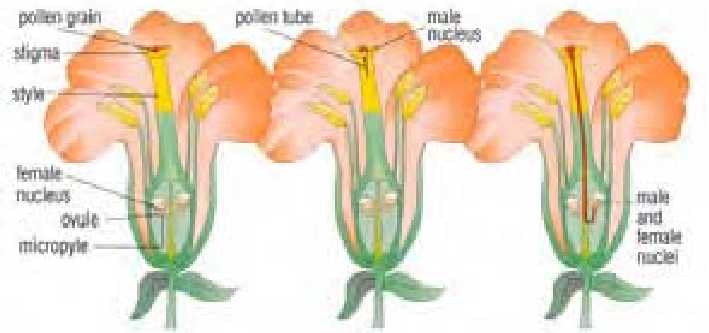
fertilization


zona pellucida
nucleus
sperm surround the ovum in the Fallopian tube
one sperm penetrates the zona pellucida
the head of the sperm, containing its nucleus, enters the ovum and the nuclei fuse

(Image © Research Machines plc)

The fertilization of an ovum by a sperm. Fertilization takes place in the Fallopian tube.

fertilization


pollen grain
stigma
style
female nucleus
ovule
micropyle
pollen tube
male nucleus
male and female nuclei

(Image © Research Machines plc)

In a flowering plant pollen grains land on the surface of the stigma, and if conditions are acceptable the pollen grain germinates, forming a pollen tube, through which the male gametes pass, entering the ovule via the micropyle in order to reach the female egg.

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fertilizer

substance containing some or all of a range of about 20 chemical elements necessary for healthy plant growth, used to compensate for the deficiencies of poor or depleted soil. Fertilizers may be organic, for example farmyard manure, composts, bonemeal, blood, and fishmeal; or inorganic (synthetic or artificial), in the form of simple compounds, mainly of nitrogen, phosphate, and potash, which have been used on a very much increased scale since 1945. Compounds of nitrogen and phosphorus are of particular importance.

Elements in the soil are taken up through the roots of plants in solution, becoming part of the compounds forming the plant. If plants are allowed to die and decompose, these compounds return to the soil as part of a natural cycle, such as the nitrogen cycle. However, when crops are harvested the cycle is interrupted, the nutrients are not returned to the soil and are used up. Fertilizers replace these elements, increasing the yield of crops and enabling the soil to be farmed year after year.

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fescue

any grass of a widely distributed group. Many are used in temperate regions for lawns and pasture. Many upland species are viviparous, producing young plantlets instead of flowers. (Genus *Festuca*, family Gramineae.)

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fetal therapy

diagnosis and treatment of conditions arising in the unborn child. While some anomalies can be diagnosed antenatally, fetal treatments are only appropriate in a few cases - mostly where the development of an organ is affected.

Fetal therapy was first used in 1963 with exchange transfusion for haemolytic disease of the newborn, once a serious problem (see also rhesus factor). Today the use of fetal therapy remains limited. Most treatments involve 'needling': introducing fine instruments through the mother's abdominal and uterine walls under ultrasound guidance. Open-womb surgery (hysterotomy) remains controversial because of the risks involved. It is available only in some centres in the USA.

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fetch-execute cycle

or processing cycle

in computing, the two-phase cycle used by the computer's central processing unit to process the instructions in a program. During the fetch phase, the next program instruction is transferred from the computer's immediate-access memory to the instruction register (memory location used to hold the instruction while it is being executed). During the execute phase, the instruction is decoded and obeyed. The process is repeated in a continuous loop.

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fetishism

in psychology, the transfer of erotic interest to an object, such as an item of clothing, whose real or fantasized presence is necessary for sexual gratification. The fetish may also be a part of the body not normally considered erogenous, such as the feet.

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fetus

stage in mammalian embryo development after fusion of gametes produced a zygote cell. The human embryo is usually termed a fetus after the eighth week of development, when the limbs and external features of the head are recognizable. The stage ends at birth.

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fever

condition of raised body temperature, usually due to infection.

Feyerabend, Paul K (1924-1994)

Austrian-born US philosopher of science, who rejected the attempt by certain philosophers (such as Karl Popper) to find a methodology applicable to all scientific research. His works include *Against Method* (1975).

Feyerabend argues that successive theories that apparently concern the same subject (for instance the motion of the planets) cannot in principle be subjected to any comparison that would aim at finding the truer explanation. According to this notion of incommensurability, there is no neutral or objective standpoint, and therefore no rational and objective way in which one particular theory can be chosen over another. Instead, scientific progress is claimed to be the result of a range of sociological factors working to promote politically convenient notions of how nature operates. In the best-selling *Against Method*, he applied an anarchic approach to the study of knowledge and espoused practices, such as the Haitian cult of voodoo, that flew in the face of conventional scientific wisdom.

Feyerabend, Paul

Go to site

Detailed critical appraisal of the life and legacy of the Austrian philosopher of science. The main events and formative influences on his work are described together with his role in the shaping of 20th-century philosophy. There is an extensive bibliography of books by and about Feyerabend and guide to other Internet resources.

Feynman, Richard P(hillips) (1918-1988)

US physicist whose work laid the foundations of quantum electrodynamics. He was awarded the Nobel Prize for Physics in 1965 for his work on the theory of radiation. He shared the award with Julian Schwinger and Sin-Itiro Tomonaga. He also contributed to many aspects of particle physics, including quark theory and the nature of the weak nuclear force.

For his work on quantum electrodynamics, he developed a simple and elegant system of **Feynman diagrams** to represent interactions between particles and how they moved from one space-time point to another. He derived rules for calculating the probability of the interaction represented by each diagram. His other major discoveries are the theory of superfluidity (frictionless flow) in liquid helium, developed in the early 1950s; his work on the weak interaction (with US physicist Murray Gell-Mann) and the strong force; and his prediction that the proton and neutron are not elementary particles. Both particles are now known to be composed of quarks.

Feynman, Richard Phillips

Go to site

Devoted to the life and contributions of physicist Richard Feynman. In addition to biographical information, you will find a list of references about Feynman and links to essays that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Feynman.

You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

Fibonacci, Leonardo (c. 1170-c. 1250)

also known as Leonardo of Pisa

Italian mathematician. He published *Liber abaci/The Book of the Calculator* in Pisa in 1202, which was instrumental in the introduction of Arabic notation into Europe. From 1960, interest increased in **Fibonacci numbers**, in their simplest form a sequence in which each number is the sum of its two predecessors (1, 1, 2, 3, 5, 8, 13, ...). They have unusual characteristics with possible applications in botany, psychology, and astronomy (for example, a more exact correspondence than is given by Bode's law to the distances between the planets and the Sun).

In 1220, Fibonacci published *Practica geometriae*, in which he used algebraic methods to solve many arithmetical and geometrical problems.

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fibre, dietary

or roughage

plant material (outer husks and peel) that cannot be digested by human digestive enzymes. It consists largely of cellulose, a carbohydrate found in plant cell walls. Fibre adds bulk to the gut contents because it can absorb water, assisting the muscular contractions that force food along the intestine. A diet low in fibre causes constipation and is believed to increase the risk of developing diverticulitis, diabetes, gall-bladder disease, and cancer of the large bowel - conditions that are rare in non-industrialized countries, where the diet contains a high proportion of unrefined cereals. It is also known as NSP (non-starch polysaccharide).

Animals are unable to produce the enzyme necessary to break down cellulose. However, cellulose still forms a necessary part of the human diet as fibre (roughage) - because it is not broken down it acts as a signal that the gut needs to contract to move the contents on. Any undigested plant material acts as fibre.

Soluble fibre consists of indigestible plant carbohydrates (such as pectins, hemicelluloses, and gums) that dissolve in water. A high proportion of the fibre in such foods as oat bran, pulses, and vegetables is of this sort. Its presence in the diet has been found to reduce the amount of cholesterol in blood over the short term, although the mechanism for its effect is disputed.

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fibreglass

glass that has been formed into fine fibres, either as long continuous filaments or as a fluffy, short-fibred glass wool. Fibreglass is heat- and fire-resistant and a good electrical insulator. It has applications in the field of fibre optics and as a strengthener for plastics in GRP (glass-reinforced plastics).

The long filament form is made by forcing molten glass through the holes of a spinneret, and is woven into textiles. Glass wool is made by blowing streams of molten glass in a jet of high-pressure steam, and is used for electrical, sound, and thermal insulation, especially for the roof space in houses.

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fibre optics

branch of physics dealing with the transmission of light and images through glass or plastic fibres known as optical fibres. Such fibres are now commonly used in both communications technology and medicine.

Fibre Optic Chronology

Go to site

Time line of the history of fibre optics. Starting with the discovery of glass in around 2500 BC and leading up to the late 1970s, this site details every discovery relevant to the history of the fibre optic cables which, among other things, make the Internet possible.

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fibrin

insoluble protein involved in blood clotting. When an injury occurs fibrin is deposited around the wound in the form of a mesh, which dries and hardens, so that bleeding stops. Fibrin is developed in the blood from a soluble protein, fibrinogen.

The conversion of fibrinogen to fibrin is the final stage in blood clotting. Platelets, a type of cell found in blood, release the enzyme thrombin when they come into contact with damaged tissue, and the formation of fibrin then occurs. Calcium, vitamin K, and a variety of enzymes called factors are also necessary for efficient blood clotting.

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fibrodysplasia ossificans progessiva

FOP

rare inherited disease that causes the body to convert muscles, ligaments, and tendons to bone if they become damaged. As the disease progresses sufferers' bones become fused, leading to eventual immobility.

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fibrositis

inflammation and overgrowth of fibrous tissue, mainly of the muscle sheaths. It is also known as muscular rheumatism. Symptoms are sudden pain and stiffness, usually relieved by analgesics and rest.

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fibula

rear lower bone in the hind leg of a vertebrate. It is paired and often fused with a smaller front bone, the tibia.

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field

in computing, a specific item of data. A field is usually part of a **record**, which in turn is part of a file.

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field

in physics, region of space in which an object exerts a force on a separate object because of certain properties they both possess. For example, there is a force of attraction between any two objects that have mass when one is within the gravitational field of the other.

Other fields of force include electric fields (caused by electric charges) and magnetic fields (caused by circulating electric currents), either of which can involve attractive or repulsive forces.

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field

enclosed area of land used for farming. Traditionally fields were measured in acres; the current unit of measurement is the hectare (2.47 acres).

In Britain, regular field systems were functioning before the Romans' arrival. The open-field system was in use at the time of the Norman Conquest. Enclosure began in the 14th century and continued into the 19th century.

In the Middle Ages, the farmland of an English rural community was often divided into three large fields (the **open-field system**). These were worked on a simple rotation basis of one year wheat, one year barley, and one year fallow. The fields were divided into individually owned strips of the width that one plough team with oxen could plough (about 20 m/66 ft). At the end of each strip would be a turning space, either a road or a **headland**. Through repeated ploughing a **ridge-and-furrow** pattern became evident. A farmer worked a number of strips, not necessarily adjacent to each other, in one field.

The open-field communities were subsequently reorganized, the land enclosed, and the farmers' holdings redistributed into individual blocks which were then divided into separate fields. This enclosure process reached its peak during the 18th century. Twentieth-century developments in agricultural science and technology have encouraged farmers to amalgamate and enlarge their fields, often to as much as 40 hectares/100 acres.

The open-field system was also found in France, Germany, Greece, and Slavonic lands.

---

fieldfare

gregarious thrush *Turdus pilaris* of the family Muscicapidae, order Passeriformes; it has chestnut upperparts with a pale-grey lower back and neck, and a dark tail. The bird's underparts are a rich ochre colour, spotted with black. Its nest is of long fine grass with an intervening layer of mud; it may be built in birch or fir trees at a height of 5 m/16 ft or less. It feeds on berries, insects, and other invertebrates.

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fifth-generation computer

anticipated new type of computer based on emerging microelectronic technologies with high computing speeds and parallel processing. The development of very large-scale integration (VLSI) technology, which can put many more circuits onto an integrated circuit (chip) than is currently possible, and developments in computer hardware and software design may produce computers far more powerful than those in current use.

It has been predicted that such a computer will be able to communicate in natural spoken language with its user; store vast knowledge databases; search rapidly through these databases, making intelligent inferences and drawing logical conclusions; and process images and 'see' objects in the way that humans do.

In 1981 Japan's Ministry of International Trade and Industry launched a ten-year project to build the first fifth-generation computer, the 'parallel inference machine', consisting of over a thousand microprocessors operating in parallel with each other. By 1992, however, the project was behind schedule and had only produced 256-processor modules and was closed down soon after. It has since been suggested that research into other technologies, such as neural networks, may present more promising approaches to artificial intelligence. Compare earlier computer generations.

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fig

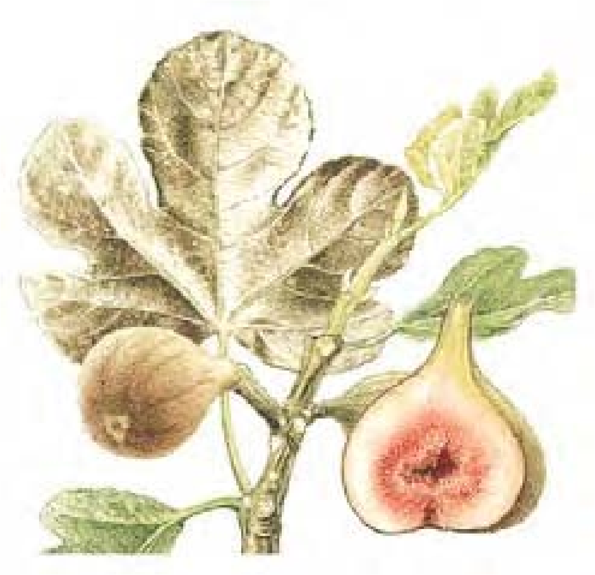
any of a group of trees belonging to the mulberry family, including the many cultivated varieties of *F. carica*, originally from western Asia. They produce two or three crops of fruit a year. Eaten fresh or dried, figs have a high sugar content and laxative properties. (Genus *Ficus*, family Moraceae.)

In the wild, *F. carica* is dependent on the fig wasp for pollination, and the wasp in turn is parasitic on the flowers. The tropical **banyan** (*F. benghalensis*) has less attractive edible fruit, and roots that grow down from its branches. The **bo tree** under which Buddha became enlightened is the Indian peepul or wild fig (*F. religiosa*).

fig

The tiny wasps that pollinate tropical figs must roam up to 632 sq m/755.87 sq yd to pollinate the figs. The pollination area for most other trees rarely exceeds 10 sq m/12 sq yd.

fig



(Image © Research Machines plc)

Plants of the fig family may range in size from small shrubs to trees reaching 40 m/130 ft or more. They are found throughout the tropics. The edible fig originated in western Asia and has been cultivated for at least 6,000 years. It is now grown mainly in Italy, Turkey, Greece, and California. The fruit may be eaten fresh or preserved and dried. Figs are pollinated by parasitic wasps.

fig

(Image © Corel)

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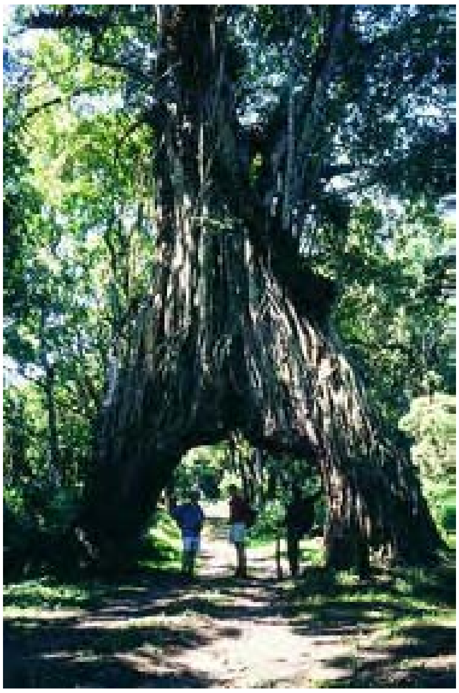
fig



(Image © Research Machines plc)

Fig tree in Arusha National Part, Tanzania. Two olive trees, one either side of the path, have been enveloped by a 'strangler' fig (genus *ficus*), in a symbiotic relationship that will eventually kill the host trees.

Fig, Common

Go to site

Informative resource relating to the common fig tree. It contains a detailed description of the tree, its habitat, and its cultivation. There are also notes on the constituents of the tree, as well as information on the possible medicinal uses of the common fig tree, which include acting as a laxative and treating warts.

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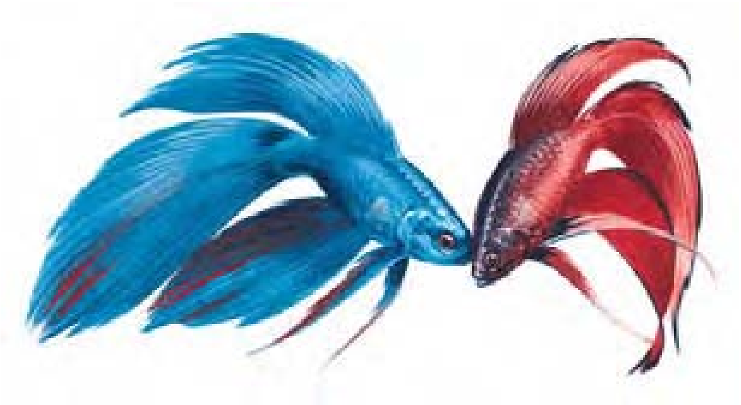
fighting fish

any of a southeast Asian genus *Betta* of fishes of the gourami family, especially *B. splendens*, about 6 cm/2 in long and a popular aquarium fish. It can breathe air, using an accessory breathing organ above the gill, and can live in poorly oxygenated water. The male has large fins and various colours, including shining greens, reds, and blues. The female is yellowish brown with short fins.

The male builds a nest of bubbles at the water's surface and displays to a female to induce her to lay. Rival males are attacked, and in a confined space fights may occur. In Thailand, public contests are held.

fighting fish



(Image © Research Machines plc)

Siamese fighting fish live in brackish water in ponds and drainage channels in Thailand. The males are extremely aggressive and are bred for their large and brightly coloured fins, which they flare during combat.

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figwort

any of a group of Old World plants belonging to the figwort family, which also includes foxgloves and snapdragons. Members of the genus have square stems, opposite leaves, and open two-lipped flowers in a cluster at the top of the stem. (Genus *Scrophularia*, family Scrophulariaceae.)

Figwort, Knotted

Go to site

Informative resource relating to the knotted figwort, or the common figwort. It contains a detailed description of the tree and its habitat. There are also notes on the possible medicinal uses of the common figwort, which include acting as a diuretic and treating burns and swellings.

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filament

in astronomy, dark, winding feature occasionally seen on images of the Sun in hydrogen light. Filaments are clouds of relatively cool gas suspended above the Sun by magnetic fields and seen in silhouette against the hotter photosphere below. During total eclipses they can be seen as bright features against the sky at the edge of the Sun, where they are known as prominences.

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filariasis

collective term for several diseases, prevalent in tropical areas, caused by certain roundworm (nematode) parasites. About 120 million people worldwide are infected with filarial worms, mostly in India and Africa.

Symptoms include damaged and swollen lymph vessels leading to grotesque swellings of the legs and genitals (Bancroftian filariasis, elephantiasis), blindness, and dry, scaly skin (onchocerciasis). The disease-causing worms are spread mainly by insects, notably mosquitoes and blackflies. Filariasis is treated by drugs to kill the worms, though this does not reverse any swelling. A World Health Organization (WHO) initiative to eliminate filariasis began in 2000.

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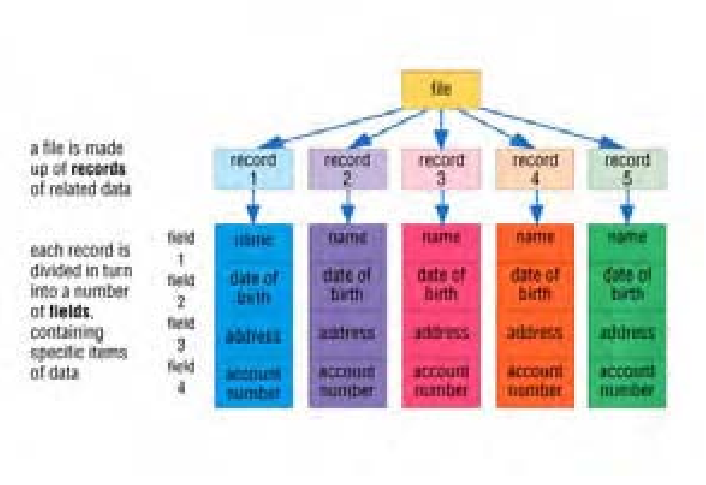
file

in computing, a collection of data or a program stored in a computer's external memory (for example, on disk). It might include anything from information on a company's employees to a program for an adventure game. Files are usually located via a directory. A popular method for identifying the format of a file is based on the part of its name following a full stop and is known as the file extension. A text file, for example, might have the extension .txt.

Database files usually consist of a set of records, each having a number of **fields** for specific items of data. For example, the data file for a class of schoolchildren might have a record for each child, with five fields of data in each record, storing: (1) family name; (2) first name; (3) house name or number; (4) street name; (5) town. To find out, for example, which children live in the same street, one would look in field 4.

file


file
a file is made up of **records** of related data
record 1
record 2
record 3
record 4
record 5
each record is divided in turn into a number of **fields**, containing specific items of data
field 1
field 2
field 3
field 4
name
date of birth
address
account number

(Image © Research Machines plc)

The file structure of a simple accounting system which stores the name, date of birth, address, and account number of each client.

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file access

in computing, the way in which the records in a file are stored, retrieved, or updated by computer. There are four main types of file organization, each of which allows a different form of access to the records: serial file, sequential file, indexed sequential file, and direct-access (or random-access) file.

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film, photographic

strip of transparent material (usually cellulose acetate) coated with a light-sensitive emulsion, used in cameras to take pictures. The emulsion contains a mixture of light-sensitive silver halide salts (for example, bromide or iodide) in gelatin. When the emulsion is exposed to light, the silver salts are invisibly altered, giving a latent image, which is then made visible by the process of developing. Films differ in their sensitivities to light, this being indicated by their speeds. Colour film consists of several layers of emulsion, each of which records a different colour in the light falling on it.

In **colour film** the front emulsion records blue light, then comes a yellow filter, followed by layers that record green and red light respectively. In the developing process the various images in the layers are dyed yellow, magenta (red), and cyan (blue), respectively.

When they are viewed, either as a transparency or as a colour print, the colours merge to produce the true colour of the original scene photographed.

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filter

in chemistry, a porous substance, such as blotting paper, through which a mixture can be passed to separate out its solid constituents.

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filter

in electronics, a circuit that transmits a signal of some frequencies better than others. A low-pass filter transmits signals of low frequency and also direct current; a high-pass filter transmits high-frequency signals; a band-pass filter transmits signals in a band of frequencies.

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filter

in optics, a device that absorbs some parts of the visible spectrum and transmits others. A beam of white light can be made into a beam of coloured light by placing a transparent colour filter in the path of the beam. For example, a green filter will absorb or block all colours of the spectrum except green, which it allows to pass through. A yellow filter absorbs only light at the blue and violet end of the spectrum, transmitting red, orange, green, and yellow light.

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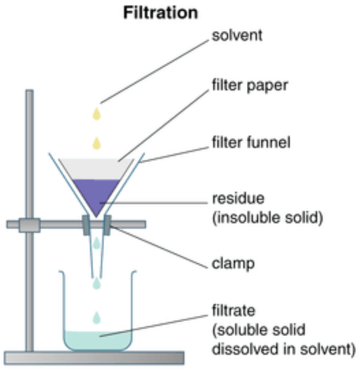
filtration

technique by which suspended solid particles in a fluid are removed by passing the mixture through a filter, usually porous paper, plastic, or cloth. The particles are retained by the filter to form a residue and the fluid passes through to make up the filtrate. For example, soot may be filtered from air, and suspended solids from water.

filtration



(Image © Research Machines plc)

The separation of a solid from a liquid by passing through a filter. The suspension is poured into the filter funnel where the filter paper traps all solid particles but allows the liquid to pass through to be collected below.

fin

in aquatic animals, flattened extension from the body that aids balance and propulsion through the water.

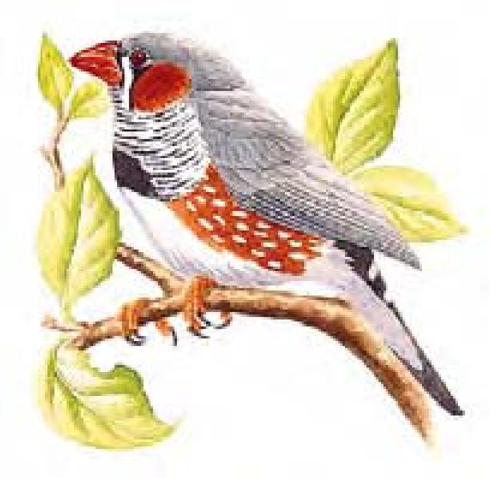
In fish they may be paired, such as the pectoral and ventral fins, or singular, such as the caudal and dorsal fins, all being supported by a series of cartilaginous or bony rays.

The fins in cetaceans (whales and dolphins) are simple extensions of the soft tissue and have no bony rays. The flippers of seals are modified five-fingered limbs and contain the same bones as the limbs of other vertebrates.

finch

any of various songbirds of the family Fringillidae, in the order Passeriformes (perching birds). They are seed-eaters with stout conical beaks. The name may also be applied to members of the Emberizidae (buntings), and Estrildidae (weaver-finches).

finch



(Image © Research Machines plc)

The zebra finch, or spotted-sided finch, is a member of the waxbill family of seed-eating birds found in Australia. While its overall coloration is comparatively uniform, it has bold markings. It has become a popular cagebird and captive breeding of these birds has developed several colour varieties.

FinchWorld

Go to site

Huge source of information on finches. Contents include practical advice for those buying a finch for the first time, tips on diet, housing, recreation activities, and avian illnesses. There are links to finch sites around the world and news of ornithological research on these songbirds.

finsen unit

FU

unit for measuring the intensity of ultraviolet (UV) light; for instance, ultraviolet light of 2 FUs causes sunburn in 15 minutes.

fiord

alternative spelling of fjord.

fir

any of a group of conifer trees belonging to the pine family. The true firs include the balsam fir (*A. balsamea*) of northern North America and the silver fir (*A. alba*) of Europe and Asia. Douglas firs of the genus *Pseudotsuga* are native to western North America and the Far East. (True fir genus *Abies*, family Pinaceae.)

Fir trees

The term fir tree is sometimes loosely used to refer to any conifer, but the true firs belong to the genus

Abies which consists of some 40-50 species. Although the fir tree is similar in appearance to the spruce, it may be identified by the circular scars left on its bark when its needles fall. The scars are not raised above the bark's surface so the bark is left almost smooth. When a needle falls from a spruce part of the bark comes away too, leaving it rough with a peglike scar. Fir tree cones stand upright on the branches and they break up when the seeds are scattered, leaving their central spikes on the tree. Spruce cones hang downwards and fall off when the seeds are scattered, leaving nothing on the tree.

Common name	Latin name	Max height		Natural home
		m	ft	
Giant fir	*Abies grandis*	91	300	western USA
Red silver fir	*Abies amabilis*	76	250	northwest USA
Red fir	*Abies magnifica*	61	200	western USA
Noble fir	*Abies nobilis*	61	200	north-central USA
Caucasian fir	*Abies nordmanniana*	61	200	Caucasus, Greece, Asia Minor
European silver fir	*Abies alba*	52	170	Europe
Japanese fir	*Abies firma*	46	150	Japan
Colorado white fir	*Abies concolor*	37	120	Colorado and New Mexico, USA
Grecian fir	*Abies cephalonica*	30	100	Greece
Algerian fir	*Abies numidica*	21	70	Algeria
Forrest's fir	*Abies forrestii*	18	60	western China
Balsam fir	*Abies balsamea*	12-23	40-75	Canada and northeast USA
Douglas fir[1]	*Pseudotsuga douglasii*	76	250	North America

[1] The Douglas firs belong to the genus *Pseudotsuga* which consists of about seven species. They have narrower and softer leaves than the *Abies* firs and their mature cones are pendulous and have seed-scales beneath.

fireball

in astronomy, very bright meteor, often bright enough to be seen in daylight and occasionally leading to the fall of a meteorite. Some fireballs are caused by satellites or other space debris burning up in the Earth's atmosphere.

firebrat

any insect of the order Thysanura (bristletail).

fire clay

a clay with refractory characteristics (resistant to high temperatures), and hence suitable for lining furnaces (firebrick). Its chemical composition consists of a high percentage of silicon and aluminium oxides, and a low percentage of the oxides of sodium, potassium, iron, and calcium.

firedamp

gas that occurs in coal mines and is explosive when mixed with air in certain proportions. It consists chiefly of methane (CH_4, natural gas or marsh gas) but always contains small quantities of other gases, such as nitrogen, carbon dioxide, and hydrogen, and sometimes ethane and carbon monoxide.

fire extinguisher

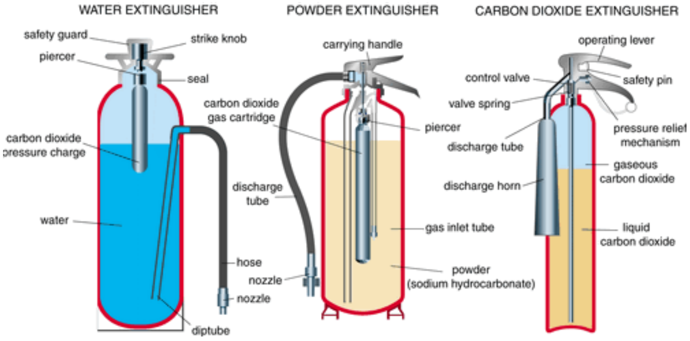
device for putting out a fire. Fire extinguishers work by removing one of the three conditions necessary for fire to continue (heat, oxygen, and fuel), either by cooling the fire or by excluding oxygen.

The simplest fire extinguishers contain water, which when propelled onto the fire cools it down. Water extinguishers cannot be used on electrical fires, as there is a danger of electrocution, or on burning oil, as the oil will float on the water and spread the blaze.

Many domestic extinguishers contain liquid carbon dioxide under pressure. When the handle is pressed, carbon dioxide is released as a gas that blankets the burning material and prevents oxygen from reaching it. Dry extinguishers spray powder, which then releases carbon dioxide gas. Wet extinguishers are often of the soda-acid type; when activated, sulphuric acid mixes with sodium bicarbonate, producing carbon dioxide. The gas pressure forces the solution out of a nozzle, and a foaming agent may be added.

Some extinguishers contain halons (hydrocarbons with one or more hydrogens substituted by a halogen such as chlorine, bromine, or fluorine). These are very effective at smothering fires, but cause damage to the ozone layer, and their use is now restricted.

fire extinguisher


WATER EXTINGUISHER
POWDER EXTINGUISHER
CARBON DIOXIDE EXTINGUISHER
safety guard
strike knob
piercer
seal
carbon dioxide pressure charge
water
diptube
hose
nozzle
carrying handle
carbon dioxide gas cartridge
discharge tube
nozzle
piercer
gas inlet tube
powder (sodium hydrocarbonate)
operating lever
control valve
safety pin
valve spring
discharge tube
pressure relief mechanism
gaseous carbon dioxide
discharge horn
liquid carbon dioxide

(Image © Research Machines plc)

Three different kinds of fire extinguisher. The **water fire extinguisher** is the most commonly used but it is suitable only for fires of ordinary combustibles, such as wood, paper, some plastics, and textiles. It is dangerous to use around electrical equipment. The **carbon dioxide fire extinguisher** needs to be used at close range and will extinguish fires of flammable liquids, such as oil, petrol, and paint. It works by starving the fire of oxygen. Carbon dioxide fire extinguishers are also used for fires involving electrical equipment. **Dry chemical fire extinguishers** are effective on most common types of fires but the powder is corrosive and it leaves a sticky residue.

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firefly

any winged nocturnal beetle of the family Lampyridae. They all emit light through the process of bioluminescence.

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firewood

the principal fuel for some 2 billion people, mainly in the developing world. In principle a renewable energy source, firewood is being cut far faster than the trees can regenerate in many areas of Africa and Asia, leading to deforestation.

In Mali, for example, wood provides 97% of total energy consumption, and deforestation is running at an estimated 9,000 hectares a year. The heat efficiency of firewood can be increased by use of well-designed stoves, but for many people they are either unaffordable or unavailable. With wood for fuel becoming scarcer the UN Food and Agricultural Organization has estimated that by the year 2000 3 billion people worldwide will face chronic problems in getting food cooked.

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firmware

computer program held permanently in a computer's ROM (read-only memory) chips, as opposed to a program that is read in from external memory as it is needed. The BIOS (basic input/output system) in a personal computer is an example of firmware.

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first aid

action taken immediately in a medical emergency in order to save a sick or injured person's life, prevent further damage, or facilitate later treatment. See also resuscitation.

First Aid

animal bites

Flush the wound immediately to remove saliva and cleanse thoroughly with mild soap and cool water for five minutes; flush with cool, running water. If the victim has been bitten by an unknown animal including cats, dogs, raccoons, coyotes, foxes, rats, mice, squirrels, skunks, or bats, the animal should be captured alive so it can be tested for rabies. If the animal must be killed, do not damage the skull. If the animal cannot be caught, the victim may have to undergo anti-rabies treatment.

bleeding

Use a clean cloth or piece of gauze to cover the wound. Apply firm pressure to the wound with your hand, holding the edges of the wound together. When bleeding has stopped, sponge the wound gently with antiseptic, such as rubbing alcohol or hydrogen peroxide, and spread a thin layer of gauze over the wound. Cover the wound with a bandage. If you can't stop the bleeding within a few minutes, seek medical help.

blisters

Sterilize a needle by holding it for ten seconds in a flame. Carefully puncture the edge of the blister next to the skin. Apply gentle pressure, squeezing the accumulated fluid out of the blister. Treat the blister with either antibiotic ointment or rubbing alcohol, and cover with several layers of sterile gauze.

breathing difficulties

To help a person who has stopped breathing, first position the victim on their back. Take necessary precautions if you suspect the person may have sustained a back or neck injury. Tilt the victim's head so that their chin is pointing up by placing one of your hands under their neck. Lift up gently while you press down gently on the victim's forehead. Check to make sure that the victim's tongue is not blocking their throat. Using the hand that is on the victim's forehead, pinch their nostrils shut to prevent leakage of air. Open your mouth wide, take a deep breath, and seal your mouth over the victim's mouth. Blow two slow breaths into the victim's lungs. If the victim does not begin to breathe on their own after the two breaths, continue to breathe into their mouth at the rate of one breath every five seconds, or 12 times per minute. Continue mouth-to-mouth resuscitation until help arrives. If the victim is an infant, you should breathe gentle puffs of air at the rate of one every three seconds, or 20 times per minute. If the victim has obviously lost their heartbeat, you should commence cardiopulmonary resuscitation (CPR). Since this technique is more complicated and could result in injury if performed improperly, receive training from a licensed practitioner before attempting it.

bruises

Apply a cold compress (a washcloth soaked in cold water works well) to the bruised area.

burns

For a first-degree burn, immediately immerse the burn in cold water and keep it immersed until you no longer feel pain. If necessary, periodically add ice cubes to the water to keep it cold. Do not put butter or any other fatty product on the burn. Apply one of the following to the burn: a commercial burn ointment, a thick layer of honey, petroleum jelly, or a thick paste of baking soda and water. Cover the burn with a loose protective bandage that allows some exposure to air. For second- or third-degree burns, seek medical help.

chemical burns

Flush the burned area with plenty of running cold water to remove traces of the chemical. Apply either a commercial burn ointment, a thick layer of honey, petroleum jelly, or a thick paste of baking soda and water to the burned area. Cover with a loose protective bandage. If the chemical burn involves the eye, immediately flush the eye with plenty of running water, cover the eye with a sterile pad to keep the lid still, and seek immediate medical help.

choking

Choking is a life-threatening emergency. First, ask the victim if they are all right. This question is less to ascertain how the victim feels and more to gauge if the victim can speak, which would mean the food is not lodged in the windpipe; persist in asking until the victim verbalizes their answer or obviously cannot speak. Do not slap the victim on the back - this may further lodge the food in the windpipe. The Heimlich Manoeuver, or abdominal thrust, can be performed on victims who are either conscious or unconscious, and who are standing, sitting, or lying down. You can even perform the manoeuver on yourself. For a victim who is standing: Stand behind the victim and wrap your arms around the victim's waist; grasp your hands in front of the victim; the hand that is resting against the victim's abdomen should be in a fist; make sure that the fist is positioned between the tip of the breastbone and the navel; with your hands tightly grasped, press your fist into the victim's abdomen, using a quick, upward thrust; the piece of food should come flying out of the victim's mouth with force; if it doesn't, repeat the thrusting motion several more times until the food is dislodged. For a victim who is sitting: Repeat the procedure as with a victim who is standing; stand behind the chair, and grasp the victim around the waist. For a victim who is lying down: Roll the victim onto their back; kneel at the victim's side, straddle their hips, or straddle one of their thighs (your position is not that important, choose the one that is most comfortable and affords you the greatest strength); place one of your hands on top of the other; the heel of your bottom hand should be positioned between the tip of the breastbone and the navel; move forward so that your shoulders are directly above the victim's abdomen; press your hands forcefully into the victim's abdomen with a rapid, upward thrust; repeat the thrusting until you can see the piece of food; you may have to remove it from the victim's mouth; act quickly so that the victim doesn't breathe it in again. For a victim who is a child: Place the child on its back across your thigh; using two or three fingers of one hand, position your fingers between the tip of the breastbone and the navel; with a quick, upward thrust, push your fingers into the child's abdomen; don't use as much force as you would use with an adult. To perform the manoeuvre on yourself: Quickly locate a firm, rigid, preferably non-moveable object that is about the height of your abdomen; rest your abdomen across the object so that it is positioned between the tip of your breastbone and your navel; you can use the edge of a counter, the edge of a table, or the back of a chair; quickly and forcefully press your weight downward so that the object works to thrust upward into your abdomen; repeat this motion until the food is dislodged.

cuts

Wash the area with warm water and soap. If the bleeding is severe, apply pressure to the wound with a clean cloth. If the bleeding is minor, apply gentle pressure until the bleeding stops. Apply an antibiotic ointment or rubbing alcohol, thoroughly cleanse the wound, and remove any debris or dirt. Cover the wound with an adhesive strip. If the cut is large, use sterile gauze and adhesive tape.

electric shock

Disconnect electrical supply, check to see if victim is breathing. If not, begin mouth-to-mouth resuscitation immediately. If there is someone else available, have them call for resuscitation help - the fire department, ambulance, or police. Continue mouth-to-mouth breathing until the ambulance arrives. A second person may initiate CPR if necessary.

eye injuries

Routine irritations (sand, dirt, and other 'foreign bodies' on the eye surface): Do not try to remove any 'foreign body' except by flushing; do not touch, press, or rub the eye, and do whatever you can to keep the child from touching it (a baby can be swaddled as a preventive measure); gently pour a steady stream of lukewarm water from a pitcher across the eye (sterile saline solution can also be used); flush for up to 15 minutes, checking the eye every five minutes to see if the foreign body has been flushed out.

Embedded foreign body (an object penetrates the globe of the eye): Call for emergency medical help; cover both eyes (the unaffected eye must be covered to prevent movement of the affected eye); if the object is small, use eye patches or sterile dressing for both; if the object is large, cover the injured eye with a small cup taped in place and the other eye with an eye patch or sterile dressing; the point is to keep all pressure off the globe of the eye; keep your child (and yourself) as calm and comfortable as possible until help arrives. Chemical exposure: Flush the eye (see above) with lukewarm water for 15-30 minutes (if both eyes are affected, do it in the shower); call for emergency medical help; call your local poison control centre for specific instructions; be prepared to give the exact name of the chemical (if you have it); cover both eyes with sterile dressings, and keep them covered until help arrives.

fainting

If you feel faint, immediately lie down; if you can't lie down, sit down and put your head between your knees. If you can, lie or sit in fresh, cool air. Stay in a head-down position for at least ten minutes. If someone does faint, help them to lie down in a comfortable position, preferably with their head lower than the rest of the body. After regaining consciousness, rest in a lying-down position for at least ten minutes before resuming activity.

food poisoning

Staphylococcal: a common type of food poisoning due to bacterial contamination of foods. Symptoms occur within a few hours after ingestion and may include pain or tenderness of the abdomen, nausea, vomiting, painful spasms, diarrhoea, and weakness. No specific treatment is necessary. Botulism: the most serious and possibly fatal type of food poisoning caused by contamination of improperly canned foods. Symptoms occur about two days after ingestion and may include dimness of vision; double vision; drooping eyelids; difficulty in talking, swallowing, and breathing. To treat: as soon as symptoms are recognized call the National Communicable Disease Center in Atlanta, Georgia, (404) 633-3311, for availability of a specific antitoxin. Then seek medical assistance for further instructions. Salmonella: bacterial contamination of cooked or uncooked foods. Symptoms occur after eight or more hours and may include nausea, chills, fever, abdominal cramps, severe diarrhoea, and localized infections. Seek medical help immediately.

foreign object in ear

Lay on your side with the affected ear up. Put several drops of warm mineral oil or warm olive oil into your ear until you feel the sensation of fullness; wait five minutes. Sit up and tilt your head to the side, with the affected ear pointed downward. If the object was small or was an insect, it should float out with the oil. Do not put oil in your ear if the object is one that would swell - a bean, wood, or any other absorbent object. If a large object is lodged in your ear, or if treatment is unsuccessful, seek medical help.

foreign object in eye

If you can see the object, lift it gently away from your eye with the corner of a clean handkerchief or a clean cotton swab. If you can't see the object, gently pull your upper eyelid out and down over your lower lid. The tears should wash the particle from your eye. Flush your eye gently with clear, cool water. If you are unable to remove a large object or if you have particles of metal in your eye, seek medical help immediately.

fractures

Fractures must receive medical attention. To avoid further injury, do not try to move the fractured area; if you suspect injury to the neck or spine, do not move the person at all - send for medical help. If the fracture is compound (the bone is sticking out of the skin) take measures to stop bleeding while medical help arrives

frostbite

Frostbite is characterized by white, waxy skin that feels numb and hard. It requires emergency medical attention. Immerse frozen areas in warm water (100-105 °F) or apply warm compresses for 30 minutes. If warm water is not available, wrap gently in warm blankets. Do not rub frostbitten skin or rub snow on it. When skin is pink and no longer numb, the area is thawed. Apply sterile dressing loosely to the area, placing it between fingers and toes if they are affected. Try not to disturb any blisters. Wrap rewarmed areas to prevent refreezing.

head injuries

External (scalp) injury: Seek medical help if victim loses consciousness, even momentarily; if victim does not lose consciousness and is alert and behaving normally, apply an ice pack or instant cold pack to the injured area for 20 minutes; if you use ice, always wrap it in a washcloth or sock; if victim shows any of the signs of internal injury (see below), seek medical help immediately. Internal injury: Call an ambulance if the victim shows any of the following symptoms: unconsciousness; abnormal breathing; obvious wound or fracture; bleeding from the nose, ear, or mouth; disturbance of speech or vision; pupils of unequal size; weakness or paralysis; dizziness; neck pain or stiffness; seizure; vomiting; loss of bladder or bowel control. Do not move victim until help arrives unless absolutely necessary.

heat exhaustion (heat prostration)

Symptoms may include fatigue, irritability, headache, faintness, weak rapid pulse, shallow breathing, cold clammy skin, and profuse perspiration. To treat, instruct the victim to lie down in a cool, shaded area or air-conditioned room. Elevate their feet. Massage the legs toward the heart. Give cold salt water (half a teaspoon to half a glass of water) or cool, sweetened drinks, especially iced tea or coffee, every 15 minutes until victim recovers. DO NOT let victim sit up, even after feeling recovered.

insect stings and bites

The two greatest risks from most insect stings are allergic reaction (which may occasionally be fatal) and infection (more likely and less serious). Bee, wasp, hornet, and yellow jacket stings: Remove sting if possible; wash affected area with soap and water and cover to keep clean; apply antihistamine ointment; seek emergency care if any of the following symptoms occur, which may indicate an allergic reaction: large area of swelling; abnormal breathing; tightness in throat or chest; dizziness; hives; fainting; nausea or vomiting; persistent pain or swelling (more than 72 hours). Spider bites: Most spiders found in the United States are harmless, with the exception of the black widow and the brown recluse (or violin) spider. Both of these are found in warm climates. Black Widow: a shiny black spider with long legs, 3/4 inch in size, marked on the underside with a red hourglass-shaped spot. Symptoms may include severe pain, nausea, muscle cramps, fever, profuse sweating, and breathing difficulties. A tingling or burning sensation may spread throughout the body. Brown Recluse: a brown spider, 1/2-5/8 of an inch in size, with long legs and a dark brown fiddle-shaped marking on the back. Symptoms may include severe pain, later possibly followed by chills, fever, joint pain, nausea, and vomiting. Tarantula: a large hairy spider, which may accompany imports of bananas and fruits from South America. Symptoms may include severe wound, intense pain at the bite site; generalized body reactions are uncommon. If you have any reason to suspect the victim has been bitten by a black widow or brown recluse spider, seek emergency help immediately. Symptoms include: a deep blue or purple area around the bite, surrounded by a whitish ring and a large outer red ring; body rash; muscle spasms, tightness, and stiffness; abdominal pain; headache or fever; general 'sick' feeling; lack of appetite; joint pain; signs of infection around the bite (swelling and redness); pink or red urine. Wash the area carefully with soap and water. Do this two or three times a day until skin is healed. Apply a cold pack, an ice pack wrapped in a cloth, or a cold, wet washcloth. Apply a paste of baking soda and water and leave it on for 15 to 20 minutes. Give acetaminophen for pain. To protect against infection, apply an antibiotic ointment and keep the victim's hands washed. In the southwest USA, an unidentified bite may be caused by a scorpion. Again, head for the emergency room.

nosebleed

Sit down and lean your head forward to allow any blood to trickle out of the mouth. Apply pressure to your nose by firmly grasping the area just below the bridge of your nose between your thumb and forefinger and apply pressure for five to ten minutes. If the bleeding does not stop within ten minutes, pack the bleeding nostril with sterile gauze and apply firm pressure at the tip of the nose. Apply a cold compress or ice bag to your face and to the base of your skull at the neck. Once the bleeding has stopped, remain quiet and avoid laughing or blowing your nose. If you cannot control the bleeding within 15-20 minutes seek medical help. The nosebleed may be due to high blood pressure or to a fracture of the nose.

plant poisoning

Swallowed plant: symptoms may include cramps, vomiting, burning sensation in mouth and throat, impaired vision, and convulsions. Call the Poison Control Center and seek medical help immediately. If breathing difficulties develop, apply emergency breathing techniques immediately. Contact plant: skin reaction due to contact with offending plants. Symptoms may not begin until 48 hours after exposure and may include: a severe rash with redness, blisters, swelling, burning, itching, and high fever. To treat, carefully remove contaminated clothing. Wash the exposed areas thoroughly with mild soap and water. Apply rubbing alcohol and calamine lotion. If a severe reaction occurs, consult professional medical help.

puncture wounds

Wash the wound well with soap and water. If bleeding is persistent, apply direct pressure until it stops. Apply sterile gauze. Seek medical help in cases of a deep puncture.

seizures

A seizure, also known as a convulsion, is a brief period of unconsciousness or altered consciousness. It may be accompanied by one or more of the following symptoms: falling; muscle spasms; drooling or 'frothing' at the mouth; loss of bladder or bowel control; a temporary halt in breathing. Seizures are caused by abnormal discharge of electrical currents in the brain and are associated with many medical conditions. Seizures may also be caused by gastrointestinal disease, poisoning, head injury, and brain disease such as a tumour. Repeated convulsions may indicate the chronic condition epilepsy. During a seizure, keep the victim's airway open. If victim is not breathing, perform mouth-to-mouth resuscitation. Do not try to restrain movements. If the victim has a prolonged seizure, take them to hospital.

shock

Shock, which generally occurs to some degree after any injury, can, when severe, cause death. A person who is in shock may look dazed and confused. They may either be pale or flushed, depending on the type of injury. They will probably be breathing irregularly and their breathing may be weak. They may vomit; in severe cases they will lose consciousness. Immediate medical help is needed. Until that help arrives, do the following: Have the person lie down on their back; keep the head level with the body or slightly elevated. Do not tilt the person so that the head is lower than the body. Loosen tight clothing at the chest and neck. If the skin is pale and cool, cover the person with one or more blankets to provide warmth, but be careful not to overheat the person. If the skin is hot and read, apply bath towels soaked in cool water until the skin returns to normal temperature and then cover the person with a blanket to keep them warm. Never give a person in severe shock anything to eat or drink.

snake bites

Mild to moderate symptoms include mild swelling or discoloration, mild pain with tingling sensation at bite site, rapid pulse, weakness, blurred vision, nausea, vomiting, and shortness of breath. Severe symptoms include rapid swelling, numbness, severe pain at bite site, pinpoint pupils, slurred speech, shock, convulsions, paralysis, unconsciousness, and no breathing or pulse. Caution: poisonous or non-poisonous snake bites should have medical attention. The victim should be taken to a hospital as soon as possible, even in cases when snakebite is only suspected. DO NOT give alcohol, sedatives, aspirin, or medications containing aspirin to relieve pain. DO NOT apply cold compresses, ice, dry ice, chemical ice packs, spray refrigerants, or other methods of cold therapy. Get medical help immediately. Telephone the nearest hospital, Poison Control Center, or doctor for additional instructions. Have the victim lie down and keep as still and calm as possible. Adjust victim's body so that the sight is below their heart level. Be alert for breathing difficulties and begin rescue breathing techniques if necessary. If pulse is not present, begin CPR immediately if you are trained in it. Treat for shock if necessary. For mild to moderate symptoms, tie a constricting band between the bite site and the heart. Check for a pulse to ensure the band is not too tight. Adjust the bandage so fluid oozes from the wound. If severe symptoms develop and medical help is not readily available, first sterilize a knife or razor blade in a flame. Make a vertical cut in the skin 1/2 inch long over each fang mark. DO NOT cut deeply and DO NOT make a crosscut incision. Suction should be applied with a suction cup for 30 minutes. If a cup is not available, suck venom from the bite with your mouth. Wash the bite thoroughly with soap and cool water. Blot dry. Apply a sterile or clean dressing, but only for a short period of time. If the snake has been killed, take it with you to the hospital for identification.

splinters

Thoroughly wash the area around the splinter with soap and warm water and rinse well. Swab the area gently with rubbing alcohol. Sterilize a needle by holding its end in a flame for ten seconds. If the end of the splinter is sticking out of the skin, grasp it with a pair of tweezers and pull it out at the same angle it entered the skin. Go slowly and avoid breaking off a bit of the splinter under the skin. If the splinter is embedded in the skin and cannot be pulled out with tweezers, use the needle to loosen the skin around the splinter and expose its end. Then grasp the end with tweezers and remove it gently. Gently squeeze the wound to encourage slight bleeding, which will wash out some bacteria. Apply antibiotic ointment or swab the wound with rubbing alcohol. Cover the wound with a bandage. Note: You should seek medical help if the splinter is buried to deep to be removed, if infection develops (indicated by redness, pain, tenderness, pus, or fever), or if the splinter was deep and you have not had a tetanus shot in the last five years. Also seek help if you are unable to remove the splinter completely.

sprains

Immediately immerse the sprained area in ice water for 20 minutes to control swelling. Repeat, using ice water or cold compresses, every four hours until the swelling has stopped. Elevate the sprained limb to at least waist level until swelling has stopped. Once the swelling has stopped, soak the sprained area in contrasting baths three times a day: first in very warm water for 20 minutes, then in icy water for 20 minutes. Once the swelling has stopped, begin gently exercising the sprained area by moving it slightly from side to side, an important step in maintaining flexibility. Don't move it so rapidly or so far that you cause much pain. Continue these flexibility exercises several times daily until the pain begins to diminish. Limit use of the sprained area; if it is an ankle, you need to use crutches until the motion of walking slowly heel-to-toe no longer hurts. If it is a wrist, avoid using your hand to eat, write, or do other things until a waving motion no longer hurts.

sunburn

Apply cool compresses to the burned area to reduce pain and swelling, or take a cool shower. If the sunburn involves your back or an area you can't reach, soak in a tub of cool water. Take aspirin or another non-aspirin pain reliever to reduce pain. Apply a thin paste of baking soda and water or calamine lotion to alleviate pain. If blisters form, never break them intentionally. If blisters do break, apply an antibiotic ointment and cover the blisters with a sterile dressing. Note: Most sunburn is minor, but you should seek medical help if the sunburn is severe, covers more than one-fourth of your body, or involves extensive blistering.

sunstroke (heat stroke)

Symptoms may include extremely high body temperature (106 °F or higher); hot, red, dry skin; absence of sweating; rapid pulse; convulsions; unconsciousness. Caution: sunstroke is a life-threatening emergency. To treat, get professional medical help immediately. Lower the body temperature quickly by placing the victim in a partially filled tub of cool, not cold, water. (Avoid overcooling.) Briskly sponge the victim's body until their temperature is reduced; then towel dry. If a tub is not available, wrap the victim in cold, wet sheets in a well-ventilated room or use fans and air conditioners until the body temperature is reduced. DO NOT give stimulating beverages such as coffee, tea, or soda.

swallowed poisons

If poisoning is suspected, encourage the victim to drink water or milk immediately to dilute the poison. If the victim is unconscious, having convulsions, becomes nauseated, or vomits, do not force fluids. At the same time, call the Poison Control Center or professional medical help. Describe the poisonous substance and the victim's condition. Ask for first aid instruction. DO NOT give any other first aid if victim is unconscious or is having convulsions. Get professional medical assistance. Apply emergency breathing techniques or CPR if necessary. If the victim is convulsing, protect them from further injury; loosen tight clothing if possible. If the victim is conscious, administer the antidote recommended by the Poison Control Center as soon as possible. Instructions for treatment on product labels may be wrong. DO NOT induce vomiting if the poison is unknown, a corrosive substance (i.e. acid, cleaning fluid, lye, drain cleaner) or a petroleum product (i. e. gasoline, turpentine, paint thinner, lighter fluid.) DO NOT use activated charcoal. Induce vomiting if the poison is known and is not a corrosive substance or a petroleum product. To induce vomiting, give an adult one ounce of syrup of ipecac (or 1/2 ounce for a child) followed by four or five glasses of water. If vomiting does not occur, repeat the procedure in 20 minutes. After the victim has vomited, follow with one ounce of powdered activated charcoal in water, if available. Take the poison container (or vomitus if poison is unknown) with the victim to hospital.

tooth injuries

A dislodged baby tooth cannot be replaced. A permanent tooth, on the other hand, can often be saved if prompt action is taken and the tooth is handled carefully. The delicate tissue covering the root, called the periodontal ligament, must be protected to ensure successful reimplantation. If a baby or toddler injures gums or teeth: If there is bleeding, put cold water on a piece of gauze and apply pressure to the site; offer them an ice pop to suck, to reduce swelling; call your dentist; he or she will probably want to see the child to assess the need for realignment, or removal of a very loose tooth; if the child is very young, the dentist may recommend a spacer to keep the rest of the teeth in place until the permanent tooth appears; over the following week, watch for signs of an abscess: fever and swollen, tender gums above the injury site. If a permanent tooth is chipped or broken: Collect all the pieces of the tooth; rinse the damaged area of the mouth with warm water; give the child a cold compress to hold on the injured tooth; see your dentist right away. If a permanent tooth is knocked out: Hold the tooth by the crown (the top), not the root; rinse the tooth immediately with saline solution or milk (tap water should be used only as a last resort (as it contains chlorine, which may damage the root); do not scrub the tooth; the best place to preserve the tooth on the way to the dentist is in its socket, if the child will cooperate, replace it gently, then have the child bite down on a gauze pad to keep it in place; if the tooth cannot be reinserted, put it in milk – a good preservative because its chemical makeup is compatible with teeth, if milk is not available, place it inside your own mouth, between your teeth and cheek; it can also be placed in the child's mouth if they are old enough not to swallow it; give the child a gauze pad or handkerchief to bite down on, which will help suppress bleeding and ease the pain; see your dentist right away.

vomiting

Most vomiting is caused by gastroenteritis, a viral infection of the gastrointestinal tract. Thankfully, these infections are usually short-lived and are more disruptive than damaging. Your most important intervention may be your bedside manner – vomiting is frightening for young children and exhausting for children of all ages. Supplement the following time-tested routines with plenty of reassurance. Rest the stomach. This may be easier said than done with a small child, who doesn't understand what's happening and is longing for a big drink of water. Try to wait a few hours, then offer small sips of water, ice chips, or a cold, wet washcloth to suck. If sips of water are not tolerated, you may wish to consult your doctor about an over-the-counter nausea medication. If your doctor approves, ask about the correct dose for your child. If sips of water are tolerated, slowly increase the amount of liquids you give your child. Then you can try other clear liquids. Milk and milk products should be avoided. Introduce foods gradually. Wait for your child to say that they are hungry, then start with dry toast or crackers. Your school-age child will probably tell you when they are ready to eat heavier food, and you can generally trust their judgement and give them what they ask for. With a younger child, stick with bland, starchy foods like potatoes and rice until you're sure they are better. The greatest risk of vomiting due to gastroenteritis is dehydration. Call your doctor if your child has diarrhoea, refuses fluids, is not urinating, cries without tears, has a dry mouth, or seems confused. You should also call if vomiting persists more than two days, which increases the risk of dehydration. The following symptoms may indicate a condition more serious than gastroenteritis and require immediate medical attention: projectile vomiting in an infant; vomiting accompanied by fever; repeated vomiting of green or yellow bile; stomach feels hard and bloated in between vomiting episodes; vomit resembles coffee grounds; vomiting blood following a head injury; vomiting during recovery from a viral infection.

Fischer, Emil Hermann (1852-1919)

German chemist who produced synthetic sugars and, from these, various enzymes. His descriptions of the chemistry of the carbohydrates and peptides laid the foundations for the science of biochemistry. He was awarded the Nobel Prize for Chemistry in 1902 for his work on the synthesis of sugars and purine compounds.

In about 1882, Fischer began working on a group of compounds that included uric acid and caffeine. He realized that they were all related to a hitherto unknown substance, which he called purine. Over the next few years he synthesized about 130 related compounds, one of which was the first synthetic nucleotide. These studies led to the synthesis of powerful hypnotic drugs derived from barbituric acids (barbiturates).

Fischer, Hans (1881-1945)

German chemist awarded the Nobel Prize for Chemistry in 1930 for his work on haemoglobin, the oxygen-carrying, red colouring matter in blood. He determined the molecular structures of three important biological pigments: haemoglobin, chlorophyll, and bilirubin.

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fish

aquatic vertebrate that uses gills to obtain oxygen from fresh or sea water. There are three main groups: the bony fishes or Osteichthyes (goldfish, cod, tuna); the cartilaginous fishes or Chondrichthyes (sharks, rays); and the jawless fishes or Agnatha (hagfishes, lampreys).

Fishes of some form are found in virtually every body of water in the world except for the very salty water of the Dead Sea and some of the hot larval springs. Of the 30,000 fish species, approximately 2,500 are freshwater.

bony fishes

These constitute the majority of living fishes (about 20,000 species). The skeleton is bone, movement is controlled by mobile fins, and the body is usually covered with scales. The gills are covered by a single flap. Many have a swim bladder with which the fish adjusts its buoyancy. Most lay eggs, sometimes in vast numbers; some cod can produce as many as 28 million. These are laid in the open sea, and probably no more than 28 of them will survive to become adults. Those species that produce small numbers of eggs very often protect them in nests, or brood them in their mouths. Some fishes are internally fertilized and retain eggs until hatched inside the body, then giving birth to live young. Most bony fishes are ray-finned fishes, but a few, including lungfishes and coelacanths, are fleshy-finned.

cartilaginous fishes

These are efficient hunters. There are fewer than 600 known species of sharks and rays. The skeleton is cartilage, the mouth is generally beneath the head, the nose is large and sensitive, and there is a series of open gill slits along the neck region. They have no swimbladder and, in order to remain buoyant, must keep swimming. They may lay eggs ('mermaid's purses') or bear live young. Some types of cartilaginous fishes, such as sharks, retain the shape they had millions of years ago.

jawless fishes

Jawless fish have a body plan like that of some of the earliest vertebrates that existed before true fishes with jaws evolved. There is no true backbone but a notochord. The lamprey attaches itself to the fishes on which it feeds by a suckerlike rasping mouth. Hagfishes are entirely marine, very slimy, and feed on carrion and injured fishes.

The world's largest fish is the whale shark *Rhineodon typus*, more than 20 m/66 ft long; the smallest is the dwarf pygmy goby *Pandaka pygmaea*), 7.5–9.9 mm long. The study of fishes is called ichthyology.

fish as food

The nutrient composition of fish is similar to that of meat, except that there are no obvious deposits of fat. Examples of fish comparatively high in fat are salmon, mackerel, and herring. White fish such as cod, haddock, and whiting contain only 0.4-4% fat. Fish are good sources of B vitamins and iodine, and the fatty fish livers are good sources of A and D vitamins. Calcium can be obtained from fish with soft skeletons, such as sardines. Roe and caviar have a high protein content (20-25%).

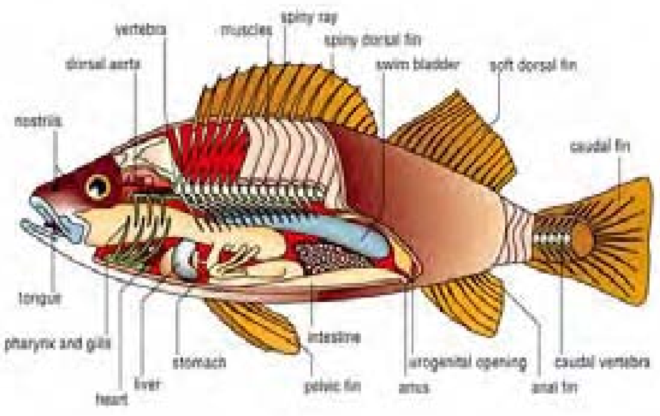
fish: names

Spurdog, alewife, twaite shad, jollytail, tadpole madtom, bummalow, walleye pollock, wrestling halfbeak, mummichog, jolthead porgy, sweetlip emperor, and slippery dick are all common names for species of fish.

fish: swimming speed

The larvae of more than 50 species of fish living in the Great Barrier Reef were found to achieve an average maximum swimming rate of 20.6 cm/8.1 in per second. This is the equivalent of a human swimmer completing the 100-m race in 3 seconds. The damselfish can cover 50 body lengths per second and a soldierfish was timed averaging 56 cm/22 in per second over 10 minutes.

fish


spiny ray
vertebra
muscles
spiny dorsal fin
dorsal aorta
swim bladder
soft dorsal fin
nostrils
caudal fin
tongue
pharynx and gills
intestine
stomach
urogenital opening
caudal vertebra
liver
pelvic fin
anus
anal fin
heart

(Image © Research Machines plc)

The anatomy of a fish. All fishes move through water using their fins for propulsion. The bony fishes, like the specimen shown here, constitute the largest group of fishes with about 20,000 species.

tasselled scorpion fish

(Image © Corel)

The tasselled scorpion fish is a carnivorous fish with a spiny head and venomous fin spines. It is a bottom-dwelling reef fish and can avoid detection on the rock beds by means of camouflage.

yellow damselfish

(Image © Corel)

Yellow damselfish on coiled yellow sponge. Damselfish vary considerably in colour and pattern; they are reef fish and are found in warm coastal waters.

Classification of fish

Order	Number of species	Examples
Class: Agnatha (jawless fishes)		
Subclass: Cyclostomota (scaleless fish with round mouths)		
Petromyzoniformes	30	lamprey
Myxiniformes	30	hagfish
Superclass: Pisces (jawed fishes)		
Class: Chondrichthyes (cartilaginous fishes)		
Subclass: Elasmobranchii (sharks and rays)		
Selachii	>200	shark
Batoidei	>300	skate, ray
Subclass: Holocephali (rabbitfishes)		
Chimaeriformes	20	chimaera, rabbitfish
Class: Osteichthyes (bony fishes)		
Subclass: Sarcopterygii (lobe-finned fishes)		
Coelacanthiformes	1	coelacanth
Ceratodiformes	1	Australian lungfish
Lepidosireniformes	4	South American and African lungfish
Subclass: Actinopterygii (ray-finned fishes)		
Polypteriformes	11	bichir, reedfish
Acipensiformes	25	paddlefish, sturgeon
Superorder: Teleostei		
Elopiformes	12	bonefish, tarpon, ladyfish
Anguilliformes	>500	eel
Clupeiformes	390	herring, anchovy
Osteoglossiformes	7	arapaima, African butterfly fish
Mormyriformes	150	elephant-trunk fish, featherback
Salmoniformes	160	salmon, trout, smelt, pike
Gonorhynchiformes	15	milkfish
Ostariophsi	6,000	carp, barb, characin, loach, catfish
Myctophiformes	300	deep-sea lantern fish, Bombay duck
Paracathopteryggi	853	toadfish, trout-perch, codfish
Atheriniformes	575	flying fish, toothcarp, halfbeak
Gasterosteiformes	150	stickleback, pipefish, seahorse
Pleuronectiformes	402	flatfish, flounder
Tetraodontiformes	250	puffer fish, triggerfish, sunfish
Perciformes	6,500	perch, cichlid, damsel fish, gobie, wrass, parrotfish, gourami, marlin, mackerel, tuna, swordfish, spiny eel, mullet, barracuda, sea bream, croaker, ice fish, butterfish

Atlantic Cod

Go to site

Information on the Atlantic cod's life cycle, migration patterns, and feeding habits. This site also includes a history of the northwest Atlantic cod fishing industry, from the discovery of the New World to the collapse of the fish stocks in the 1980s.

Fish FAQ

Go to site

Answers to hundreds of questions about fish and shellfish. Unfortunately the questions are not grouped, or searchable, in any way, but they do include answers to such things as 'Do fish sleep?' and 'Are Hawaiian monk seals coming back?'.

Fisher, Ronald Aylmer (1890-1962)

English statistician and geneticist. He modernized Charles Darwin's theory of evolution, thus securing the key biological concept of genetic change by natural selection. Fisher developed several new statistical techniques and, applying his methods to genetics, published *The Genetical Theory of Natural Selection* (1930).

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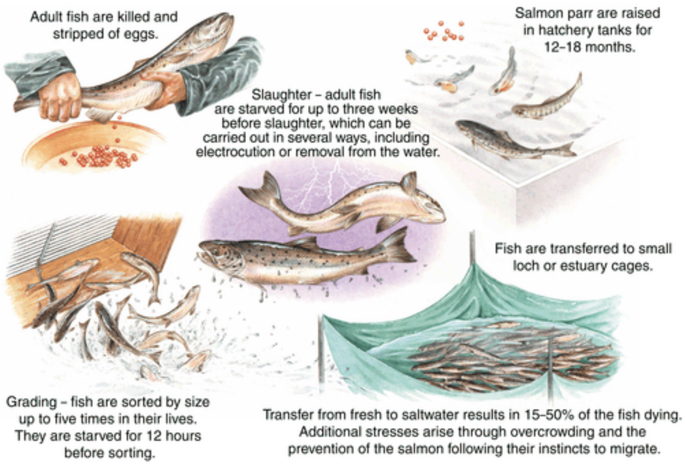
fish farming

or aquaculture

raising fish (including molluscs and crustaceans) under controlled conditions in tanks and ponds, sometimes in offshore pens. It has been practised for centuries in the Far East, where Japan today produces some 100,000 tonnes of fish a year; the USA, Norway, and Canada are also big producers. Fish farms are environmentally controversial because of the risk of escapees that could spread disease and alter the genetic balance of wild populations.

A total of 600,000 metric tonnes of salmon was produced by world fish farms in 1995, accounting for 37% of salmon consumed. Globally, aquaculture production climbed to 28.6 million metric tons in 1997. By 2002, shrimp farms worldwide were producing 1.5 million metric tonnes of shrimps per year.

fish farming


Adult fish are killed and stripped of eggs.
Salmon parr are raised in hatchery tanks for 12–18 months.
Slaughter – adult fish are starved for up to three weeks before slaughter, which can be carried out in several ways, including electrocution or removal from the water.
Fish are transferred to small loch or estuary cages.
Grading – fish are sorted by size up to five times in their lives. They are starved for 12 hours before sorting.
Transfer from fresh to saltwater results in 15–50% of the fish dying. Additional stresses arise through overcrowding and the prevention of the salmon following their instincts to migrate.

(Image © Research Machines plc)

The cycle of events on a fish farm. Fish farming is an intensive form of farming. Fish are crowded together and rely heavily on antibiotics. The resulting organic waste and chemical residues become pollution.

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fishing and fisheries

the harvesting of fish and shellfish from the sea or from freshwater; for example, cod from the North Sea and carp from the lakes of China and India. Fish are an excellent source of protein for humans, and fish products such as oils and bones are used in industry to produce livestock feed, fertilizers, glues, and drugs. Most of the world's catch comes from the oceans. The world's total fish catch is about 100 million tonnes a year (1995).

The world fish catch increased by an average of 7% each year 1950-70. Refrigerated factory ships allowed filleting and processing to be done at sea, and Japan evolved new techniques for locating shoals (by sonar and radar) and catching them (for example, with electrical charges and chemical baits). By the 1970s, overfishing had led to serious depletion of stocks, and heated confrontations between countries using the same fishing grounds. A partial solution was the extension of fishing limits to 320 km/200 mi. The North Sea countries have experimented with the artificial breeding of fish eggs and release of small fry into the sea. In 1988, overfishing of the northeastern Atlantic led to hundreds of thousands of seals starving on the north coast of Norway. A United Nations (UN) resolution was passed in 1989 to end drift-net fishing (an indiscriminate method) by June 1992. Marine pollution is blamed for the increasing number (up to 30%) of diseased fish in the North Sea.

Stocks of several deep-water fish have been decreasing since the 1970s because of the global boom in deep-water fishing. As traditional fisheries in shallow water became depleted, there was a growth in commercial interest in deep-water fisheries, but deep-water fish are slow-growing and do not reproduce rapidly enough. For example, stocks of New Zealand's orange roughy, one of the first deep-water fish to be exploited, fell by 90% in the 1970s, and there are no signs of recovery. This may have a permanent effect on deep-water ecosystems, with the disappearance of slow-growing species in favour of faster-reproducing fish.

Fishing: Declining Stocks

a balanced ecosystem

Declining fish stocks used to be seen as a regional issue affecting particular communities, but has developed into a crisis that threatens both the ecological balance of the oceans and the chief source of protein for many of the world's people.

In theory, commercial fisheries remove a surplus of each fish population – the fish that would naturally be killed by other predators or would fail to reproduce – so that the overall population level of a particular species does not suffer. This has some ecological implications, of course, but in general allows a balanced ecosystem to remain while providing humans with a valuable food source.

overexploiting fish stocks

In the last few decades, fish stocks have been exploited way beyond their natural limits. Over 40 years, the world catch increased by four times. Gigantic drift nets trawl up vast populations of fish, including many unwanted species that are simply abandoned. The largest nets can encompass the equivalent of 12 Boeing 747 jumbo jets, and even larger nets are under construction.

Far from taking a surplus, fishing fleets have been mining the core population of successive fish species, resulting in a series of population crashes. Populations of Atlantic cod, herring and mackerel have fallen dramatically. Many lesser species, caught by accident, are also endangered. Of the world's 15 leading oceanic fisheries, 13 are in decline. The survival of turtles, dolphins, and other sea creatures is under serious threat simply because they are inadvertently caught up in the world's fishing catch. Sea birds around the UK have suffered a rapid population collapse because there are insufficient fish to feed their young.

an unsustainable system

Such a wasteful system is demonstrably unsustainable. The catches of the world's vast fishing fleets threaten both the marine environment and the livelihoods of many smaller fishing communities throughout the world. About 200 million people in the developing world rely on fisheries for their livelihood.

The problem of declining fish stocks has become a key environmental issue. One of the main reasons for Norway refusing to join the European Union in 1995 was a fear that doing so would open up its rich fishing grounds to Spanish trawlers; Spanish fishermen clashed with Canadian authorities earlier the same year, and European politicians responsible for fishing policies constantly haggle over quotas.

fishing and fisheries

(Image © Research Machines plc)

The Brixham sailing trawler was a type of wooden fishing vessel built in the town of Brixham between the 1880s and 1920s. More than three hundred were built and sailed out of Brixham, a fishing port on the south Devon coast. Brixham was once home to one of the largest wooden trawler fleets in the world. Today, only a few of the original boats remain.

fishing and fisheries

(Image © Research Machines plc)

Fishermen from Chile. Chilean waters are the primary area for fishing in South America, and one of the most important fisheries in the world. The main types of fish caught are mackerel, sardines, and anchovies.

fishing and fisheries

(Image © Research Machines plc)

Fishing boats with mussels and fish, Chile. Chile is the most important fishery in South America, and one of the world's leading exporters of fish. With a very long marine coastline and excellent water quality, Chile's waters are home to an abundance of fish and crustaceans, which form an important part of the country's economy.

fishing and fisheries

(Image © Research Machines plc)

Industrial fishing, especially tuna fishing and canning, is an increasingly significant factor in the economy of the Seychelles. Earnings from licence fees, paid by foreign trawlers to fish Seychelles territorial waters, are growing every year.

fishing and fisheries

(Image © Corel)

A sardine fisherman casting a net in the Sea of Cortez, Mexico. This is a traditional mthod of catching fish, superseded in many parts of the world by ships trawling with much larger nets.

Fisheries

Go to site

Web site of the Fisheries Department of the United Nations Food and Agriculture Organization. This is a comprehensive report on the state of the world's fisheries and how to manage them for future generations. Information can be accessed via species and by country and there are links to a large number of international and scientific bodies concerned with fishing.

fission

in physics, the splitting of a heavy atomic nucleus into two or more major fragments. It is accompanied by the emission of two or three neutrons and the release of large amounts of nuclear energy.

Fission occurs spontaneously in nuclei of uranium-235, the main fuel used in nuclear reactors. However, the process can also be induced by bombarding nuclei with neutrons because a nucleus that has absorbed a neutron becomes unstable and soon splits. For example:

$^{235}{}_{92}U + {}^{1}{}_{0}n \rightarrow {}^{236}{}_{92}U \rightarrow 2$ nuclei + 2-3 neutrons + energy

The neutrons released spontaneously by the fission of uranium nuclei may therefore be used in turn to induce further fissions, setting up a chain reaction that must be controlled if it is not to result in a nuclear explosion. In a nuclear power station, heat energy released from the chain reaction is used to boil water to produce steam. The steam is used to drive the turbine of a generator to produce electricity. An atomic bomb uses pure uranium-235 to start an uncontrolled nuclear reaction, producing large amounts of heat energy. The minimum amount of fissile material that can undergo a continuous chain reaction is referred to as the critical mass.

fistula

in medicine, an abnormal pathway developing between adjoining organs or tissues, or leading to the exterior of the body. A fistula developing between the bowel and the bladder, for instance, may give rise to urinary-tract infection by intestinal organisms.

fit

in medicine, popular term for convulsion.

fitness

in genetic theory, a measure of the success with which a genetically determined character can spread in future generations. By convention, the normal character is assigned a fitness of one and variants (determined by other alleles) are then assigned fitness values relative to this. Those with fitness greater than one will spread more rapidly and will ultimately replace the normal allele; those with fitness less than one will gradually die out.

fixed point

temperature that can be accurately reproduced and used as the basis of a temperature scale. In the Celsius scale, the fixed points are the temperature of melting ice, defined to be 0°C (32°F), and the temperature of boiling water (at standard atmospheric pressure), defined to be 100°C (212°F).

fjord

or fiord

narrow sea inlet enclosed by high cliffs. Fjords are found in Norway, New Zealand, Southern Chile, and western parts of Scotland. They are formed when an overdeepened U-shaped glacial valley is drowned by a rise in sea-level. At the mouth of the fjord there is a characteristic lip causing a shallowing of the water. This is due to reduced glacial erosion and the deposition of moraine at this point.

Fiordland is the deeply indented southwest coast of the South Island, New Zealand; one of the most beautiful inlets is Milford Sound.

Norwegian fjord

(Image © Corel)

Granite cliffs alongside deep fjord waters in Norway. The hard granite was carved out by powerful glaciers. Today, due to the warming influence of the Gulf Stream and the salt content of the water, the Norwegian fjords are ice-free all year.

flaccidity

in botany, the loss of rigidity (turgor) in plant cells, caused by loss of water from the central vacuole so that the cytoplasm no longer pushes against the cellulose cell wall. If this condition occurs throughout the plant then wilting is seen.

Flaccidity can be induced in the laboratory by immersing the plant cell in a strong saline solution. Water leaves the cell by osmosis causing the vacuole to shrink. In extreme cases the actual cytoplasm pulls away from the cell wall, a phenomenon known as plasmolysis.

flag

in botany, another name for iris, especially yellow flag (*Iris pseudacorus*), which grows wild in damp places throughout Europe; it is a true water plant but adapts to garden borders. It has a thick rhizome (underground stem), stiff bladelike leaves, and stems up to 150 cm/5 ft high. The flowers are large and yellow.

flagellum

(plural flagella) small hairlike organ on the surface of certain cells. Flagella are the motile organs of certain protozoa and single-celled algae, and of the sperm cells of higher animals. Unlike cilia, flagella usually occur singly or in pairs; they are also longer and have a more complex whiplike action.

Each flagellum consists of contractile filaments producing snakelike movements that propel cells through fluids, or fluids past cells. Water movement inside sponges is also produced by flagella.

flag of convenience

national flag flown by a ship that has registered in that country in order to avoid legal or tax commitments (also known as offshore registry). Flags of convenience are common in the merchant fleets of Liberia and Panama; ships registered in these countries avoid legislation governing, for example, employment of sailors and minimum rates of pay.

In 1995 75 million gross tonnes of shipping was registered in Panama, making it the world's largest merchant fleet. Ships registered under flags of convenience accounted in 1993 for 34% of the world's fleet but 60% of all maritime accidents.

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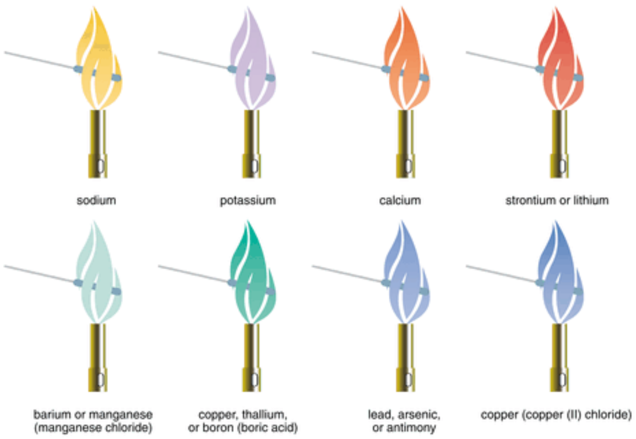
flame test

in chemistry, the use of a flame to identify metal cations present in a solid.

A nichrome or platinum wire is moistened with acid, dipped in a compound of the element, either powdered or in solution, and then held in a hot non-luminous flame. The colour produced in the flame is characteristic of metals present; for example, sodium burns with an orange-yellow flame, and potassium with a lilac one.

flame test


sodium
potassium
calcium
strontium or lithium
barium or manganese (manganese chloride)
copper, thallium, or boron (boric acid)
lead, arsenic, or antimony
copper (copper (II) chloride)

(Image © Research Machines plc)

Metals heated in the flame of a Bunsen burner burn with characteristic coloured flames. This is because when heated the electrons in the metal move around and give off light. Flame tests are useful for identifying unknown metals.

Flame test colours

element	colour of flame
sodium	orange-yellow
potassium	lilac
calcium	red or yellow-red
strontium, lithium	crimson
barium, manganese (manganese chloride)	pale green
copper, thallium, boron (boric acid)	bright green
lead, arsenic, antimony	livid blue
copper (copper (II) chloride)	bright blue

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flame tree

any of various trees with brilliant red flowers, including the smooth-stemmed semi-deciduous *Brachychiton acerifolium* with scarlet bell-shaped flowers, native to Australia, but spread throughout the tropics.

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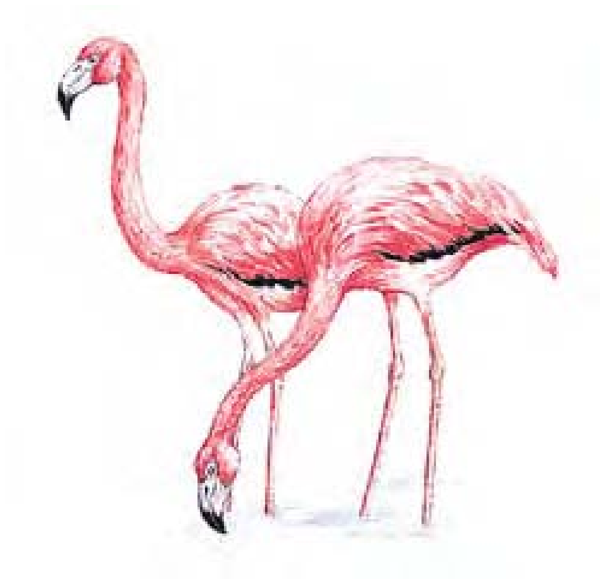
flamingo

long-legged and long-necked wading bird, family Phoenicopteridae, of the stork order Ciconiiformes. Largest of the family is the greater or roseate flamingo *Phoenicopterus ruber*, found in Africa, the Caribbean, and South America, with delicate pink plumage and 1.25 m/4 ft tall. They sift the mud for food with their downbent bills, and build colonies of high, conelike mud nests, with a little hollow for the eggs at the top.

flamingo



(Image © Research Machines plc)

The greater, or roseate, flamingo may seem strangely built but it is, in fact, perfectly adapted to its environment. Its long legs enable it to feed while standing in water; its beak is held horizontally beneath the water. Water flows into the beak and is expelled through a mesh of fine hairs which sieves out food particles.

Flamsteed, John (1646-1719)

English astronomer. He began systematic observations of the positions of the stars, Moon, and planets at the Royal Observatory he founded at Greenwich, London, in 1676. His observations were published in *Historia Coelestis Britannica* (1725).

As the first Astronomer Royal of England, Flamsteed determined the latitude of Greenwich, the slant of the ecliptic, and the position of the equinox. He also worked out a method of observing the absolute right ascension (a coordinate of the position of a heavenly body) that removed all errors of parallax, refraction, and latitude. Having obtained the positions of 40 reference stars, he then computed positions for the rest of the 3,000 stars in his catalogue.

Flamsteed, John

Go to site

Biography of the English astronomer. Aside from his methodical astronomical observations Flamsteed is most noted for having the Royal Observatory at Greenwich built for him during his period as astronomer royal. Several literature sources for further reading on the life and works of Flamsteed are listed here, and his portrait is also shown at this Web site.

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flash flood

flood of water in a normally arid area brought on by a sudden downpour of rain. Flash floods are rare and usually occur in mountainous areas. They may travel many kilometres from the site of the rainfall.

Because of the suddenness of flash floods, little warning can be given of their occurrence. In 1972 a flash flood at Rapid City, South Dakota, USA, killed 238 people along Rapid Creek.

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flash memory

type of EEPROM memory that can be erased and reprogrammed without removal from the computer.

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flatfish

bony fishes of the order Pleuronectiformes, having a characteristically flat, asymmetrical body with both eyes (in adults) on the upper side. Species include flounders, turbots, halibuts, plaice, and the European soles.

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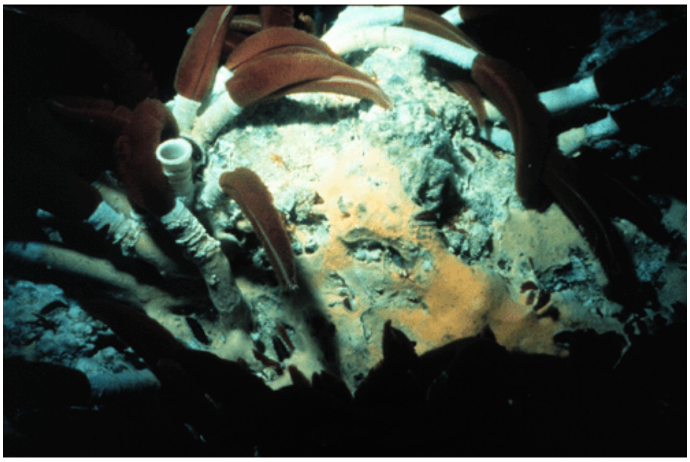
flatworm

invertebrate of the phylum Platyhelminthes. Some are free-living, but many are parasitic (for example, tapeworms and flukes). The body is simple and bilaterally symmetrical, with one opening to the intestine. Many are hermaphroditic (with both male and female sex organs) and practise self-fertilization.

flatworm

In many flatworm species, the sperm is not received into a genital opening, instead the penis pierces the skin to inject sperm straight into the body. As this causes some damage to the flatworm, in each sexual encounter both flatworms attempt to take the male role. Consequently flatworms will vie with each other for an hour or more with each attempting to stab the other with its penis, whilst avoiding being stabbed itself.

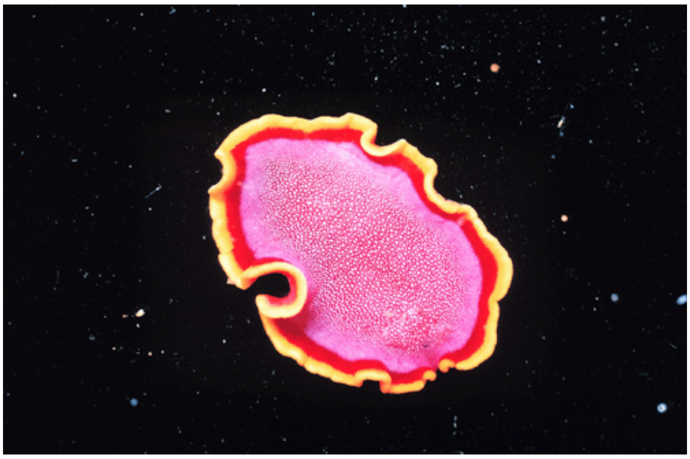
worm



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

These tube worms live at great depth around hydrothermal vents in the eastern Pacific. They were discovered in 1979, when marine geologists were exploring areas of sea bed not far from the Atacama Trench, about 160 km/100 mi from the coasts of Peru and Chile. The tube worms were given the scientific name *Riftia pachyptila*: *Riftia* after the Trench, and *pachyptila* meaning thickly frond-covered.

flatworm



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

A marine turbellarian flatworm seems to propel itself along simply by rippling the ribbonlike edges of its flat body. In fact, the body surface of the flatworm is covered in tiny mucus-covered hairlike projections, and the ripples create waves of mucus, through which the creature pulls itself smoothly forward, using the hairlike projections.

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flax

any of a group of plants including the cultivated *L. usitatissimum*; **linen** is produced from the fibre in its stems. The seeds yield **linseed oil**, used in paints and varnishes. The plant, of almost worldwide distribution, has a stem up to 60 cm/24 in high, small leaves, and bright blue flowers. (Genus *Linum*, family Linaceae.)

After extracting the oil, what is left of the seeds is fed to cattle. The stems are retted (soaked) in water after harvesting, and then dried, rolled, and scutched (pounded), separating the fibre from the central core of woody tissue. The long fibres are spun into linen thread, twice as strong as cotton, yet more delicate, and suitable for lace; shorter fibres are used to make string or paper.

Annual world production of flax fibre amounts to approximately 60,000 tonnes, with Russia, Ukraine, Belarus, and Latvia accounting for half of the total. Other producers are Belgium, the Netherlands, and Northern Ireland.

Flax

Go to site

Informative resource relating to flax. It contains detailed descriptions of the plant, its habitat, and even its history. There are also notes on the constituents of the plant, as well as information on it's possible medicinal uses, which include acting as a laxative and treating burns.

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flea

wingless insect of the order Siphonaptera, with blood-sucking mouthparts. Fleas are parasitic on warm-blooded animals. Some fleas can jump 130 times their own height.

Species include the human flea *Pulex irritans*; the rat flea *Xenopsylla cheopsis*, the transmitter of plague and typhus; and (fostered by central heating) the cat and dog fleas *Ctenocephalides felis* and *C. canis*.

flea: acceleration

As a flea jumps, its rate of acceleration is 20 times that of a space shuttle during launching. It reaches a speed of 100 m per sec within the first 500th of a second.

flea: larvae

The wormlike larvae of fleas are eyeless and legless. They do not suck blood, but feed on digested blood excreted by the adult flea.

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fleabane

any of several plants of the genera *Erigeron* and *Pulicaria*, of the daisy or composite family. Poor Robin's plantain *E. pulchellus* has lavender-rayed flowers on tall, slender stalks and is native to eastern North America.

Fleming, Alexander (1881-1955)

Scottish bacteriologist who was awarded a Nobel Prize for Physiology or Medicine in 1945 for his discovery of the bactericidal effect of penicillin in 1928. In 1922 he had discovered lysozyme, an antibacterial enzyme present in saliva, nasal secretions, and tears. While studying this, he found an unusual mould growing on a culture dish, which he isolated and grew into a pure culture. This led to his discovery of penicillin, which came into use in 1941. He shared the award with Howard W Florey and Ernst B Chain, whose research had brought widespread realization of the value of penicillin with its isolation and its development as an antibiotic drug.

Fleming, Alexander

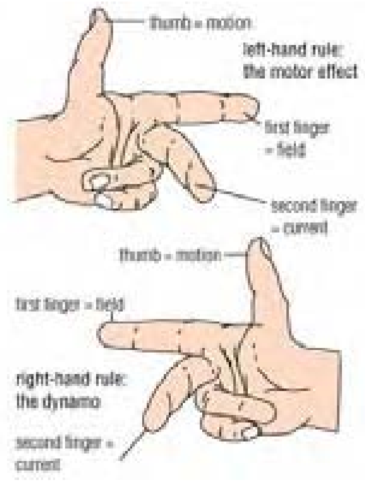
Go to site

Biography of the Scottish bacteriologist, accompanied by an explanation of his discovery of penicillin.

Fleming's rules

memory aids used to recall the relative directions of the magnetic field, current, and motion in an electric generator or motor, using one's fingers. The three directions are represented by the thu*m*b (for *m*otion), *f*orefinger (for *f*ield), and second finger (for conventional current), all held at right angles to each other. The right hand is used for generators and the left for motors. The rules were devised by the English physicist John Fleming.

Fleming's rules



(Image © Research Machines plc)

Fleming's rules give the direction of the magnetic field, motion, and current in electrical machines. The left hand is used for motors, and the right hand for generators and dynamos.

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flesh fly

medium-sized fly varying from golden-brown to dark grey. The larvae feed on carrion and animal waste, though the larvae of *Wohlfahrtia* often invade the skin of children and young animals and other larvae will cause myiasis (invasion of the tissues) when the skin is already broken by a cut or abrasion.

classification

Flesh flies are members of the genera *Sarcophaga* and *Wohlfahrtia* in the family Sarcophagidae of the insect order Diptera, class Insecta, phylum Arthropoda.

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flexor

any muscle that bends a limb. Flexors usually work in opposition to other muscles, the extensors, an arrangement known as antagonistic.

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flight

or aviation

method of transport in which aircraft carry people and goods through the air. People first took to the air in lighter-than-air craft such as balloons in 1783 and began powered flight in 1852 in airships, but the history of aviation, both for civilian and military use, is dominated by the heavier-than-air craft called airplanes. Developed from glider design, with wings, a tail, and a fuselage, the first successful flight of a powered, heavier-than-air craft was in 1896 by S P Langley's unmanned plane (*Model No 5*), for 3/4 of a mile near the Potomac River; then, in 1903, the Wright brothers flew the first piloted plane at Kitty Hawk. In 1903, Glenn Curtiss publicized flight in the USA and began the first flying school in 1909. A competition for the development of airplanes was inspired by a series of flights and air races in the USA and Europe, and planes came into their own during World War I, being used by both sides. Biplanes were generally succeeded by monoplanes in the 1920s and 1930s, and they used runways or water (seaplanes and flying boats) for takeoffs and landings at airfields that soon became airports. In these decades airlines were formed for international travel, airmail, and cargo. The first jet plane was produced in Germany in 1939, the Heinkel He-178, but conventional prop planes were used for most of the destruction and transport of World War II. The 1950s brought economical passenger air travel on turboprops and jet airliners, which by the 1970s flew transatlantic in about six hours. The Concorde, a supersonic jetliner, flew passengers over that route in about three hours.

balloons

The beginning of the development of the balloon was the work of two brothers, Joseph and Etienne Montgolfier, who came to the conclusion that a paper bag filled with a 'substance of a cloud-like nature' would float in the atmosphere. They made a number of experiments which attracted attention and further efforts from others. Progress was made gradually, and the first person-carrying ascent took place in October 1783, when Pilatre de Rozier went up in a Montgolfier captive balloon. The first woman to ascend was Madame Thible, who went up from Lyons in 1784. In 1859 a balloon flight of over 994 mi/1,600 km was made in the USA.

adding power

It had long been recognized that the difficulty with balloons was navigating through the air. Oars were tried, but were not successful. The first attempt to navigate the balloon by means of a small, light engine came in 1852, the experiment being made by Henri Giffard. From 1897 the development of the airship was the special work of Ferdinand Zeppelin. In 1900 he made his first flight with a dirigible balloon carrying five men. It was made of aluminium, supported by gas-bags, and driven by two motors, each of about 12 kW. His first experiment met with some success, a second, more powerful version was wrecked, and a third met with great success. This airship carried 11 passengers and attained a speed of about 34 mph/55 kph, traveling about 248 mi/400 km in 11 hours, but was wrecked by a storm in 1908, caught fire, and was completely destroyed.

powered flight

In the late 19th century experiments were being made with soaring machines and hang gliders, chiefly by Otto Lilienthal, who, with an arrangement formed on the plan of birds' wings, attempted to imitate their 'soaring flight'. Following up Lilienthal's ideas, the Wright brothers produced their first powered airplane in 1903. Their first successful machine was simply an airplane that flew in a straight line, but this received many modifications; and in 1908 they went to France to carry on experiments, during which Wilbur Wright created a record by remaining in the air for over an hour while carrying a passenger. He also attained a speed of 37 mph/60 kph.

In Europe, at the beginning of the 20th century, France led in airplane design and Louis Blériot brought aviation much publicity by crossing the English Channel in 1909, as did the Reims air races of that year. The first powered flight in the UK was made by Samuel Franklin Cody in 1908. In 1912 Sopwith and Bristol both built small biplanes. The first big twin-engined airplane was the Handley Page bomber of 1917. The stimulus of World War I (1914-18) and rapid development of the gasoline engine led to increased power, and speeds rose to 200 mph/320 kph. Streamlining the body of planes became imperative: the body, wings, and exposed parts were reshaped to reduce drag. Eventually the biplane was superseded by the internally braced monoplane structure. Probably the most successful plane of this type ever produced was the Douglas DC-3 and all its variants – with about 10,000 built, used for passengers and cargo in the 1930s and war duty in World War II. The DC-3 is still in daily use. Although by the 1930s planes had acquired the range for long-distance flights needed in cargo, mail, and passenger service, by the 1940s new design concepts were developed especially for warplanes that later became important to peacetime aviation, such as the jet engine.

jet aircraft

The German Heinkel 178, built in 1939, was the first jet plane; it was driven, not by a propeller as all planes before it, but by a jet of hot gases. German jets were in use during World War II by 1943; British jet fighters went into action during the last year of the war. The rapid development of the jet plane led to enormous increases in power and speed until air-compressibility effects were felt near the speed of sound, which at first seemed to be a flight speed limit (the sound barrier). The sound barrier was first broken in the USA in 1947 by a rocket-powered aircraft piloted by Chuck Yeager. To attain supersonic speed, streamlining the aircraft body became insufficient: wings were swept back, engines buried in wings and tail units, and bodies were even eliminated in all-wing delta designs. In the 1950s the first jet airliners, such as the Comet (first introduced in 1949), were introduced into service. The late 1960s saw the introduction of the jumbo jet, and in 1976 the Anglo-French Concorde, which made a transatlantic crossing in under three hours, came into commercial service and continued until October 2003. Today jet planes dominate both military and civilian aviation, although many light planes – for sport and business – still use piston engines and propellers. Clubs now restore old and antique planes, which are flown in demonstrations, displayed and flown in airshows, and donated to museums. Prop planes still see use in agricultural crop dusting, in bush piloting (especially in Alaska), and for sky writing.

other developments

During the 1950s and 1960s research was done on V/STOL (vertical and/or short takeoff and landing) aircraft. The British Harrier jet fighter has been the only VTOL aircraft to achieve commercial success, but STOL technology has fed into subsequent generations of aircraft. The 1960s and 1970s also saw the development of variable geometry ('swing-wing') aircraft, the wings of which can be swept back in flight to achieve higher speeds. In the 1980s much progress was made in 'fly-by-wire' aircraft with computer-aided controls. International partnerships have developed both civilian and military aircraft. The Airbus is a wide-bodied airliner built jointly by companies from France, Germany, the UK, the Netherlands, and Spain. The Eurofighter 2000 is a joint project between the UK, Italy, Germany, and Spain. The B-2 bomber, (a stealth bomber) developed by the US Air Force in 1989, is invisible to radar. The altitude record for a solar-powered plane was set in 1997 by Pathfinder, a 98-ft/30-m wingspan aircraft, which reached 67,349 ft/20,528 m above sea level over Hawaii.

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flight simulator

computer-controlled pilot-training device, consisting of an artificial cockpit mounted on hydraulic legs, that simulates the experience of flying a real aircraft. Inside the cockpit, the trainee pilot views a screen showing a computer-controlled projection of the view from a real aircraft, and makes appropriate adjustments to the controls. The computer monitors these adjustments, changes both the alignment of the cockpit on its hydraulic legs, and the projected view seen by the pilot. In this way a trainee pilot can progress to quite an advanced stage of training without leaving the ground.

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flint

compact, hard, brittle mineral (a variety of chert), brown, black, or grey in colour, found as nodules in limestone or shale deposits. It consists of cryptocrystalline (grains too small to be visible even under a light microscope) silica, SiO_2, principally in the crystalline form of quartz. Implements fashioned from flint were widely used in prehistory.

The best flint, used for Neolithic tools, is **floorstone**, a shiny black flint that occurs deep within chalk.

Because of their hardness (7 on the Mohs scale), flint splinters are used for abrasive purposes and, when ground into powder, added to clay during pottery manufacture. Flints have been used for making fire by striking the flint against steel, which produces a spark, and for discharging guns. Flints in cigarette lighters are made from cerium alloy.

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flocculation

in soils, the artificially induced coupling together of particles to improve aeration and drainage. Clay soils, which have very tiny particles and are difficult to work, are often treated in this way. The method involves adding more lime to the soil.

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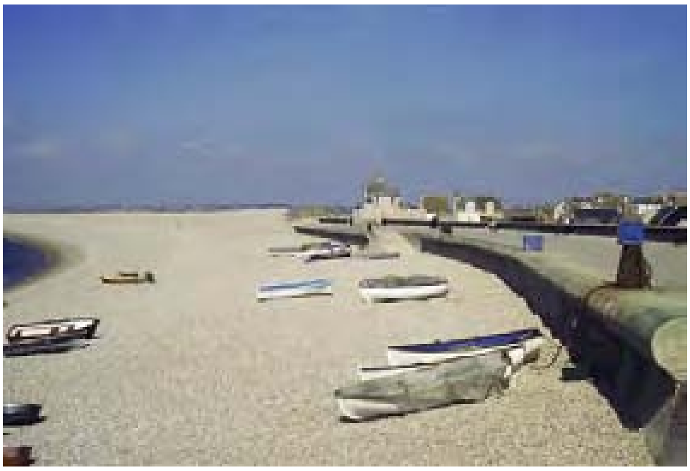
flooding

the inundation of land that is not normally covered with water. Flooding from rivers commonly takes place after heavy rainfall or in the spring after winter snows have melted. The river's discharge (volume of water carried in a given period) becomes too great, and water spills over the banks onto the surrounding flood plain. Small floods may happen once a year – these are called **annual floods** and are said to have a one-year return period. Much larger floods may occur on average only once every 50 years, or once every

100 years.

Flooding is least likely to occur in an efficient channel that is semicircular in shape. Flooding can also occur at the coast in stormy conditions (see storm surge) or when there is an exceptionally high tide. The Thames Flood Barrier was constructed in 1982 to prevent the flooding of London from the sea.

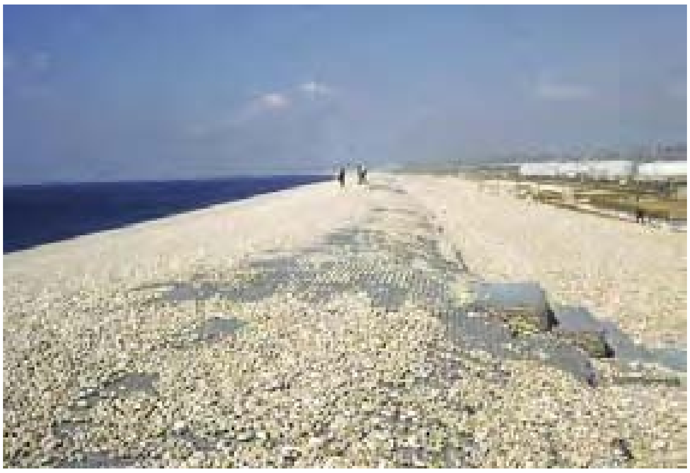
flooding



(Image © Garret Nagle)

Repeated flooding at Chiswell, Dorset, England, led to the construction of large-scale beach defences. This consisted of a sea wall, as shown here, and huge cages of pebbles (known as gabions) laid down on top of the beach. Some of the floods were caused by water soaking through the pebble beach, and flooding the low-lying village behind the beach. To prevent this, engineers placed steel piles down through the beach, diverting water away from the village of Chiswell.

flooding



(Image © Garret Nagle)

Repeated flooding at Chiswell, Dorset, led to the construction of large-scale beach defences. This consisted of a sea wall, shown here, and huge cages of pebbles (known as gabions) laid down on top of the beach. The gabions are partly covered by shingle thrown up during a storm.

Flood!

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page concerns many aspects of flooding. It takes an historical look at floods and examines the measures that engineers have taken to combat them. Three major rivers are discussed: the Yellow, Nile, and Mississippi. In addition to learning about the negative effects of floods, you can also find out about the benefits that floods bestow on farmland. There are many images dispersed throughout the site, plus an audio clip of a flood in progress.

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flood plain

area of periodic flooding along the course of a river valley. When river discharge exceeds the capacity of the channel, water rises over the channel banks and floods the surrounding low-lying lands. As water spills out of the channel some alluvium (silty material) will be deposited on the banks to form levees (raised river banks). This water will slowly seep onto the flood plain, depositing a new layer of rich fertile alluvium as it does so. Many important flood plains, such as the inner Nile delta in Egypt, are in arid areas where their exceptional productivity is very important to the local economy.

A flood plain is a natural feature, flooded at regular intervals. By plotting floods that have occurred we can speak of the size of flood we would expect once every 10 years, 100 years, 500 years, and so on.

Even the most energetic flood-control plans (such as dams, dredging, and channel modification) sometimes fail, and if towns and villages are built on a flood plain there is always some risk. It is wiser to use flood plains in ways that are compatible with flooding, such as for agriculture or parks.

Flood-plain features include meanders and oxbow lakes.

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floppy disk

in computing, a storage device consisting of a light, flexible disk enclosed in a cardboard or plastic jacket. The disk is placed in a disk drive, where it rotates at high speed. Data are recorded magnetically on one or both surfaces.

Floppy disks were invented by IBM in 1971 as a means of loading programs into a computer. They were originally 20 cm/8 in in diameter and typically held about 240 kilobytes of data. Present-day floppy disks, widely used on microcomputers, are 8.8 cm/3.5 in in diameter, and generally hold up to 2 megabytes, depending on the disk formatting.

Floppy disks are inexpensive, and light enough to send through the post, but have slower access speeds and are more fragile than hard disks. The use of floppy disks is increasingly being replaced by the higher capacity and more robust memory stick or pen-drive. (See also disk.)

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floral diagram

diagram showing the arrangement and number of parts in a flower, drawn in cross section. An ovary is drawn in the centre, surrounded by representations of the other floral parts, indicating the position of each at its base. If any parts such as the petals or sepals are fused, this is also indicated. Floral diagrams allow the structure of different flowers to be compared, and are usually shown with the floral formula.

---

floral formula

symbolic representation of the structure of a flower. Each kind of floral part is represented by a letter (K for calyx, C for corolla, P for perianth, A for androecium, G for gynoecium) and a number to indicate the quantity of the part present, for example, C5 for a flower with five petals. The number is in brackets if the parts are fused. If the parts are arranged in distinct whorls within the flower, this is shown by two separate figures, such as A5 + 5, indicating two whorls of five stamens each.

A flower with radial symmetry is known as **actinomorphic**; a flower with bilateral symmetry as **zygomorphic**.

---

floret

small flower, usually making up part of a larger, composite flower head. There are often two different types present on one flower head: disc florets in the central area, and ray florets around the edge which usually have a single petal known as the ligule. In the common daisy, for example, the disc florets are yellow, while the ligules are white.

Florey, Howard Walter (1898-1968)

Baron Florey

Australian pathologist who was awarded the Nobel Prize for Physiology or Medicine in 1945 with Ernst Chain for the isolation of penicillin and its development as an antibiotic drug. His research into lysozyme, an antibacterial enzyme discovered by Alexander Fleming (who shared the prize), led him to study penicillin (another of Fleming's discoveries), which he and Chain isolated and prepared for widespread use.

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flotation, law of

law stating that a floating object displaces its own weight of the fluid in which it floats. See Archimedes principle.

---

flotation process

common method of preparing mineral ores for subsequent processing by making use of the different wetting properties of various components. The ore is finely ground and then mixed with water and a specially selected wetting agent. Air is bubbled through the mixture, forming a froth; the desired ore particles attach themselves to the bubbles and are skimmed off, while unwanted dirt or other ores remain behind.

flounder

any of a number of flatfishes of several genera. A common North American species is the southern flounder *Paralichthys lethostigma*, a valuable food fish about 20 in/50 cm long.

---

flour beetle

beetle that is a major pest of stored agricultural products, such as flour. They are found worldwide in granaries and stores where both the adult beetles and the larvae feed on damaged grain or flour. Neither adults nor larvae can eat intact grains.

classification

Flour beetles are in the genus *Tribolium*, family Tenebrionidae, class Insecta, phylum Arthropoda.

---

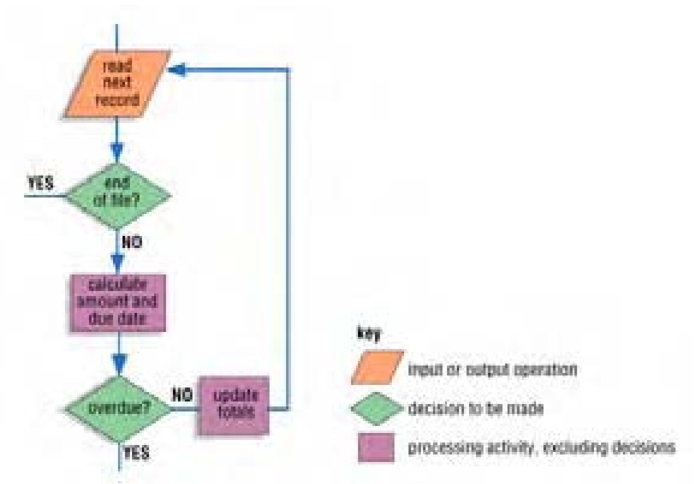
flow chart

diagram, often used in computing, to show the possible paths that data can take through a system or program.

A **system flow chart**, or **data flow chart**, is used to describe the flow of data through a complete data-processing system. Different graphic symbols represent the clerical operations involved and the different input, storage, and output equipment required. Although the flow chart may indicate the specific programs used, no details are given of how the programs process the data.

A **program flow chart** is used to describe the flow of data through a particular computer program, showing the exact sequence of operations performed by that program in order to process the data. Different graphic symbols are used to represent data input and output, decisions, branches, and subroutines.

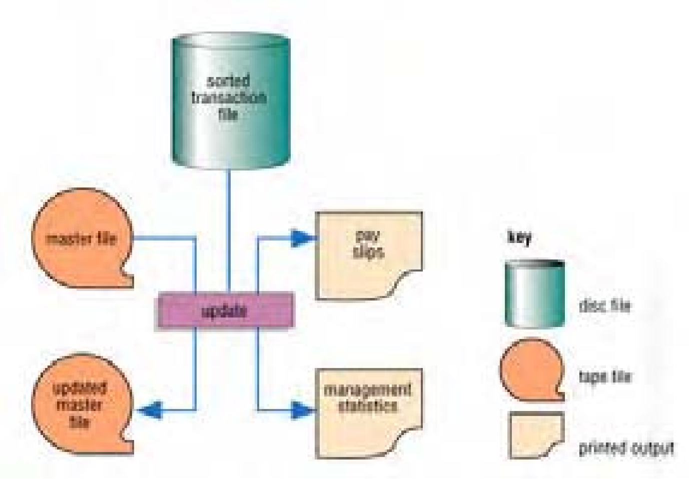
flow chart


read next record
YES
end of file?
NO
calculate amount and due date
overdue?
NO
update totals
YES
key
input or output operation
decision to be made
processing activity, excluding decisions

(Image © Research Machines plc)

A program flow chart shows the sequence of operations needed to achieve a task, in this case reading customer accounts and calculating the amount due for each customer. After an account has been processed, the program loops back to process the next one.

flow chart



(Image © Research Machines plc)

A system flow chart describes the flow of data through a data-processing system. This chart shows the data flow in a basic accounting system.

---

flower

reproductive unit of an angiosperm (flowering plant), typically consisting of four whorls of modified leaves: sepals, petals, stamens, and carpels. These are borne on a central axis or receptacle. The many variations in size, colour, number, and arrangement of parts are closely related to the method of pollination. Flowers adapted for wind pollination typically have reduced or absent petals and sepals and long, feathery stigmas that hang outside the flower to trap airborne pollen. In contrast, the petals of insect-pollinated flowers are usually conspicuous and brightly coloured.

structure

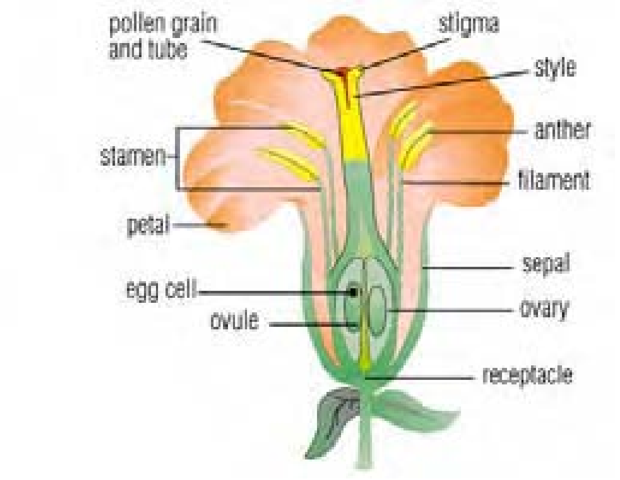
The sepals and petals form the **calyx** and **corolla** respectively and together comprise the **perianth** with the function of protecting the reproductive organs and attracting pollinators.

The stamens lie within the corolla, each having a slender stalk, or filament, bearing the pollen-containing anther at the top. Collectively they are known as the **androecium** (male organs). The inner whorl of the flower comprises the carpels, each usually consisting of an ovary in which are borne the ovules, and a stigma borne at the top of a slender stalk, or style. Collectively the carpels are known as the **gynoecium** (female organs).

types of flower

In size, flowers range from the tiny blooms of duckweeds scarcely visible to the naked eye to the gigantic flowers of the Malaysian *Rafflesia*, which can reach over 1 m/3 ft across. Flowers may grow either individually or in groups called inflorescences. The stalk of the whole inflorescence is termed a **peduncle**, and the stalk of an individual flower is termed a **pedicel**. A flower is termed hermaphrodite when it contains both male and female reproductive organs. When male and female organs are carried in separate flowers, they are termed **monoecious**; when male and female flowers are on separate plants, the term **dioecious** is used.

flower



(Image © Research Machines plc)

Cross section of a typical flower showing its basic components: sepals, petals, stamens (anthers and filaments), and carpel (ovary and stigma). Flowers vary greatly in the size, shape, colour, and arrangement of these components.

Birth flowers

Month	Flower
January	carnation, snowdrop
February	primrose, violet
March	jonquil, violet
April	daisy, sweet pea
May	hawthorn, lily of the valley
June	honeysuckle, rose
July	larkspur, water lily
August	gladiolus, poppy
September	aster, morning glory
October	calendula, cosmos
November	chrysanthemum
December	holly, narcissus, poinsettia

flowering plant

term generally used for angiosperms, which bear flowers with various parts, including sepals, petals, stamens, and carpels.

Sometimes the term is used more broadly, to include both angiosperms and gymnosperms, in which case the cones of conifers and cycads are referred to as 'flowers'. Usually, however, the angiosperms and gymnosperms are referred to collectively as seed plants, or spermatophytes.

The earliest flowering plant identified so far has been dated as being between 125 and 142 million years old, by Chinese palaeontologists, in 1998. The fossil *Archefructus* was found in northeast China. In 1996 UK palaeontologists found fossils in southern England of *Bevhalstia pebja*, a wetland herb about 25 cm/10 in high, which has been dated as early Cretaceous, about 130 million years old.

flue-gas desulphurization

process of removing harmful sulphur pollution from gases emerging from a boiler. Sulphur compounds such as sulphur dioxide are commonly produced by burning fossil fuels, especially coal in power stations, and are the main cause of acid rain.

The process is environmentally beneficial but expensive, adding about 10% to the cost of electricity generation.

fluid mechanics

study of the behaviour of fluids (liquids and gases) in motion. Fluid mechanics is important in the study of the weather, the design of aircraft and road vehicles, and in industries, such as the chemical industry, which deal with flowing liquids or gases.

fluke

any of various parasitic flatworms of the classes Monogenea and Digenea, that as adults live in and destroy the livers of sheep, cattle, horses, dogs, and humans. Monogenetic flukes can complete their life cycle in one host; digenetic flukes require two or more hosts, for example a snail and a human being, to complete their life cycle.

Fluke-caused diseases, such as bilhazia, affect tens of millions of people, mostly in sub-Saharan Africa.

fluorescence

short-lived luminescence (a glow not caused by high temperature). Phosphorescence lasts a little longer.

Fluorescence is used in strip and other lighting, and was developed rapidly during World War II because it was a more efficient means of illumination than the incandescent lamp. Recently, small bulb-size fluorescence lamps have reached the market. It is claimed that, if widely used, their greater efficiency could reduce demand for electricity. Other important applications are in fluorescent screens for television and cathode-ray tubes.

fluorescence microscopy

technique for examining samples under a microscope without slicing them into thin sections. Instead, fluorescent dyes are introduced into the tissue and used as a light source for imaging purposes. Fluorescent dyes can also be bonded to monoclonal antibodies and used to highlight areas where particular cell proteins occur.

fluoridation

addition of small amounts of fluoride salts to drinking water by certain water authorities to help prevent tooth decay. Experiments in Britain, the USA, and elsewhere have indicated that a concentration of fluoride of 1 part per million in tap water retards the decay of children's teeth by more than 50%.

Much concern has been expressed about the risks of medicating the population at large by the addition of fluoride to the water supply, but the medical evidence demonstrates conclusively that there is no risk to the general health from additions of 1 part per million of fluoride to drinking water.

fluoride

F^-

negative ion formed when hydrogen fluoride dissolves in water; compound formed between fluorine and another element.

The ending 'ide' in halides (such as fluorides, chlorides, and iodides) indicates that the halogen acts as the more electronegative partner (see electronegativity). As fluorine is the most electronegative element of all, this would apply to all of its compounds, but fluorinated hydrocarbons are not normally referred to as fluorides.

fluorine

chemical symbol F

pale yellow, gaseous, non-metallic element, atomic number 9, relative atomic mass 19. It is the first member of the halogen group of elements, and is pungent, poisonous, and highly reactive, uniting directly with nearly all the elements. It occurs naturally as the minerals fluorite (CaF_2) and cryolite (Na_3AlF_6). Hydrogen fluoride is used in etching glass, and the freons, which all contain fluorine, are widely used as refrigerants.

Fluorine was discovered by the Swedish chemist Karl Scheele in 1771 and isolated by the French chemist Henri Moissan in 1886. Combined with uranium as UF_6, it is used in the separation of uranium isotopes.

The Infrared Space Observatory detected hydrogen fluoride molecules in an interstellar gas cloud in the constellation Sagittarius in 1997. It was the first time fluorine had been detected in space.

Fluorine

Go to site

Attractive page describing this highly reactive gas, part of a much larger site containing online resources for teachers. Hypertext links show the importance of fluorine in areas such as the development of non-stick coatings and the prevention of tooth decay.

fluorite

or fluorspar

glassy, brittle halide mineral, calcium fluoride CaF_2, forming cubes and octahedra; colourless when pure, otherwise violet, blue, yellow, brown, or green.

Fluorite is used as a flux in iron and steel making; colourless fluorite is used in the manufacture of microscope lenses. It is also used for the glaze on pottery, and as a source of fluorine in the manufacture of hydrofluoric acid.

fluorocarbon

compound formed by replacing the hydrogen atoms of a hydrocarbon with fluorine. Fluorocarbons are used as inert coatings, refrigerants, synthetic resins, and as propellants in aerosols.

There is concern that the release of fluorocarbons - particularly those containing chlorine (chlorofluorocarbons, CFCs) - depletes the ozone layer, allowing more ultraviolet light from the Sun to penetrate the Earth's atmosphere, and increasing the incidence of skin cancer in humans.

fluvioglacial

of a process or landform associated with glacial meltwater. Meltwater, flowing beneath or ahead of a glacier, is capable of transporting rocky material and creating a variety of landscape features, including eskers, kames, and outwash plains.

---

flux

in smelting, a substance that combines with the unwanted components of the ore to produce a fusible slag, which can be separated from the molten metal. For example, the mineral fluorite, CaF_2, is used as a flux in iron smelting; it has a low melting point and will form a fusible mixture with substances of higher melting point such as silicates and oxides.

---

flux

in soldering, a substance that improves the bonding properties of solder by removing contamination from metal surfaces and preventing their oxidation, and by reducing the surface tension of the molten solder alloy. For example, with solder made of lead-tin alloys, the flux may be resin, borax, or zinc chloride.

---

fly

any insect of the order Diptera. A fly has a single pair of wings, antennae, and compound eyes; the hind wings have become modified into knoblike projections (halteres) used to maintain equilibrium in flight. There are over 90,000 species.

The mouthparts project from the head as a proboscis used for sucking fluids, modified in some species, such as mosquitoes, to pierce a victim's skin and suck blood. Discs at the ends of hairs on their feet secrete a fluid enabling them to walk up walls and across ceilings. Flies undergo complete metamorphosis; their larvae (maggots) are without true legs, and the pupae are rarely enclosed in a cocoon. The sexes are similar and coloration is rarely vivid, though some are metallic green or blue. The fruitfly, genus *Drosophila*, is much used in genetic experiments as it is easy to keep, fast-breeding, and has easily visible chromosomes.

fly

Fruit flies (*Drosophila*) reach sexual maturity in less than two weeks. This means that there are 25 generations a year. Every female can lay 100 eggs or more.

fly: sperm cells

The fruit fly *Drosophila bifurca* (1.5 cm/0.6 in long) has sperm cells that are 6 cm/2.4 in long (1,200 times longer than human sperm). Its testes take up 50% of its abdominal cavity and it produces fewer than 20 sperm cells at a time (human males produce millions).

Flies and Mosquitoes

Go to site

Colour photographs of flies and mosquitoes from Iowa State University's Entomology Image Gallery. They include the crane fly and crane fly larva, and several dozen images of different species of mosquito and mosquito parts. Click on a link to view each insect. There is a search engine at the top of the page to look for other species of insect.

---

flying dragon

lizard *Draco volans* of the family Agamidae. It lives in southeast Asia, and can glide on flaps of skin spread and supported by its ribs. This small (7.5 cm/3 in head and body) arboreal lizard can glide between trees for 6 m/20 ft or more.

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flying fish

any marine bony fishes of the family Exocoetidae, order Beloniformes, best represented in tropical waters. They have winglike pectoral fins that can be spread to glide over the water.

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flying fox

another name for the fruit bat, a fruit-eating bat of the suborder Megachiroptera.

---

flying lizard

another name for flying dragon.

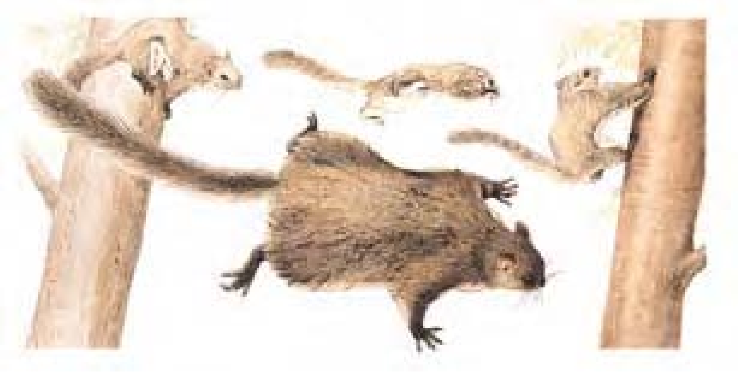
---

flying squirrel

any of 43 known species of squirrel, not closely related to the true squirrels. They are characterized by a membrane along the side of the body from forelimb to hindlimb (in some species running to neck and tail) which allows them to glide through the air. Several genera of flying squirrel are found in the Old World; the New World has the genus *Glaucomys*. Most species are eastern Asian.

The giant flying squirrel *Petaurista* grows up to 1.1 m/3.5 ft including tail.

flying squirrel



(Image © Research Machines plc)

Giant flying squirrels can glide over 400 m/440 yd between trees by stretching the broad, fur-covered membranes that extend from the sides of the body to the toes. They live in forested regions of Asia and are active at night.

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flystrike

or blowfly strike or sheep strike

infestation of the flesh of living sheep by blowfly maggots, especially those of the blue blowfly. It is one of the most costly sheep diseases in Australia, affecting all the grazing areas of New South Wales. Control has mainly been by insecticide, but nonchemical means, such as docking of tails and mulesing, are increasingly being encouraged. Mulesing involves an operation to remove the wrinkles of skin which trap moisture and lay the sheep open to infestation.

---

flywheel

heavy wheel in an engine that helps keep it running and smooths its motion. The crankshaft in a petrol engine has a flywheel at one end, which keeps the crankshaft turning in between the intermittent power strokes of the pistons. It also comes into contact with the clutch, serving as the connection between the engine and the car's transmission system.

FM

in physics, abbreviation for frequency modulation, or the variation of the frequency of a carrier wave in accordance with the signal to be transmitted. Used in radio, FM signals are constant in amplitude and have much better signal-to-noise ratio than AM (amplitude modulation). FM was invented by the US electronic engineer Edwin Armstrong.

---

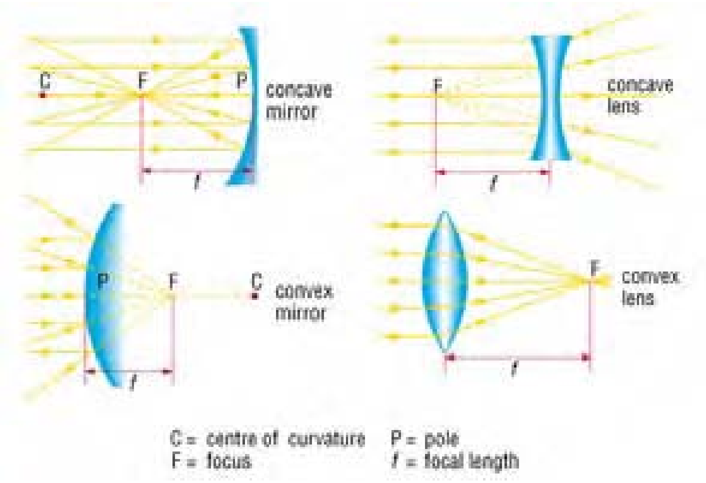
focal length

or focal distance

distance from the centre of a lens or curved mirror to the focal point. For a concave mirror or convex lens, it is the distance at which rays of light parallel to the principal axis of the mirror or lens are brought to a focus (for a mirror, this is half the radius of curvature). For a convex mirror or concave lens, it is the distance from the centre to the point from which rays of light originally parallel to the principal axis of the mirror or lens diverge after being reflected or refracted.

With lenses, the greater the power (measured in dioptres) of the lens, the shorter its focal length. The human eye has a lens of adjustable focal length to allow the light from objects of varying distance to be focused on the retina.

focal length



(Image © Research Machines plc)

The distance from the pole (P), or optical centre, of a lens or spherical mirror to its principal focus (F). The focal length of a spherical mirror is equal to half the radius of curvature (f = CP/2). The focal length of a lens is inversely proportional to the power of that lens (the greater the power the shorter the focal length).

---

focus

in astronomy, either of two points lying on the major axis of an elliptical orbit on either side of the centre. One focus marks the centre of mass of the system and the other is empty. In a circular orbit the two foci coincide at the centre of the circle and in a parabolic orbit the second focus lies at infinity. See Kepler's laws.

---

focus

or focal point

in optics, the point at which light rays converge, or from which they appear to diverge. Other electromagnetic rays, such as microwaves, and sound waves may also be brought together at a focus. Rays parallel to the principal axis of a lens or mirror are converged at, or appear to diverge from, the principal focus.

---

focus

in photography, the distance that a lens must be moved in order to focus a sharp image on the light-sensitive film at the back of the camera. The lens is moved away from the film to focus the image of closer objects. The focusing distance is often marked on a scale around the lens; however, some cameras now have an automatic focusing (autofocus) mechanism that uses an electric motor to move the lens.

---

fog

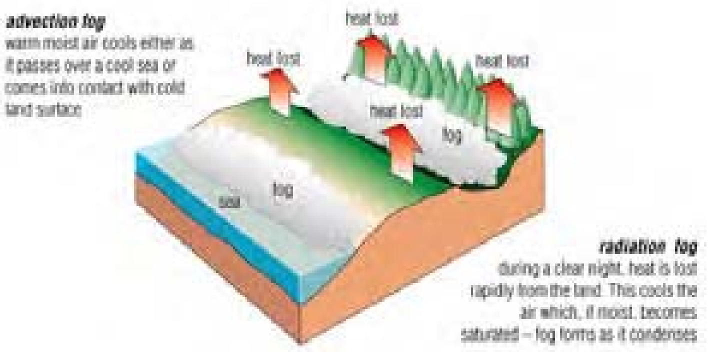
cloud that collects at the surface of the Earth, composed of water vapour that has condensed on particles of dust in the atmosphere. Cloud and fog are both caused by the air temperature falling below dew point. The thickness of fog depends on the number of water particles it contains. Officially, fog refers to a condition when visibility is reduced to 1 km/0.6 mi or less, and mist or haze to that giving a visibility of 1-2 km/0.6-1.2 mi.

There are two types of fog. An **advection fog** is formed by the meeting of two currents of air, one cooler than the other, or by warm air flowing over a cold surface. Sea fogs commonly occur where warm and cold currents meet and the air above them mixes. A **radiation fog** forms on clear, calm nights when the land surface loses heat rapidly (by radiation); the air above is cooled to below its dew point and condensation takes place. A **mist** is produced by condensed water particles, and a haze by smoke or dust.

In some very dry areas, for example Baja California, Canary Islands, Cape Verde Islands, Namib Desert, and parts of Peru and Chile, coastal fogs enable plant and animal life to survive without rain and are a potential source of water for human use (by means of water collectors exploiting the effect of condensation).

Industrial areas uncontrolled by pollution laws have a continual haze of smoke over them, and if the temperature falls suddenly, a dense yellow smog forms.

fog


advection fog
warm moist air cools either as it passes over a cool sea or comes into contact with cold land surface
heat lost
heat lost
heat lost
heat lost
fog
fog
sea
radiation fog
during a clear night, heat is lost rapidly from the land. This cools the air which, if moist, becomes saturated – fog forms as it condenses

(Image © Research Machines plc)

Advection fog occurs when two currents of air, one cooler than the other meet, or by warm air flowing over a cold surface. Radiation fog forms through rapid heat loss from the land, causing condensation to take place and a mist to appear.

föhn

or foehn

warm dry wind that blows down the leeward slopes of mountains.

The air heats up as it descends because of the increase in pressure, and it is dry because all the moisture was dropped on the windward side of the mountain. In the valleys of Switzerland it is regarded as a health hazard, producing migraine and high blood pressure. A similar wind, chinook, is found on the eastern slopes of the Rocky Mountains in North America.

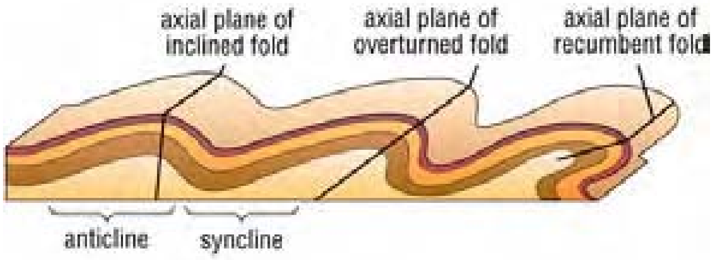
fold

in geology, a deformation (bend) in beds or layers of rock. Folds are caused by pressures within the Earth's crust resulting from plate-tectonic activity. Rocks are slowly pushed and compressed together, forming folds. Such deformation usually occurs in sedimentary layers that are softer and more flexible. If the force is more sudden, and the rock more brittle, then a fault forms instead of a fold.

Folding can result in gentle slopes or mountain chains such as the Rocky Mountains and the Alps. They can be eroded to form escarpments, giving rise to an undulating topography.

If the bend of the fold is arched up in the middle it is called an **anticline**; if it sags downwards in the middle it is called a **syncline**. The line along which a bed of rock folds is called its axis. The axial plane is the plane joining the axes of successive beds.

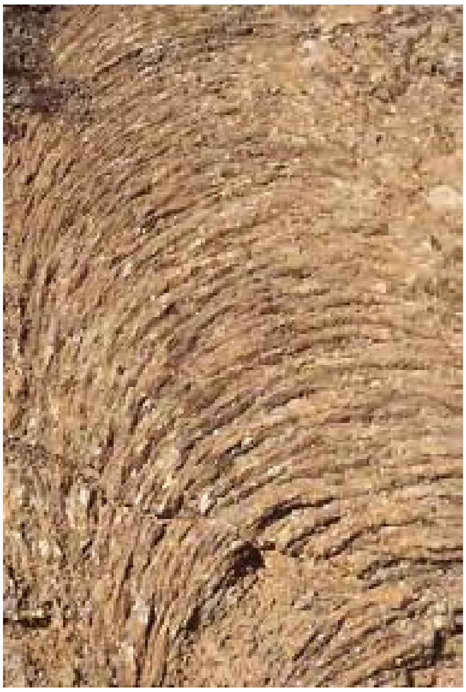
fold


axial plane of inclined fold
axial plane of overturned fold
axial plane of recumbent fold
anticline
syncline

(Image © Research Machines plc)

The folding of rock strata occurs where compression causes them to buckle. Over time, folding can assume highly complicated forms, as can sometimes be seen in the rock layers of cliff faces or deep cuttings in the rock. Folding contributed to the formation of great mountain chains such as the Himalayas.

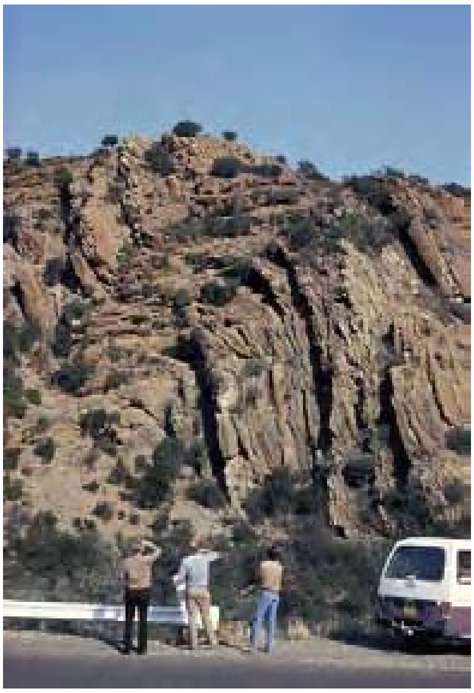
fold



(Image © Garret Nagle)

Some of the lava from the 1973 eruption of Helgafell, a volcano on the Icelandic island of Heimaey, was distorted as it flowed from the cone. Pressure from movements of the Earth caused it to bend; as the lava cooled and solidified, the curves and folds were preserved.

fold



(Image © Garret Nagle)

Folded rocks in the Little Karoo, South Africa. Owing to the movements of tectonic plates, horizontal rock layers (strata) are folded or bent. The folded rock may fracture, producing lines of weakness. These weaknesses or faults are exploited by rivers and other agents of erosion, and are more easily broken down than unfractured rock.

---

folic acid

vitamin of the B complex. It is found in liver, legumes and green leafy vegetables, and whole grain foods, and is also synthesized by the intestinal bacteria. It is essential for growth, and plays many other roles in the body. Lack of folic acid causes anaemia because it is necessary for the synthesis of nucleic acids and the formation of red blood cells.

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follicle

in botany, a dry, usually many-seeded fruit that splits along one side only to release the seeds within. It is derived from a single carpel. Examples include the fruits of the larkspurs *Delphinium* and columbine *Aquilegia*. It differs from a pod, which always splits open (dehisces) along both sides.

---

follicle

in zoology, a small group of cells that surround and nourish a structure such as a hair (hair follicle) or a cell such as an egg (Graafian follicle; see menstrual cycle).

---

follicle-stimulating hormone

FSH

hormone produced by the pituitary gland. It affects the ovaries in women, stimulating the production of an egg cell.

Luteinizing hormone is needed to complete the process. In men, FSH stimulates the testes to produce sperm. It is used to treat some forms of infertility.

Fomalhaut

or Alpha Piscis Austrini

brightest star in the southern constellation Piscis Austrinus and the 18th-brightest star in the night sky. It is 25 light years from the Sun, with a true luminosity 13 times that of the Sun.

Fomalhaut is one of a number of stars around which IRAS (the Infra-Red Astronomy Satellite) detected excess infrared radiation. This comes from a region of solid particles around the star that has now been imaged by the Hubble Space Telescope. This material may be a planetary system in the process of formation.

---

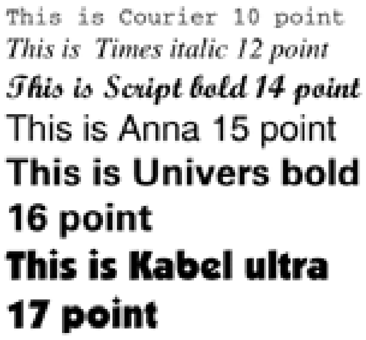
font

or fount

complete set of printed or display characters of the same typeface, size, and style (bold, italic, underlined, and so on).

Fonts used in computer setting are of two main types: bit-mapped and outline.
Bit-mapped fonts are stored in the computer memory as the exact arrangement of pixels or printed dots required to produce the characters in a particular size on a screen or printer.
Outline fonts are stored in the computer memory as a set of instructions for drawing the circles, straight lines, and curves that make up the outline of each character. Bit-mapped fonts become very ragged in appearance if they are enlarged and so a separate set of bit maps is required for each font size. In contrast, outline fonts (often marked as TT, or true type) can be scaled to any size and maintain exactly the same appearance.

font



This is Courier 10 point
This is Times italic 12 point
This is Script bold 14 point
This is Anna 15 point
This is Univers bold 16 point
This is Kabel ultra 17 point

(Image © Research Machines plc)

An example of different font typefaces and sizes.

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food

anything eaten by human beings and other animals, or absorbed by plants, to sustain life and health. The building blocks of food are nutrients, and humans can utilize the following nutrients: **carbohydrates** as starches found in bread, potatoes, and pasta; as simple sugars in sucrose and honey; and as fibres in cereals, fruit, and vegetables; **proteins** from nuts, fish, meat, eggs, milk, and some vegetables; **fats** as found in most animal products (meat, lard, dairy products, fish), also in margarine, nuts and seeds, olives, and edible oils; **vitamins**, found in a wide variety of foods, except for vitamin B_{12} which is found mainly in foods of animal origin; and **minerals**, found in a wide variety of foods (for example, calcium from milk and broccoli, iodine from seafood, and iron from liver and green vegetables).

Nutritive value of foods

The energy value of each food is given in kilojoules (kJ) and kilocalories (kcal), and both have been calculated from the protein, fat, and carbohydrate content per 100 g of edible portion.

Food	Energy		Protein (g)	Fat (g)	Saturated fat (g)	Carbohydrate (g)
	kJ	kcal				
Cereal and cereal products						
Bread, brown	927	218	8.5	2.0	0.4	44.3
Bread, white	1,002	235	8.4	1.9	0.4	49.3
Flour, plain, white	1,450	341	9.4	1.3	0.2	77.7
Flour, wholemeal	1,318	310	12.7	2.2	0.3	63.9
Oats, porridge, raw	1,587	375	11.2	9.2	1.6	66.0
Rice, brown, boiled	597	141	2.6	1.1	0.3	32.1
Rice, white, boiled	587	138	2.6	1.3	0.3	30.9
Spaghetti, white, boiled	442	104	3.6	0.7	0.1	22.2
Dairy products						
Butter	3,031	737	0.5	81.7	54.0	0.0
Cheddar cheese	1,708	412	25.5	34.4	21.7	0.1
Cottage cheese	413	98	13.8	3.9	2.4	2.1
Cream, fresh, heavy	1,849	449	1.7	48.0	30.0	2.7
Cream, fresh	817	198	2.6	19.1	11.9	4.1
Eggs, boiled	612	147	12.5	10.8	3.1	0.0
Low-fat spread	1,605	390	5.8	40.5	11.2	0.5
Margarine, polyunsaturated	3,039	739	0.2	81.6	16.2	1.0
Milk, semi-skimmed	195	46	3.3	1.6	1.0	5.0
Milk, skimmed	140	33	3.3	0.1	0.1	5.0
Milk, whole	275	66	3.2	3.9	2.4	4.8
Yoghurt, whole milk, plain	333	79	5.7	3.0	1.7	7.8
Fish/seafood						
White fish, steamed, flesh only	417	98	22.8	0.8	0.2	0.0
Shrimps, boiled	451	107	22.6	1.8	0.4	0.0
Fruit						
Apples	199	47	0.4	0.1	0.0	11.8
Apricots	674	158	4.0	0.6	0.0	36.5
Avocados	784	190	1.9	19.5	4.1	1.9
Bananas	403	95	1.2	0.3	0.1	23.2
Cherries	203	48	0.9	0.1	0.0	11.5
Grapefruit	126	30	0.8	0.1	0.0	6.8
Grapes	257	60	0.4	0.1	0.0	15.4
Mangoes	245	57	0.7	0.2	0.1	14.1
Melon	119	28	0.6	0.1	0.0	6.6
Oranges	158	37	1.1	0.1	0.0	8.5
Peaches	142	33	1.0	0.1	0.0	14.0
Pears	169	40	0.3	0.1	0.0	10.0
Plums	155	36	0.6	0.1	0.0	8.8
Raspberries	109	25	1.4	0.3	0.1	4.6
Strawberries	113	27	0.8	0.1	0.0	6.0
Meat						
Beef, lean only, raw	517	123	20.3	4.6	1.9	0.0
Chicken, meat and skin, raw	954	230	17.6	17.7	5.9	0.0
Lamb, lean only, raw	679	162	20.8	8.8	4.2	0.0
Pork, lean only, raw	615	147	20.7	7.1	2.5	0.0
Vegetables						
Aubergine	64	15	0.9	0.4	0.1	2.2
Beetroot	195	46	2.3	0.0	0.0	9.5
Cabbage	109	26	1.7	0.4	0.1	4.1
Celery	32	7	0.5	0.2	0.0	0.9
Courgettes	74	18	1.8	0.4	0.1	1.8

Cucumber	40	10	0.7	0.1	0.0	1.5
Lettuce	59	14	0.8	0.5	0.1	1.7
Mushrooms	55	13	1.8	0.5	0.1	0.4
Onions	150	36	1.2	0.2	0.0	7.9
Parsnips	278	66	1.6	1.2	0.2	12.9
Peas	291	69	6.0	0.9	0.2	9.7
Peppers	65	15	0.8	0.3	0.1	2.6
Potatoes, new, flesh only	298	70	1.7	0.3	0.1	16.1
Potatoes, old, flesh only	318	75	2.1	0.2	0.0	17.2
Spinach	90	21	3.0	0.8	0.1	0.5
Sweetcorn kernels	519	122	2.9	1.2	0.2	26.6
Sweet potatoes	358	84	1.1	0.3	0.1	20.5
Tofu, soybean, steamed	304	73	8.1	4.2	0.5	0.7
Watercress	94	22	3.0	1.0	0.3	0.4

Food and Agriculture Organization

FAO

United Nations specialized agency that coordinates activities to improve food and timber production and levels of nutrition throughout the world. It is also concerned with investment in agriculture and dispersal of emergency food supplies. It has headquarters in Rome and was founded in 1945.

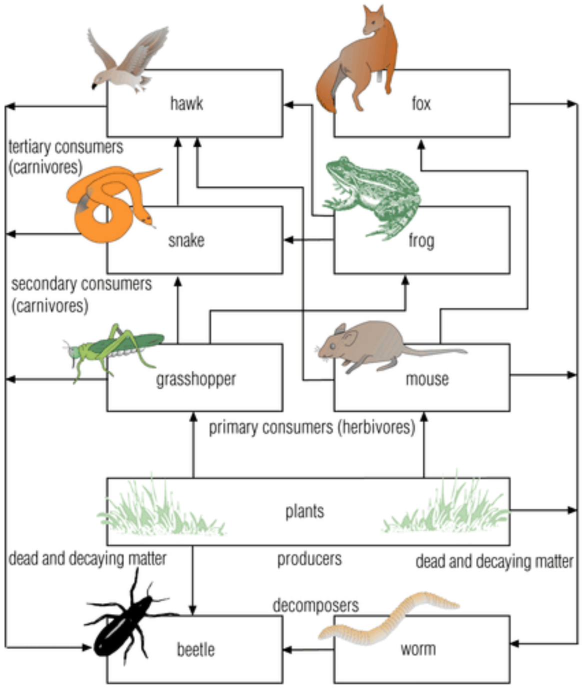
The USA cut its FAO funding in 1990 from $61.4 million to $18 million because of its alleged politicization.

food chain

in ecology, a sequence showing the feeding relationships between organisms in a habitat or ecosystem. It shows who eats whom. An organism in one food chain can belong to other food chains. This can be shown in a diagram called a **food web**.

One of the most important aspects of food is that it provides energy for an organism. So a food chain shows where each organism gets its energy. The arrow in a food chain represents the direction of energy flow. Not all of the energy in all of the organisms at one step of a food chain is available to the organisms later in the chain. In general, fewer organisms are found at each step, or trophic level, of the chain. A pyramid of numbers shows this clearly. Some organisms may be small but very numerous, so population size may not be a good measure of how much of an organism there is in a habitat. Biomass - the total mass of organisms in an area - may be a more useful measure.

food web



(Image © Research Machines plc)

The complex interrelationships between animals and plants in a food web. A food web shows how different food chains are linked in an ecosystem. Note that the arrows indicate movement of energy through the web. For example, an arrow shows that energy moves from plants to the grasshopper, which eats the plants.

food irradiation

exposure of food to low-level irradiation to kill micro-organisms; a technique used in food technology. In irradiation, X-rays from a radioactive or electron beam are passed through the food, and so the food is treated with ionizing radiation. The process helps to stop vegetables, for example potatoes, from sprouting, delays fruit from ripening, destroys insects and pests that may damage food, and destroys micro-organisms that may cause food spoilage. Irradiation is highly effective, and does not make the food any more radioactive than it is naturally. There is no major change to the macronutrients – carbohydrates, proteins, and fats – or the mineral content of the irradiated food. However, the micronutrient content of vitamins A, C, E, and K may be affected.

Irradiation is a relatively new technology, introduced into the UK in 1991. It is a method of preservation and is strictly controlled. Food preserved by irradiation must be clearly labelled. Safety regulations control the processing of the irradiated food and risk assessment is undertaken.

From Reactor to Refrigerator

Go to site

Part of the Why Files project, published by the National Institute for Science Education (NISE) and funded by the National Science Foundation, this page explains the how, why, and what of food irradiation. The highly readable text, laid out over five pages, includes information about other techniques being offered as means to protect food. Numerous images and diagrams enhance the text throughout. You will also find a comprehensive bibliography of sources for further research.

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food poisoning

any acute illness characterized by vomiting and diarrhoea and caused by eating food contaminated with harmful bacteria (for example, listeriosis), poisonous food (for example, certain mushrooms or puffer fish), or poisoned food (such as lead or arsenic introduced accidentally during processing). A frequent cause of food poisoning is *Salmonella* bacteria. Salmonella comes in many forms, and strains are found in cattle, pigs, poultry, and eggs. Some people are more susceptible to food poisoning than others, and extra care is taken with food products designed for babies, pregnant women, or elderly people. Many types of bacteria can cause food poisoning and the incubation periods, symptoms, and methods of control vary.

Under cooking poultry that has not been properly thawed is a common cause of food poisoning. Attacks of salmonella also come from contaminated eggs that have been eaten raw or cooked only lightly. Pork may carry the roundworm *Trichinella*, and rye the parasitic fungus ergot. The most dangerous food poison is the bacillus that causes botulism. This is rare but leads to muscle paralysis and often death. Food irradiation is intended to prevent food poisoning.

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food supply

availability of food, usually for human consumption. Food supply can be studied at scales ranging from individual households to global patterns. Since the 1940s the industrial and agricultural aspects of food supply have become increasingly globalized. New farming, packaging, and distribution techniques mean that the seasonal aspect of food supply has been reduced in wealthier nations such as the USA and the UK. In some less developed countries there are often problems of food scarcity and distribution caused by climate-related crop failure.

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food technology

the application of science to the commercial processing of foodstuffs. Food is processed to make it more palatable or digestible, for which the traditional methods include boiling, frying, flour-milling, bread-, yogurt-, and cheese-making, and brewing; to prevent the growth of bacteria, moulds, yeasts, and other micro-organisms; or to preserve it from spoilage caused by the action of enzymes within the food that change its chemical composition, resulting in changes in flavour, odour, colour, and texture. These changes are not always harmful or undesirable; examples of desirable changes are the ripening of cream in butter manufacture, flavour development of cheese, and the hanging of meat to tenderize the muscle fibres. Fatty or oily foods suffer oxidation of the fats, which makes them rancid.

Preservation enables foods that are seasonally produced to be available all the year. Traditional forms of **food preservation** include salting, smoking, pickling, drying, bottling, and preserving in sugar. Modern food technology also uses many novel processes and additives, which allow a wider range of foodstuffs to be preserved. All foods undergo some changes in quality and nutritional value when subjected to preservation processes. No preserved food is identical in quality to its fresh counterpart, therefore only food of the highest quality should be preserved.

In order to grow, bacteria, yeasts, and moulds need moisture, oxygen, a suitable temperature, and food. The various methods of food preservation aim to destroy the micro-organisms within the food, to remove one or more of the conditions essential for their growth, or to make the foods unsuitable for their growth. Adding large amounts of salt or sugar reduces the amount of water available to micro-organisms, because the water tied up by these solutes cannot be used for microbial growth. This is the principle in salting meat and fish, and in the manufacture of jams and jellies. These conditions also inhibit the enzyme activity in food. Preservatives may also be developed in the food by the controlled growth of micro-organisms to produce fermentation that may make alcohol, or acetic or lactic acid. Examples of food preserved in this way are vinegar, sour milk, yogurt, sauerkraut, and alcoholic beverages.

Refrigeration below 5°C/41°F (or below 3°C/37°F for cooked foods) slows the processes of spoilage, but is less effective for foods with a high water content. This process cannot kill micro-organisms, nor stop their growth completely, and a failure to realize its limitations causes many cases of food poisoning. Refrigerator temperatures should be checked as the efficiency of the machinery (see refrigeration) can decline with age, and higher temperatures are dangerous.

Deep freezing (preserving foods at very low temperatures – -18°C/-1°F for domestic freezers and from -18°C/-1°F to -29°C/-20°F for commercial freezers) stops almost all spoilage processes, except residual enzyme activity in uncooked vegetables and most fruits, which are blanched (dipped in hot water to destroy the enzymes) before freezing. Preservation by freezing works by rendering the water in foodstuffs unavailable to micro-organisms by converting it to ice. Micro-organisms cannot grow or divide while frozen, but most remain alive and can resume activity once defrosted. Some foods are damaged by freezing, notably soft fruits and salad vegetables, the cells of which are punctured by ice crystals, leading to loss of crispness. Foods must be frozen very quickly so that small ice crystals form in the cells and no damage is caused to the structure of the food. A slow freezing process allows large uneven ice crystals to form that will later rupture the cells and cause the flavour, texture, and nutritional value to change when the food is thawed. Fatty foods such as cows' milk and cream tend to separate. Freezing has little effect on the nutritive value of foods, though a little vitamin C may be lost in the blanching process for fruit and vegetables. Various processes are used for deep-freezing foods commercially.

Pasteurization, a method of heat treatment, is used mainly for milk. By holding the milk at 72°C/162°F for 15 seconds, then cooling it rapidly to 10°C/50°F, all disease-causing bacteria (pathogens) can be destroyed. Less harmful bacteria survive, so the milk will still go sour within a few days.

Ultra-heat treatment is used to produce UHT milk. This process uses higher temperatures than pasteurization, and kills all bacteria present, giving the milk a long shelf life but altering the flavour. Milk is heated to 130–40°C/265–85°F for 1–5 seconds. The advantages of this process over the traditional sterilization process is that there is little colour change, only a slight change in taste, and very little loss of nutrient content. UHT milk is sold in airtight cartons and will keep for up to six months.

Drying is effective because both micro-organisms and enzymes need water to be active. This is one of the oldest, simplest, and most effective ways of preserving foods. In addition, drying concentrates the soluble ingredients in foods, and this high concentration prevents the growth of bacteria, yeasts, and moulds. Dried food will deteriorate rapidly if allowed to become moist, but provided they are suitably packaged, products will have a long shelf life. Traditionally, foods were dried in the sun and wind, but commercially today, products such as dried milk and instant coffee are made by spraying the liquid into a rising column of dry, heated air; solid foods, such as fruit, are spread in layers on a heated surface.

Accelerated Freeze-Drying (AFD) is carried out under vacuum. This is the most modern method of commercial drying. It produces a dried product of excellent quality. It is less damaging to food than straight dehydration in the sense that foods reconstitute better, and it is used for quality instant coffee and dried vegetables. The food is frozen and then the temperature is increased, to vaporize the ice that turns to steam as it dries out the food. The colour, texture, and most of the flavour are kept, the nutritional profile is retained, the food does not shrink as much as with other methods, and the food is preserved for longer than with other drying methods. The foods lose much of their weight, but retain the original size and shape. They have a spongelike texture, and rapidly reabsorb liquid when reconstituted. Refrigeration is unnecessary during storage; the shelf-life is similar to dried foods, provided the product is not allowed to become moist. The success of the method is dependent on a fast rate of freezing, and rapid conversion of the ice to vapour. Therefore, the most acceptable results are obtained with thin pieces of food, and the method is not recommended for pieces thicker than 3 cm/1 in. Fruit, vegetables, meat, and fish have proved satisfactory. This method of preservation is commercially used but the products are most often used as constituents of composite dishes, such as packet meals. The process is, however, a more costly method of drying, and AFD foods need to be handled with care as they crumble easily.

Canning relies on high temperatures to destroy micro-organisms and enzymes. The food is sealed in a can to prevent recontamination. The effect of heat processing on the nutritive value of food is variable. For instance, the vitamin-C content of green vegetables is much reduced, but, owing to greater acidity, in fruit juices vitamin C is quite well retained. There is also a loss of 25–50% of water-soluble vitamins if the liquor is not used. Vitamin B (thiamine) is easily destroyed by heat treatment, particularly in alkaline conditions. Acid products retain thiamine well, because they require only minimum heat during sterilization. The sterilization process seems to have little effect on retention of vitamins A and B_2. During storage of canned foods, the proportion of vitamins B and C decreases gradually. Drinks may be canned to preserve the carbon dioxide that makes them fizzy.

Pickling utilizes the effect of acetic (ethanoic) acid, found in vinegar, in stopping the growth of moulds. In sauerkraut, lactic acid, produced by bacteria, has the same effect. Similar types of non-harmful, acid-generating bacteria are used to make yogurt and cheese.

Curing of meat involves soaking in salt (sodium chloride) solution, with saltpetre (sodium nitrate) added to give the meat its pink colour and characteristic taste. Bacteria convert the nitrates in cured meats to nitrites and nitrosamines, which are potentially carcinogenic to humans.

Irradiation is a method of preserving food by subjecting it to low-level radiation (see food irradiation).

Puffing is a method of processing cereal grains. They are subjected to high pressures, then suddenly ejected into a normal atmospheric pressure, causing the grain to expand sharply. This is used to make puffed wheat cereals and puffed rice cakes.

Chemical treatments are widely used, for example in margarine manufacture, in which hydrogen is bubbled through vegetable oils in the presence of a catalyst to produce a more solid, spreadable fat. The catalyst is later removed. Chemicals introduced in processing that remain in the food are known as **food additives** and include flavourings, preservatives, anti-oxidants, emulsifiers, and colourings.

food technology

The US Food and Drug Administration (FDA) has guidelines for acceptable levels of insect contamination in food. For example it is acceptable to have up to 3 fruitfly maggots per 200 g/7 oz of tomato juice; 100 insect fragments per 25 g/0.8 oz of curry powder; and up to 13 insect heads per 100 g/3.5 oz of fig paste.

GCSE Food Technology Help Page

Go to site

Help page on understanding lactose intolerance and on ways in which milk and cheese can be substituted in recipes. The site is divided into three parts: 'Lactose intolerance', 'Milk and soya milk', and 'Foods available'. Each section is packed with information specially selected to be relevant to a food technology course.

HowStuffWorks

Go to site

Aims to inform those interested in finding out how popular consumer products, from car engines to washing machines, work. It is an invaluable resource for considering the best way to design a product, and will help with a wide variety of project research.

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food test

any of several types of simple test, easily performed in the laboratory, used to identify the main classes of food.

starch-iodine test

Food is ground up in distilled water and iodine solution is added. A dense black colour indicates that starch is present.

sugar-Benedict's test

Food is ground up in distilled water and placed in a test tube with Benedict's reagent. The tube is then heated in a boiling water bath. If glucose is present the colour changes from blue to brick-red.

protein-Biuret test

Food is ground up in distilled water and a mixture of copper(II) sulphate and sodium hydroxide is added. If protein is present a mauve colour is seen.

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foot

symbol ft

imperial unit of length, equivalent to 0.3048 m, in use in Britain since Anglo-Saxon times. It originally represented the length of a human foot. One foot contains 12 inches and is one-third of a yard.

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foot-and-mouth disease

contagious eruptive viral disease of cloven-hoofed mammals, characterized by blisters in the mouth and around the hooves. In cattle it causes deterioration of milk yield and abortions. It is an airborne virus, which makes its eradication extremely difficult.

In the UK, affected herds are destroyed; inoculation is practised in Europe and the USA. The existing vaccine for the disease leaves vaccinated animals as carriers that can infect those animals that remain unvaccinated, and a more effective vaccine is under development in the USA.

Despite health scares, a report in 2001 stated that there had only been 40 confirmed cases of foot-and-mouth disease in humans worldwide.

In February 2001, an outbreak of foot-and-mouth spread rapidly across the UK. By March, cases were discovered in France, Ireland, and the Netherlands. Severe restrictions on the movement of livestock were imposed across Europe; many countries banned imports of British and French meat, and some banned imports from all European Union countries. By the end of June 2001, over 5 million animals in the UK had been slaughtered due to the foot-and-mouth outbreak. The outbreak was the worst in world history.

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forage crop

plant that is grown to feed livestock; for example, grass, clover, and kale (a form of cabbage). Forage crops cover a greater area of the world than food crops, and grass, which dominates this group, is the world's most abundant crop, though much of it is still in an unimproved state.

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foraminifera

any marine protozoan of the order Foraminiferida, with shells of calcium carbonate. Their shells have pores through which filaments project. Some form part of the plankton, others live on the sea bottom.

The many-chambered *Globigerina* is part of the plankton. Its shells eventually form much of the chalky ooze of the ocean floor.

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forbidden line

in astronomy, emission line seen in the spectra of certain astronomical objects that are not visible under the conditions prevailing in laboratory experiments. They indicate that the hot gas emitting them is at extremely low density. Forbidden lines are seen, for example, in the tenuous gas of the Sun's corona, in HII regions (regions of hot, ionized hydrogen), and in the centres of certain active galaxies.

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force

any influence that tends to change the state of rest of a body its uniform motion in a straight line. The action of an unbalanced or resultant force results in the acceleration of a body in the direction of action of the force, or it may, if the body is unable to move freely, result in its deformation (see Hooke's law). A force is a push or a pull on an object. A force will cause an object to move if it is stationary, change direction, slow down, or speed up. Force is a vector quantity, possessing both magnitude and direction; its SI unit is the newton.

Forces that make contact with an object are called contact forces. Examples are normal push/pull force, surface tension, air resistance, and frictional forces. Forces that are able to cause a push/pull without making contact with an object are called non-contact forces. Examples are magnetic force, gravity, and electric force. A newton is used to measure how much pull the force of gravity has on an object; this corresponds to the weight of an object. A mass of 1 kg = 9.8 newtons (N). A newton is defined as the amount of force needed to move an object of 1 kg so that it accelerates at 1 metre per second per second.

speed and distance

In order to understand movement and what causes it, we need to be able to describe it. Speed is a measure of how fast something is moving. Speed is measured by dividing the distance travelled by the time taken to travel that distance. Hence speed is distance moved in unit time. Speed is a scalar quantity in which the direction of travel is not important, only the rate of travel. It is often useful to represent motion using a graph. Plotting distance against time in a distance-time graph enables one to calculate the total distance travelled. The gradient of the graph represents the speed at a particular point, the instantaneous speed. A straight line on the distance-time graph corresponds to a constant speed. A form of this graph that shows the stages on the journey is called a travel graph. A speed-time graph plots speed against time. It shows the instantaneous speed at each point. A horizontal line on the speed-time graph corresponds to a constant speed.

velocity and acceleration

Velocity is the speed of an object in a given direction. Velocity is therefore a vector quantity, in which both magnitude and direction of movement must be taken into account. Acceleration is the rate of change of velocity with time. This is also a vector quantity. Acceleration happens when there is a change in speed, or a change in direction, or a change in speed and direction.

forces and motion

Galileo discovered that a body moving on a perfectly smooth horizontal surface would neither speed up nor slow down. All moving bodies continue moving with the same velocity unless a force is applied to cause an acceleration. The reason we appear to have to push something to keep it moving with constant velocity is because of frictional forces acting on all moving objects on Earth. Friction occurs when two solid surfaces rub on each other; for example, a car tyre in contact with the ground. Friction opposes the relative motion of the two objects in contact and acts to slow the velocity of the moving object. A force is required to push the moving object and to cancel out the frictional force. If the forces combine to give a net force of zero, the object will not accelerate but will continue moving at constant velocity. A resultant force is a single force acting on a particle or body whose effect is equivalent to the combined effects of two or more separate forces. Galileo's work was developed by Isaac Newton. According to Newton's second law of motion, the magnitude of a resultant force is equal to the rate of change of momentum of the body on which it acts; the force F producing an acceleration a metres per second per second on a body of mass m kilograms is therefore given by: $F = ma$. Thus Newton's second law states that change of momentum is proportional to the size of the external force and takes place in the direction in which the force acts. Momentum is a function both of the mass of a body and of its velocity. This agrees with our experience, because the idea of force is derived from muscular effort, and we know that we have to exert more strength to stop the motion of a heavy body than a light one, just as we have to exert more strength to stop a rapidly moving body than a slowly moving one. Force, then, is measured by change of momentum, momentum being equal to mass multiplied by velocity. (See also Newton's laws of motion.) Newton's third law of motion states that if a body A exerts a force on a body B, then body B exerts an equal force on body A but in the opposite direction. This equal and opposite force is called a reaction force.

free fall and terminal velocity

Galileo also established that freely falling bodies, heavy or light, have the same, constant acceleration and that this acceleration is due to gravity. This acceleration, due to the gravitational force exerted by the Earth, is also known as the acceleration of free fall. It has a value of 9.806 metres per second per second/32.174 feet per second per second. However, air resistance acts when an object falls through the air. This increases greatly as the object's velocity increases, so the object tends to reach a terminal velocity. It then continues to fall with this same velocity (it has stopped accelerating because its weight is cancelled out by air resistance) until it reaches the ground. The acceleration due to gravity can be measured using a pendulum.

statics

Statics is the branch of mechanics concerned with the behaviour of bodies at rest or moving with constant velocity. The forces acting on the body under these circumstances cancel each other out; that is, the forces are in equilibrium.

Acceleration and Forces

Go to site

Acceleration is defined in a multitude of ways on this text-only page. An example is given of different concepts of acceleration and of common pitfalls in its understanding.

Animations for Physics

Go to site

Simple site with animated GIFs demonstrating different types of acceleration. The user can view one-dimensional positive and negative acceleration, two-dimensional constant acceleration plus uniform circular motion, and more. Each type of motion is demonstrated visually and described.

Balanced and Unbalanced Forces

Go to site

Detailed document explaining exactly what can be defined as a balanced or unbalanced force. It contains numerous diagrams to help illustrate points made in the text. A self-test section is provided, with the facility for checking answers. There are also links to other physics-related topics on the site.

Motion and Force

Go to site

Clearly explained site covering speed, velocity, acceleration, inertia, momentum, friction, and more. It is a good overview of forces and motion.

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forceps

in medicine, twin-bladed metal instruments that are used to seize and hold objects firmly in surgical, obstetric, and dental procedures.

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force ratio

the amount by which a machine increases or decreases the applied force; see mechanical advantage.

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forces, fundamental

in physics, four fundamental interactions currently known to be at work in the physical universe. There are two long-range forces: the **gravitational force**, or **gravity**, which keeps the planets in orbit around the Sun and acts between all particles that have mass; and the **electromagnetic force**, which stops solids from falling apart and acts between all particles with electric charge. There are two very short-range forces, which operate over distances comparable with the size of the atomic nucleus: the **weak nuclear force**, responsible for the reactions that fuel the Sun and for the emission of beta particles by some particles; and the **strong nuclear force**, which binds together the protons and neutrons in the nuclei of atoms. The relative strengths of the four forces are: strong, 1; electromagnetic, 10^{-2}; weak, 10^{-6}; gravitational, 10^{-40}.

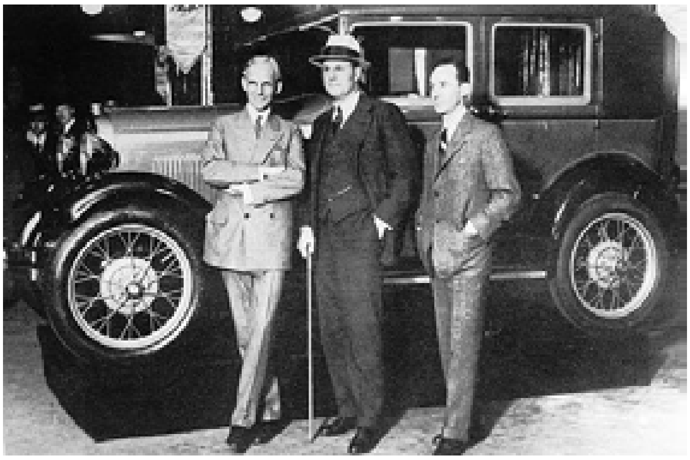
By 1971, the US physicists Steven Weinberg and Sheldon Glashow, the Pakistani physicist Abdus Salam, and others had developed a theory that suggested that the weak and electromagnetic forces were aspects of a single force called the **electroweak force**; experimental support came from observation at the European particle-physics laboratory CERN in the 1980s. Physicists are now working on theories to unify all four forces. See supersymmetry.

Ford, Henry (1863-1947)

US car manufacturer. He built his first car in 1896 and founded the Ford Motor Company in 1903 with 11 investors. Ford held 25.5% of the stock, and it was three years before he took a controlling interest and was named president. His first car, the Model A, was sold in 1903. He was a pioneer of large-scale manufacture and his Model T (1908-27) was the first car to be constructed solely by assembly-line methods; 15 million had been sold by the time production ceased. Ford's innovative policies, such as a daily minimum wage and a five-day working week, revolutionized employment practices, but he staunchly opposed and impeded the introduction of trade unions.

Ford launched the Model T (or 'Tin Lizzie') in 1908. Having disagreed with his backers that only cars for the rich were profitable, he marketed it as a reasonably priced and efficient car. To meet growing demand, he opened the Highland Park factory in 1910 and in 1913 developed a moving assembly line, which drastically reduced production time for a car to 93 minutes. He set up a dealer franchise system to sell and service cars and by the 1920s there were 7,000 Ford dealers across the USA. In 1914 Ford introduced his minimum wage scheme and reduced the working shifts by an hour to increase productivity. By 1927 he had built a huge, self-sufficient industrial facility on the River Rouge at Dearborn, Michigan, employing over 100,000 staff.

Ford



(Image © Billie Love)

Henry Ford, Tex Rickard, and Henry's son Edsel Ford, standing in front of a Model A Ford. This photograph was taken in Madison Square Garden in New York, USA, in 1927, the year in which the first Model A rolling prototype was produced. It was not until 1928 that the Model A was commercially manufactured, and replaced the original Model T Ford.

Life of Henry Ford

Go to site

Good biography of the car manufacturer from the Henry Ford Museum in Detroit. This comprehensive account of Ford's private and business life provides many interesting and little-known facts about the man. There is a good bibliography and links to other Ford sites.

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forensic medicine

in medicine, branch of medicine concerned with the resolution of crimes. Examples of forensic medicine include the determination of the cause of death in suspicious circumstances or the identification of a criminal by examining tissue found at the scene of a crime. Forensic psychology involves the establishment of a psychological profile of a criminal that can assist in identification.

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forensic science

use of scientific techniques to solve criminal cases. A multidisciplinary field embracing chemistry, physics, botany, zoology, and medicine, forensic science includes the identification of human bodies or traces. Ballistics (the study of projectiles, such as bullets), another traditional forensic field, makes use of such tools as the comparison microscope and the electron microscope.

Traditional methods such as fingerprinting are still used, assisted by computers; in addition, blood analysis, forensic dentistry, voice and speech spectrograms, and genetic fingerprinting are increasingly applied. Chemicals, such as poisons and drugs, are analysed by chromatography. ESDA (electrostatic document analysis) is a technique used for revealing indentations on paper, which helps determine if documents have been tampered with. Forensic entomology is also a branch of forensic science.

Forensic Science: Recent Advances

the scientific support for Inspector Morse

The forensic scientist has to provide evidence that will stand scrutiny in a court of law. This is why crime laboratories need to keep up with the latest research and maintain the highest standards.

Every contact leaves a trace. The ordinary microscope is still a vital instrument for examining trace evidence – hairs, fibres, fragments of glass or paint – but the scanning electron microscope is also used. It provides high magnification with good resolution, and can also incorporate a **microprobe** that identifies the actual elements, particularly metallic ones, in the surface being examined.

Surface elements absorb electrons and emit X-rays, which the microprobe converts into an X-ray emission spectrum with a characteristic pattern that reveals the elements present. In this way, it is possible to detect and identify particles invisible to the optical microscope, such as those scattered from a firearm when discharged. These particles can indicate the type and make of ammunition used.

anti-crime antibodies

Advances have also been made in analytical techniques called **immunoassays**, which use antibodies to detect and measure drugs, poisons, proteins, and even explosives such as TNT and Semtex. When a foreign chemical, such as a disease organism, enters the human body, antibodies are produced that recognize and react with the foreign substance.

The same process occurs in animals, which can be used to produce antibodies against a wide variety of chemicals. An animal is injected with a target substance, such as cocaine, and the resulting antibodies can be separated and used to recognize the substance against a background of body fluids, or in a body swab.

When trying to detect a target compound, such as the presence of explosive residue on a person's hands, it is vital to take account of possible contamination, since the substance might have been picked up casually. Also, it is important that the method used detects the target compound and no other. The value of antibodies is that they are specific to the compound that triggered their production. With other analytical methods, such as **thin-layer chromatography**, care has to be taken to eliminate other compounds that could show the same experimental result.

DNA fingerprinting

One impressive recent scientific advance is DNA fingerprinting, or DNA profiling. This has been used effectively in assault, rape, and murder cases and in paternity disputes. It figured prominently in the O J Simpson trial. For forensic purposes two DNA fingerprints are necessary – one from the suspect and another taken from the crime scene. There must be a convincing match to establish a link.

DNA profiling involves using special enzymes to cut up precisely a sample of DNA extracted from body cells. Only a very small amount of DNA – from just a few cells – is needed; the polymerase chain reaction (PCR) can amplify it into sufficient material to profile. The resulting 'bits' are separated by gel electrophoresis and can be blotted onto a special membrane, marked radioactively with specialized probes and then visualized as the familiar sequence of bars (known as an autoradiograph). Alternatively, the DNA bands can be labelled or highlighted in the actual gel then scanned with a laser. The result is a graphical print out showing peaks where the bands occur. These peaks can be converted into digital codes for storage on a computer. This is the method employed in building up national DNA databases, which store, for rapid recall, the DNA profiles of known offenders, suspects, and tissue samples taken from crime scenes. Rapid comparison can establish that a suspect could be linked with a number of scenes.

controversies

Should blood for DNA profiling purposes be taken not only from suspects but from suspicious persons, unwanted persons, even undesirable persons? If a person refuses to submit to supplying a sample for DNA analysis (as is their entitlement) what inference should be drawn from this refusal? Should everyone be DNA profiled shortly after birth so that the ordinary citizen can more easily be monitored? Despite refinements and increased effectiveness, DNA profiling must be treated with caution. If two profiles convincingly match, they may not come from the same person. The chances of this are very small – but not as small as once thought. Identical twins have the same DNA profile, but DNA profiles of people from small communities with significant in-breeding can be deceptively similar. If two bands on adjacent profiles correspond, but not exactly, statistical analysis may be needed to decide if there is a match. In the end, despite the statistical back-up, the matching of two DNA profiles is a matter of expert opinion.

electrostatic document analysis

Electrostatic document analysis (ESDA) is a recent technique used for revealing indentations on paper. Left on an underlying sheet, these indicate what has been written on the paper above.

The method uses a high electrostatic voltage to transfer the indentations onto imaging film where they are visualized by photographic toner. If the resulting impressions are markedly uneven – perhaps one half is more heavily indented than the other – then the writing under examination (on the top sheet) may have been written at two different times, showing that the document has been tampered with. The release of the 'Guildford Four' and the 'Birmingham Six' in the UK was clinched when the ESDA machine revealed 'doctored' written evidence at the original trial.

computers on the beat

The increasing power of computers has been responsible for great advances in forensic science, as in other sciences. Computers have revolutionized the storage and retrieval of information. For example, all car registration numbers and owners' names are stored on computer for almost instant access. Information can be rapidly communicated to police officers in the field. This has increased the power of those who hold the information and, in addition to speeding the response to crime, has helped in the monitoring of 'undesirables' and in maintaining order on the streets.

Identification of a suspect fingerprint, by comparison with thousands stored on file, was once a time-consuming process. Nowadays, with a computer, the process takes minutes, even seconds. Even so, the final decision on fingerprint identification is still made visually by a trained expert. No matter how sophisticated the hardware, the human senses are still vital in forensic work.

the carnage on the roads

A vast amount of police time is consumed by road traffic problems. It would be correct to say that two scientific instruments – the Breathalyser and the Radar Speed Device (or gun) have had more impact on the general public than all other forensic scientific hardware put together. Scientific evidence presented in a court of law must be accurate, reliable, and based on thorough research in order to convince a Magistrate or jury. Confirmatory or back-up tests must be available when necessary. Scientific efforts designed to reduce the number of deaths and injuries caused by the drunk driver have resulted in the development of a roadside breath screening device; an evidential breath alcohol testing instrument; and a confirmatory blood test. The Breathalyser relies on a fuel cell to estimate the level of alcohol in a driver's breath.

The intoximeter, used in the police station, is based on the absorption of infra red light (at 3.4 microns) by alcohol molecules and accurately establishes the breath alcohol level. The confirmatory blood test employs headspace gas chromatography to find the blood alcohol concentration or BAC. All these procedures use a different scientific principle for their method of operation.

The radar speed device has aimed to bring about some reduction in the devastation caused by speeding, particularly on modern motorways and highways. Its operation depends upon the Doppler effect and its output – often a photograph and accompanying data when it is linked to a camera – is valid as evidence in a court of law. All radar speed devices are checked rigorously in order to maintain the required accuracy and reliability. More efficient, but much more expensive, is the laser speed device that relies on the reflection of impulses of light from a moving source to calculate speed. Both these devices are easy to operate and to carry around.

If public pressure results in the legislation of some, or maybe all, recreational drugs then scientists will be obliged to design roadside screening tests for particular, or all, drugs with back-up evidential and confirmatory procedures. Apparently it is much more dangerous to drive a vehicle when 'stoned' with drugs than when drunk. Work has already begun on these problems. Trials are due to start in the UK on the use of absorbent pads impregnated with special chemicals. When pressed against the skin, sweat diffuses into the pad and a colour reaction denotes the presence of a particular drug. This is a noninvasive technique, but for evidential testing, blood or urine would be required and subjected to an immune assay and perhaps chromatography or even mass spectrometry. In the USA, efforts have so far centred on urine testing and the opinion has been expressed that eventually each police car will be followed closely by a 'urine bus' or 'slash van'.

surveillance techniques

The recent developments and use of sophisticated surveillance techniques seen in car parks, town centres, business premises and around the residences of the rich and powerful, bear testimony to the trend. Most notable is CCTV (closed circuit television). Whether this actually reduces crime or merely drives the criminals elsewhere is open to debate. However the concern raised about such techniques, which extend to telephone tapping, is about the invasion of privacy. This could represent one or many steps down the slippery slope of monitoring the innocent and the guilty going about their daily business. Apart from the implications of 'Big Brother', there is the perennial vexed question of who monitors those who do the monitoring?

a dream or a nightmare?

The aim of the forensic scientist is to link a suspect with a crime scene, victim or incident, using the very latest in scientific technology. If there is no suspect then data can be collected and stored only as far as time and money allow. Nothing further can be done until the breakthrough occurs as a result of a stroke of luck or a tip-off. In the end, all that is required for a watertight case might be available – a suspect whose name and address is known and an impressive array of evidence and statements. But if the suspect has gone to ground and all enquiries are met with a wall of silence, no amount of scientific evidence will find someone determined to 'melt away'. Maybe it would be wise to tag everybody electronically at birth and monitor their every move on a central computer. This would solve the problem of the vanishing suspect and the missing person, but is it a dream or a ghastly nightmare?

Forensic Science Web Page

Go to site

Aimed at the layperson, this site explains the basics of forensic science. It is broken up into a series of articles, each explaining a different discipline. Topics covered include firearms and toolmark identification, forensic psychiatry, and crime-scene processing. Each article includes a number of diagrams in order to make the science more easily understandable.

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forest

area where trees have grown naturally for centuries, instead of being logged at maturity (about 150-200 years). A natural, or old-growth, forest has a multistorey canopy and includes young and very old trees (this gives the canopy its range of heights). There are also fallen trees contributing to the very complex ecosystem, which may support more than 150 species of mammals and many thousands of species of insects. Globally forest is estimated to have covered around 68 million sq km/26.25 million sq mi during prehistoric times. By the late 1990s this is believed to have been reduced by half to 34.1 million sq km/13.2 million sq mi.

The Pacific forest of the west coast of North America is one of the few remaining old-growth forests in the temperate zone. It consists mainly of conifers and is threatened by logging – less than 10% of the original forest remains.

Forests: The Hunt for Sustainability

introduction

After years of neglect, forests are now higher on the international agenda than ever before. Alarm about deforestation in the tropics is now matched by fears concerning a parallel loss of forest quality in temperate and boreal countries. Recognition that forests are important for more than just timber production is also forcing a rethink about their management and protection. Current efforts are concentrating on the preservation of representative samples of all forest ecosystems, sustainable management of forests not in protected areas, and, in many cases, restoration of forests in areas where these have already been degraded or destroyed.

a variety of different initiatives

Since the 1992 Earth Summit the global crisis has been addressed by a bewildering array of initiatives. An Intergovernmental Panel on Forests is investigating options for conservation and sustainable management. The World Commission on Forests and Sustainable Development has held a series of public consultations around the world aimed at identifying the root causes of conflicts between different forest users. The International Tropical Timber Organisation, long a thorn in the side of environmental groups because of its support for timber exploitation, has now set a year 2000 deadline for introducing sustainable forest management within the tropics. In addition, forestry issues are being addressed by both the Convention on Biological Diversity and the Climate Change Convention, in the latter case because of the role that forest biomass has in storing carbon and thus reducing global warming. Finally, the Forest Stewardship Council has been established in Oaxaca, Mexico, to coordinate independent forest certification schemes as a guarantee of good forest management. Perhaps even more important are a series of regional, intergovernmental efforts to develop criteria and indicators of sustainable forest management. This is less esoteric than it seems at first sight. Many governments are agreeing on how to identify and measure the full range of goods and services that forests supply, with the aim of helping to design management policies that cater for all these needs. For the first time, forestry departments around the world are sitting down together and discussing how biodiversity conservation, the rights of indigenous peoples and even the spiritual and cultural values of forests can be incorporated into day-to-day management policies. To date, the best developed of these schemes have been the Helsinki Process, involving most European countries, and the Montréal Process, catering for other temperate and boreal forest countries. Other initiatives are under way – including the Tarapoto Process for South American countries (named after the small Peruvian town which hosted the first meeting) – and discussions are taking place in Africa, Central America, and Asia. Governments will not only have to agree on far broader approaches to management, but countries' performances will be measured and compared. The spotlight on countries failing to take forest management seriously will be further increased by the United Nations' *Forest Resource Assessment* which, from now on, will be measuring a wide range of issues connected to forest quality.

news from the forest floor

Unfortunately, the discussions in the boardrooms of international conferences have not, as yet, always been translated into similar changes in the forest. Since the Earth Summit, rates of destruction have continued to increase in many countries, and new forest ecosystems have come under threat in Suriname, Guyana, Bolivia, Peru, Zaire, Cameroon, Cambodia, the Solomon Islands, Canada, and elsewhere. Asian transnational logging companies have joined those from Europe and North America in a rapid and usually unsustainable harvest of many tropical forests. Worse still, there has been a concerted backlash against environmental regulations in some countries, including the USA where much of the 1–2% of old-growth forest that still remains intact has been opened up to logging by the government. On the other hand, there have been some welcome improvements. Governments and some private forest owners are starting to change systems of forest management to take more account of nature. The so-called 'new forestry' includes, for example, leaving some older trees standing after cutting, retaining some dead timber to act as habitat for specialized plant and animal species, and using prescribed burning to mimic fire ecology. Timber certification is rapidly increasing; for example, buyers responsible for approximately one quarter of UK timber purchases are already committed to only buying certified timber when this becomes available. Important new protected areas have also been created in many countries. Australia has committed to setting 15% of its forests aside as a 'Gift to the Earth' – an area twice the size of Germany. Discussions regarding Global Forest Convention are starting again in earnest, although the shape and remit of this remain unclear. Many non-governmental organizations would prefer to see existing legislation used properly, rather than spending years negotiating a new agreement. Whatever happens, it seems likely that international interest in forests will remain high for years to come.

Fire Effects Information

Go to site

Developed at the USDA Forest Service Intermountain Research Station's Fire Sciences Laboratory in Missoula, Montana, this site provides up-to-date information on the effects of fire on plants and animals.

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forestry

science of forest management. Recommended forestry practice aims at multipurpose crops, allowing the preservation of varied plant and animal species as well as human uses (lumbering, recreation). Forestry has often been confined to the planting of a single species, such as a rapid-growing conifer providing softwood for paper pulp and construction timber, for which world demand is greatest. In tropical countries, logging contributes to the destruction of rainforests, causing global environmental problems. Small unplanned forests are woodland.

The earliest planned forest dates from 1368 at Nuremberg, Germany; in Britain, planning of forests began in the 16th century. In the UK, Japan, and other countries, forestry practices have been criticized for concentration on softwood conifers to the neglect of native hardwoods.

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forget-me-not

any marsh plant of the genus *Myosotis* of the borage family. These plants have hairy leaves; bear clusters of small blue, white, or red flowers; and are considered a symbol of fidelity and friendship. The European true forget-me-not *Myosotis scorpioides*, 12–28 in/30–70 cm in height, now grows widely in North America.

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forging

one of the main methods of shaping metals, which involves hammering or a more gradual application of pressure. A blacksmith hammers red-hot metal into shape on an anvil, and the traditional place of work is called a forge. The blacksmith's mechanical equivalent is the drop forge. The metal is shaped by the blows from a falling hammer or ram, which is usually accelerated by steam or air pressure. Hydraulic presses forge by applying pressure gradually in a squeezing action.

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formaldehyde

common name for methanal.

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formalin

aqueous solution of formaldehyde (methanal) used to preserve animal specimens.

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formatting

in computing, short for disk formatting (laying down a structure for organizing, saving, and retrieving data), or text formatting (changing its appearance). Modern office programs and desktop publishing packages also allow the formatting of objects such as pictures and frames.

Formica

trademark of the Formica Corporation for a heat-proof plastic laminate, widely used as a veneer on wipe-down kitchen surfaces and children's furniture. It is a plastic made from ureaformaldehyde bonded to fabric or paper. It was first put on the market in 1913.

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formic acid

common name for methanoic acid.

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formula

in chemistry, a representation of a molecule, radical, or ion, in which the component chemical elements are represented by their symbols. For example, the formula for carbon dioxide is CO_2, showing that a molecule of carbon dioxide consists of one atom of carbon (C) and two atoms of oxygen (O_2). An **empirical formula** indicates the simplest ratio of the elements in a compound, without indicating how many of them there are or how they are combined. A **molecular formula** gives the number of each type of element present in one molecule. A **structural formula** shows the relative positions of the atoms and the bonds between them. For example, for ethanoic (acetic) acid, the empirical formula is CH_2O, the molecular formula is $C_2H_4O_2$, and the structural formula is CH_3COOH.

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formula

in mathematics, a set of symbols and numbers that expresses a fact or rule. For example, $A = \pi r^2$ is the formula for calculating the area of a circle. $E = mc^2$ is Einstein's famous formula relating energy and mass. Other common formulae exist for density, mass, volume, and area.

Forssmann, Werner (1904-1979)

German heart surgeon who was awarded a Nobel Prize for Physiology or Medicine in 1956 for his work on the technique for passing a catheter into the heart for diagnostic purposes, which he originated by practising the technique on himself in 1929.

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forsythia

any of a group of temperate eastern Asian shrubs, which bear yellow bell-shaped flowers in early spring before the leaves appear. (Genus *Forsythia*, family Oleaceae.)

FORTRAN

or fortran; contraction of formula translation

high-level computer-programming language suited to mathematical and scientific computations. Developed by John Backus at IBM in 1956, it is one of the earliest computer languages still in use. A recent version, Fortran 90, is now being used on advanced parallel computers. BASIC was strongly influenced by FORTRAN and is similar in many ways. As of 2006, Fortran 2003 was the latest and most advanced of the many versions of the language.

Fortran FAQ

Go to site

Comprehensive text-only FORTRAN 'Frequently Asked Questions' list. It provides background information on FORTRAN and its evolution, as well as listing FORTRAN books and Internet resources, and answering technical questions.

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fossil

(Latin fossilis 'dug up')

cast, impression, or the actual remains of an animal or plant preserved in rock. Dead animals and plant remains that fell to the bottom of the sea bed or an inland lake were gradually buried under the accumulation of layers of sediment. Over millions of years, the sediment became sedimentary rock and the remains preserved within the rock became fossilized. Fossils may include footprints, an internal cast, or external impression. A few fossils are preserved intact, as with mammoths fossilized in Siberian ice, or insects trapped in tree resin that is today amber. The study of fossils is called palaeontology. Palaeontologists are able to deduce much of the geological history of a region from fossil remains. The existence of fossils is key evidence that organisms have changed with time, that is, evolved (see evolution).

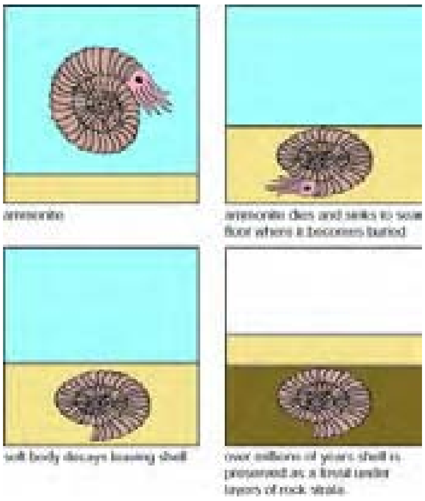
About 250,000 fossil species have been discovered – a figure that is believed to represent less than 1 in 20,000 of the species that ever lived.
Microfossils are so small they can only be seen with a microscope. They include the fossils of pollen, bone fragments, bacteria, and the remains of microscopic marine animals and plants, such as foraminifera and diatoms.

fossil

(Image © Garret Nagle)

These unique deposits are formed by the growth of bacteria around old tree stumps. The bacteria have become fossilized, and now form a fossil forest in Dorset, England. The fossil forest is even more spectacular because of the concentration of so many examples in a relatively small area.

fossil


ammonite
ammonite dies and sinks to sea
floor where it becomes buried
soft body decays leaving shell
over millions of years shell is
preserved as a fossil under
layers of rock strata.

(Image © Research Machines plc)

One way in which fossils were formed. When a marine animal dies it sinks to the sea floor (if it is not eaten), where it is eventually buried by sediment. The soft body parts decay and the hard parts may be preserved. Over time more and more sediment accumulates forming layers of rock.

Fossil Collections of the World

Go to site

Comprehensive pages of information about fossils and fossil sites around the world. This is where to find out about geological timescales, the history of fossil collecting, famous fossil collections and collectors, and maps of sites. There are also links to numerous other related sites.

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fossil fuel

combustible material, such as coal, lignite, oil, peat, and natural gas, formed from the fossilized remains of plants that lived hundreds of millions of years ago. Such fuels are non-renewable resources - once they are burnt, they cannot be replaced.

Fossil fuels are hydrocarbons (they contain atoms of carbon and hydrogen). They generate large quantities of heat when they burn in air, a process known as combustion. In this process carbon and hydrogen combine with oxygen in the air to form carbon dioxide, water vapour, and heat.

Fuels of the Future

reliance on fossil fuels

Since the Industrial Revolution in the 18th century, people in the Western world have needed fossil fuels (coal, oil, and gas) to run the many machines used in industry and everyday life. However, preparing for the demise of 'the age of oil' is becoming increasingly important, as concerns about limited resources of fossil fuels and the environmental consequences of burning them become pressing. It is vital to increase efficiency in the use of energy and, to that end, alternative energy sources are being developed.

why is there a need for alternative energy?

Although technologies for finding and extracting fossil fuels are advancing all the time, there is still only a finite supply.

Burning any type of fossil fuel leads to environmental pollution, such as increased levels of carbon dioxide in the atmosphere, which most scientists believe is a major cause of **global warming**. Fossil-fuel combustion has increased atmospheric concentrations of carbon dioxide by more than 25% since pre-industrial times. In addition, burning fossil fuels at high temperatures, such as in boilers, jets, or car engines, allows reaction of oxygen with nitrogen in the atmosphere, leading to the formation of nitrogen oxides. Nitrogen oxides, along with sulphur dioxide, another by-product of burning fossil fuels, dissolve in rainwater, producing nitric acids and sulphuric acids, which are components of **acid rain**. Both nitrogen oxides and sulphur dioxide are poisonous to humans, and acid rain destroys buildings, forests, and lakes.

Nuclear power is initially less polluting, as it does not produce any greenhouse gases, sulphur, or nitrogen oxides. However, the radioactivity from its waste products lives on for hundreds of years, and many people feel that the potential health risks resulting from radiation escaping from nuclear power stations by accident are unacceptable.

energy efficiency

To improve fuel economy and to lower emissions, advances are being made in energy efficiency. The car industry has been investigating ways to reduce the emissions of the internal combustion engine. One of the products of their research is the **exhaust gas recirculation valve**. This valve sends some of the exhaust gas back into the engine cylinders, thereby reducing combustion temperature and consequently the emission of nitrogen oxides.

Other new technologies include **gasoline direct injection**. It has been found that fuel is burned more completely if it is injected directly into the engine cylinder. More complete combustion leads to lower emissions and little or no nitrogen oxides due to the lower combustion temperatures.

However, because these developments still involve the use of fossil fuels, they can only reduce pollution rather than eliminate it. Alternative methods of automotive power are being researched. An exciting development is the possibility of installing **fuel cells** in electric vehicles. Fuel cells are extremely energy efficient and clean. They have been in existence for over 150 years and have provided electricity on spacecraft since the 1960s. Fuel cells are similar to batteries in that they convert chemical energy into an electric current, but, unlike batteries, they are endlessly rechargeable. They work by means of the reaction of hydrogen with oxygen from the air in a chemical medium known as an electrolyte, which generates electricity. The only by-product from this reaction is water. As hydrogen in air is highly explosive, it is potentially very dangerous to have a tank of hydrogen gas in a car, so research is underway into methods of extracting hydrogen from other chemicals, including methanol (a type of alcohol), for use in fuel cells.

Energy efficiency is also being increased in other industries, notably electricity generation. Most electricity power plants require steam under pressure to rotate a turbine. This activates a generator, producing electricity. Much of the steam is still produced by boiling water, heated by burning fossil fuels. More energy-efficient ways of rotating turbines are now in use, including gas turbines. Gas turbines work by burning a fuel in air, producing a high-temperature, high-pressure gas. The gas is forced out of the combustor and pushes against the turbine blades, causing them to rotate and produce electricity. Turbines are now being developed that use natural gas as the fuel.

renewable energy

The need to reduce emissions of **greenhouse gases** has been recognized globally, and it is hoped that renewable energy sources will replace fossil fuels in the future. Renewable energy is dependent on sources of natural energy in our environment, such as sunshine, wind, movement of water, and the internal heat of the Earth. As these sources are constantly replenished, they will last for millions of years. However, generators for renewable sources are expensive to build and can themselves have a negative effect on the environment. In the UK, approximately 2% of electricity is currently derived from renewable energy.

geothermal energy

Although this type of energy is not strictly renewable, as the supply from geothermal wells will eventually run out, electricity generation can be made more efficient and cleaner by using steam produced from reservoirs of hot water found several miles underneath the Earth's surface.

hydroelectric power

The conversion of energy from flowing water into electricity is known as hydroelectric power (or hydropower). The most common type of hydropower plant uses a dam on a river to store water in a reservoir. Water is released from the reservoir to the turbine, thus rotating it and activating the generator. However, there are concerns about the damage that hydropower can cause to river habitats and freshwater fish populations, and vegetation building up behind dams may actually release large amounts of carbon dioxide into the atmosphere.

wind power

Wind turbines, grouped together in windy areas, could theoretically produce as much as 20% of the UK's electricity requirements. Wind power is clean and economically competitive, but there are concerns about its environmental impact. Some people consider wind turbines to be an eyesore on the local landscape – they are inevitably sited on prominent ridges and hills, which are usually in attractive countryside. There have also been concerns about the noise generated by the turbines, and the blades are thought to kill thousands of birds every year. Plans by multinational energy companies to erect thousands of wind turbines in upland regions of north and west Britain have divided local communities between those who welcome the jobs and the rental income, and those fighting to save their landscape. The remote, beautiful, but poor Outer Hebrides have found themselves at the centre of the row – 500 turbines, 100 m/330 ft tall, are planned in a process that has been dubbed 'turbinisation'.

solar energy

In recent years, large-scale 'solar thermal' plants have been set up in places that receive plenty of sunshine. These focus the sun's rays so as to heat water and produce steam for electricity generation. Even in the UK, not famed for its sunny climate, solar energy is slowly becoming more popular, and passive solar designs, which use large south-facing glazed areas to trap the solar heat, are commonplace in modern offices and houses. **Photovoltaic cells** use solar energy to generate electricity through chemical reactions. Mainly used only for powering space satellites, these cells are becoming less expensive and are increasingly being used worldwide in rural areas where there is no grid electricity. The town of Woking, Surrey, runs the first fuel cell power station in Europe, generating its power through mini power stations and photovoltaic cells on house roofs. The town saves about £1 million per annum on fuel bills, and produces 1 million litres of pure water as a by-product.

biomass energy

By using biomass energy (the animal and plant resources in the environment) we have the potential to reduce greenhouse gas emissions by replacing fossil fuel use, to recycle more water and nutrients, and to limit pollution. There are several sources of biomass energy, including fumes from domestic and industrial wastes at landfill sites; the combustion of biomass, such as the use of bagasse (residue from the extraction of sugar) by the sugar industry to produce heat and electricity; the planting of **biomass feedstocks** (fast-growing, carbon-dioxide absorbing trees and grasses) to replace those used for combustion, thus counteracting carbon dioxide emissions; the production of carbon-rich efficient fuel by heating biomass feedstocks in the absence of oxygen; the use of **bio-diesel** (an alternative fuel made directly from crops such as rapeseed, sunflower, and soya, or by recycling cooking oil). Bio-diesel is not without emissions but has far less of an impact upon the environment than petroleum-based diesel.

However, the global biomass industry is currently underdeveloped due to the high costs involved in setting up a biomass business, along with the lack of public and political awareness of the potential of biofuels as a cleaner energy source.

a thought for the future

The use of fossil fuels continues to shape our social, economic, and political outlook on the world, and also, importantly, attitudes to our environment. The effects of pollution from fossil fuel combustion are in evidence everywhere – from global warming to acid rain. Many energy-efficient systems and alternative energy sources are now being embraced, although these are not without their own issues. It is clear that the global advantages of alternative energy sources far outweigh any local disadvantages, and there is a growing need for mankind to satisfy its energy needs in the future by balanced use of renewable sources.

What Are Fossil Fuels?

Go to site

Information on what fossil fuels are, and how they are used in society. The site also includes an explanation of how acid rain forms, and the 'greenhouse effect'.

Foucault, (Jean Bernard) Léon (1819-1868)

French physicist who used a pendulum to demonstrate the rotation of the Earth on its axis, and invented the gyroscope in 1852. In 1862 he made the first accurate determination of the velocity of light.

Foucault investigated heat and light, discovered eddy currents induced in a copper disc moving in a magnetic field, invented a polarizer, and made improvements in the electric arc. In 1860, he invented high-quality regulators for driving machinery at a constant speed; these were used in telescope motors and factory engines.

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four-colour process

colour printing using four printing plates, based on the principle that any colour is made up of differing proportions of the primary colours blue, red, and yellow. Ink colours complementary to those represented on the plates are used for printing - cyan for the blue plate, magenta for the red, and yellow for the yellow. The first stage in preparing a colour picture for printing is to produce separate films, one each for the cyan, magenta, and yellow respectively in the picture (colour separations). From these separations three printing plates are made, with a fourth plate for black. The black is used for shading or outlines and type, and also to darken colour without making the ink too dense.

Fourdrinier machine

papermaking machine patented by the Fourdrinier brothers Henry and Sealy in England in 1803. On the machine, liquid pulp flows onto a moving wire-mesh belt, and water drains and is sucked away, leaving a damp paper web. This is passed first through a series of steam-heated rollers, which dry it, and then between heavy calender rollers, which give it a smooth finish.

Such machines can measure up to 90 m/300 ft in length, and are still in use.

Fourier, (Jean Baptiste) Joseph (1768-1830)

French applied mathematician whose formulation of heat flow in 1807 contains the proposal that, with certain constraints, any mathematical function can be represented by trigonometrical series. This principle forms the basis of **Fourier analysis**, used today in many different fields of physics. His idea, not immediately well received, gained currency and is embodied in his *Théorie analytique de la chaleur/ The Analytical Theory of Heat* (1822).

Light, sound, and other wavelike forms of energy can be studied using Fourier's method, a developed version of which is now called harmonic analysis.

Fourier, Joseph

Go to site

Extensive biography of the French mathematician Joseph Fourier. The site contains a description of his contributions to mathematics, including his work on the mathematical theory of heat conduction, which led to his discoveryof Fourier analysis. Several references for further reading are also listed, and the Web site also features a portrait of Fourier.

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four-stroke cycle

engine-operating cycle of most petrol and diesel engines. The 'stroke' is an upward or downward movement of a piston in a cylinder. In a petrol engine the cycle begins with the induction of a fuel mixture as the piston goes down on its first stroke. On the second stroke (up) the piston compresses the mixture in the top of the cylinder. An electric spark then ignites the mixture, and the gases produced force the piston down on its third, power, stroke. On the fourth stroke (up) the piston expels the burned gases from the cylinder into the exhaust.

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fourth-generation language

in computing, a type of programming language designed for the rapid programming of applications but often lacking the ability to control the individual parts of the computer. Such a language typically provides easy ways of designing screens and reports, and of using databases. Other 'generations' (the term implies a class of language rather than a chronological sequence) are machine code (first generation); assembly languages, or low-level languages (second); and conventional high-level languages such as BASIC and Pascal (third).

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fowl

chicken or chickenlike bird. Sometimes the term is also used for ducks and geese. The red jungle fowl *Gallus gallus* is the ancestor of all domestic chickens. It is a forest bird of Asia, without the size or egg-laying ability of many domestic strains. Guinea fowl are of African origin.

---

fox

one of the smaller species of wild dog of the family Canidae, which live in Africa, Asia, Europe, North America, and South America. Foxes feed on a wide range of animals from worms to rabbits, scavenge for food, and also eat berries. They are very adaptable, maintaining high populations close to urban areas.

Most foxes are nocturnal, and make an underground den, or 'earth'. The common or red fox *Vulpes vulpes* is about 60 cm/2 ft long plus a tail ('brush') 40 cm/1.3 ft long. The fur is reddish with black patches behind the ears and a light tip to the tail. Other foxes include the Arctic fox *Alopex lagopus*, the fennec, the grey foxes genus *Urocyon* of North and Central America, and the South American genus *Dusicyon*, to which the extinct Falkland Islands dog belonged.

fox: feeding

The average British fox obtains only about a third of its food from hunting. The remainder is acquired by scavenging.

fox: litters

Foxes often split a litter between them, with the father taking half the litter and the mother taking the other half, and one parent moving their cubs to a new site. This maximizes the chance of most cubs in the litter surviving.

fox: reproduction

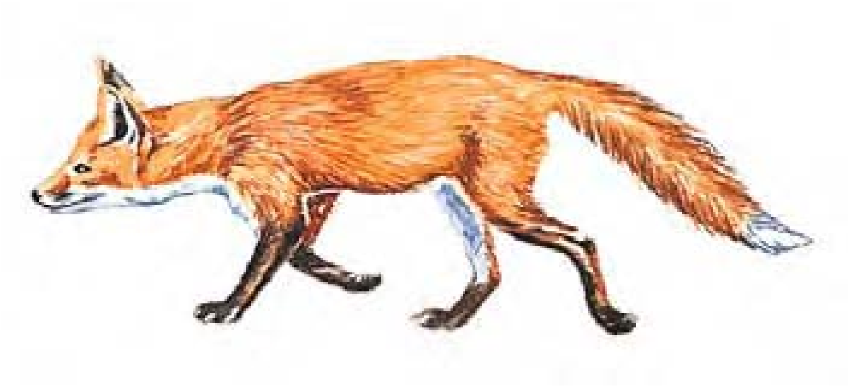
During the breeding season in December, a male fox's testes swell to six times their usual size.

Arctic fox

(Image © Corel)

The Arctic fox *Alopex lagopus* has white fur in the winter for camouflage against the snow, and a grey-brown coat in the summer. To reduce heat loss its ears are shorter and more furry than those of other foxes.

fox



(Image © Research Machines plc)

The common or red fox is versatile and intelligent. It is a skilful hunter, preying on rodents, hares, birds, and insects. In urban areas, the red fox is a scavenger of dustbins.

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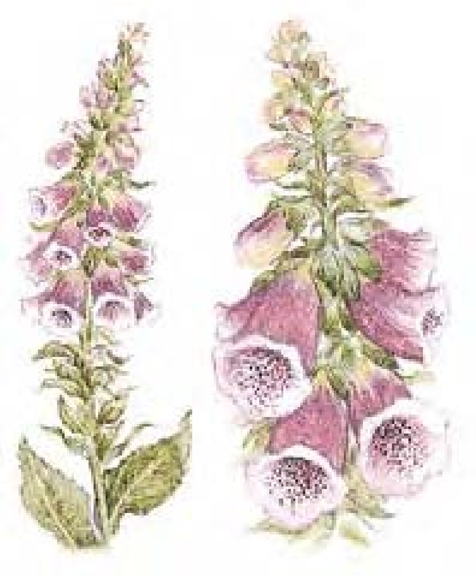
foxglove

any of a group of flowering plants found in Europe and the Mediterranean region. They have showy spikes of bell-like flowers, and grow up to 1.5 m/5 ft high. (Genus *Digitalis*, family Scrophulariaceae.)

The wild species (*D. purpurea*), native to Britain, produces purple to reddish flowers. Its leaves were the original source of digitalis, a drug used for some heart problems.

foxglove



(Image © Research Machines plc)

Foxgloves with their erect spikes of purple, golden, or white flowers are natives of Europe, Asia, and North Africa. They are adaptable plants but prefer semi-shaded positions.

foxglove

(Image © Research Machines plc)

Foxgloves, *Digitalis purpurea*, grow in the wild on steep banks, or at the edges of paths or heaths, in acid soil. The plant has a long history in folk medicine, and its active components, digitoxin and digoxin, are still used today, as a conventional treatment for heart conditions. Its German name, *Fingerhut*, suggests the way generations of children have used the thimble-shaped, bright-pink flowers in their play.

Digitalis Purpurea

Go to site

Selection of images of foxgloves from the University of Washington, including photographs taken from different distances and in different weather. There are also a number of links to related sites.

---

foxhound

small, keen-nosed hound, up to 60 cm/2 ft tall and black, tan, and white in colour. There are two recognized breeds: the English foxhound, bred for some 300 years to hunt foxes, and the American foxhound, not quite as stocky, used for foxes and other game.

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f.p.s. system

system of units based on the foot, pound, and second as units of length, mass, and time, respectively. It has now been replaced for scientific work by the SI system.

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fractal

(from Latin fractus 'broken')

irregular shape or surface produced by a procedure of repeated subdivision. Generated on a computer screen, fractals are used in creating models of geographical or biological processes (for example, the creation of a coastline by erosion or accretion, or the growth of plants).

Sets of curves with such discordant properties were developed in the 19th century in Germany by Georg Cantor and Karl Weierstrass. The name was coined by the French mathematician Benoit Mandelbrot. Fractals are also used for computer art.

---

fraction

in chemistry, a group of similar compounds, the boiling points of which fall within a particular range and which are separated during fractional distillation (fractionation).

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fraction

(from Latin fractus 'broken')

in mathematics, a number that indicates one or more equal parts of a whole. Usually, the number of equal parts into which the unit is divided (denominator) is written below a horizontal or diagonal line, and the number of parts comprising the fraction (numerator) is written above; for example, 2/3 has numerator 2 and denominator 3. Such fractions are called vulgar fractions or **simple fractions**. The denominator can never be zero.

proper and improper fractions

A proper fraction is one in which the numerator is less than the denominator. For example, 2/5, 3/5, and 7/8 are all proper fractions.

An improper (or top heavy) fraction has a numerator that is larger than the denominator. For example:

14/5 means 14 ÷ 5

$$\begin{array}{r} 2\,\mathrm{r}\,4 \\ 5\overline{)14} \end{array} \quad \text{or} \quad 2\,{}^{4}\!/_{5}$$

14/5 = 24/5

This is called a mixed number.

denominator of zero

A combination such as 5/0 is not regarded as a fraction (an object cannot be divided into zero equal parts). Zero divided by any number is zero, and any number divided by zero is infinity.

decimal fractions

A decimal fraction has as its denominator a power of 10. Exact decimals can be changed into fractions using place values. For example:

0.37 means 3 tenths and 7 hundredths

$$\begin{aligned} 0.37 &= \frac{3}{10} + \frac{7}{100} \\ &\overset{\times 10}{=} \frac{30}{100} + \frac{7}{100} \\ &= \frac{37}{100} \end{aligned}$$

0.37 is the equivalent to 37/100 as a fraction and 37% as a percentage.

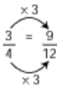
Most fractions can be expressed exactly as decimal fractions (1/3 = 0.333...). Fractions are also known as rational numbers; that is, numbers formed by a ratio. Integers may be expressed as fractions with a denominator of 1, so 6 is 6/1, for example.

addition and subtraction

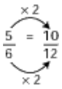
To add or subtract with fractions a common denominator (a number divisible by both the bottom numbers) needs to be identified. For example:

3/4 + 5/6

First both denominators should be the same. 12 is the lowest number of which both 4 and 6 are factors - it is the lowest common denominator. To change 3/4 into twelfths the denominator is multiplied by 3.
The numerator must also be multiplied by 3:



To change 5/6 into twelfths the denominator is multiplied by 2. The numerator must also be multiplied by 2:



3/4 + 5/6 = 9/12 + 10/12 = 19/12 = 17/12

If whole numbers appear in the calculation they can be added/subtracted separately first.

multiplication and division

All whole numbers in a division or multiplication calculation must first be converted into improper fractions. For multiplication, the numerators are then multiplied together and the denominators are then multiplied to provide the solution. For example:

72/3 × 41/2 = 23/3 × 9/2 = 207/6 = 341/2

In division, the procedure is similar, but the second fraction must be inverted before multiplication occurs. For example,

55/12 ÷ 11/8 = 65/12 ÷ 9/8 = 65/12 × 8/9 = 520/108 = 422/27

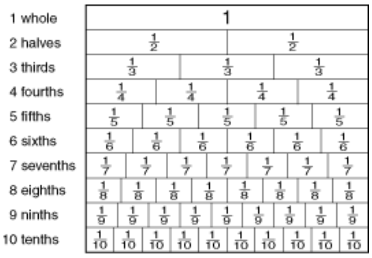
fraction of an amount

For example:

to find 1/2 of £300 divide by 2 to get £150 to find 1/5 of 250 m divide by 5 to get 50 m

the fraction wall

This is a useful visual tool when working with fractions.


1 whole 1
2 halves 1/2 1/2
3 thirds 1/3 1/3 1/3
4 fourths 1/4 1/4 1/4 1/4
5 fifths 1/5 1/5 1/5 1/5 1/5
6 sixths 1/6 1/6 1/6 1/6 1/6 1/6
7 sevenths 1/7 1/7 1/7 1/7 1/7 1/7 1/7
8 eighths 1/8 1/8 1/8 1/8 1/8 1/8 1/8 1/8
9 ninths 1/9 1/9 1/9 1/9 1/9 1/9 1/9 1/9 1/9
10 tenths 1/10 1/10 1/10 1/10 1/10 1/10 1/10 1/10 1/10 1/10

fractions

To remember the rule of division of fractions:

The number you are dividing by
Turn upside down and multiply

Fractions

Go to site

Simple but clearly laid out introduction to fractions and decimals. It covers topics such as improper fractions, converting fractions to decimals, and adding and multiplying fractions. The site would be helpful for learning about fractions for the first time, or just for revision.

Maths for Morons Like Us

Go to site

Aiming to 'Help you understand maths concepts better', this site contains lessons beginning with 'Pre-algebra' which covers the basics, through 'Geometry' to 'Calculus'. Most of the site is made up of tutorials and practice questions, but there are also interactive quizzes to attempt.

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fractional distillation

or fractionation

process used to split complex mixtures (such as petroleum) into their components, usually by repeated heating, boiling, and condensation; see distillation. In the laboratory it is carried out using a fractionating column.

Fractional distillation is used to separate mixtures of miscible liquids, such as ethanol and water. The process depends on the components of the mixture having different boiling points. The liquid is heated so that it turns into a gas. The vapours pass up a fractionating column where they are gradually cooled. As each of the components of the mixture cools to its boiling point, it turns back into a liquid. The different components of the mixture condense at different levels in the fractionating column and thus may be separated.

In industry, fractional distillation is used to separate the compounds in crude oil (unrefined petroleum) into useful fractions, each fraction containing compounds with similar boiling points. Air is also separated by fractional distillation. This is done by cooling air until it condenses and then allowing the temperature of the liquid air to rise. Each gas will distill off at its own boiling point.

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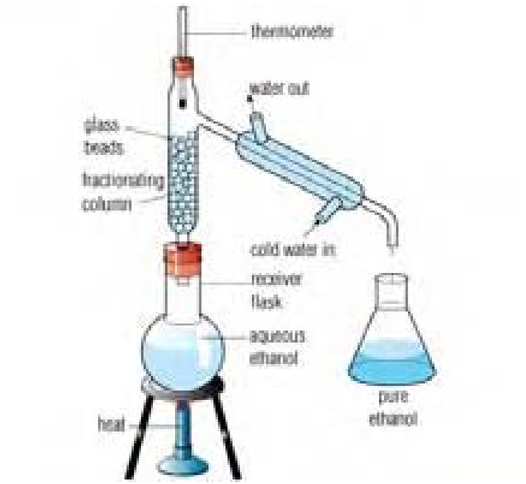
fractionating column

device in which many separate distillations can occur so that a liquid mixture can be separated into its components. The technique is known as fractional distillation, or fractionation.

Various designs exist but the primary aim is to allow maximum contact between the hot rising vapours and the cooling descending liquid. As the mixture of vapours ascends the column it becomes progressively enriched in the lower-boiling-point components, so these separate out first.

fractionating column



(Image © Research Machines plc)

Laboratory apparatus for fractional distillation. Fractional distillation is the main means of separating the components of crude oil.

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francium

chemical symbol Fr

radioactive metallic element, atomic number 87, relative atomic mass 223. It is one of the alkali metals and occurs in nature in small amounts as a decay product of actinium. Its longest-lived isotope has a half-life of only 21 minutes. Francium was discovered and named in 1939 by Marguérite Perey, to honour her country.

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frangipani

any of a group of tropical American trees, especially the species *P. rubra*, belonging to the dogbane family. Perfume is made from the strongly scented waxy flowers. (Genus *Plumeria*, family Apocynaceae.)

Frank, Charles (1911-1998)

English physicist who explained the primary mechanism by which crystals grow and who contributed to liquid-crystal and alloy research. He also made contributions to geophysics and polymer physics. He was knighted in 1977.

Frank, Robert (1924-)

US photographer. He is best known for his informal and unromanticized pictures of American life. These were published, with a foreword by the US novelist Jack Kerouac, as *The Americans* (1959). He then concentrated mainly on film-making until 1966, when he virtually gave up photography.

Born in Zürich, Switzerland, Frank emigrated to New York in 1947. During 1947-51 he did freelance fashion and advertising photography for *Harper's* and *The New York Times* among others. The first European to receive a Guggenheim scholarship (1955), he spent the following two years travelling across the USA to capture images of daily life with his 35mm camera, publishing *The Americans*. One of the founders of the New American Cinema Group, he received the Edward MacDowell Medal for outstanding contribution to the arts in 2002.

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frankincense

resin of various African and Asian trees, burned as incense. Costly in ancient times, it is traditionally believed to be one of the three gifts brought by the Magi to the infant Jesus. (Genus *Boswellia*, family Burseraceae.)

Frankincense

Go to site

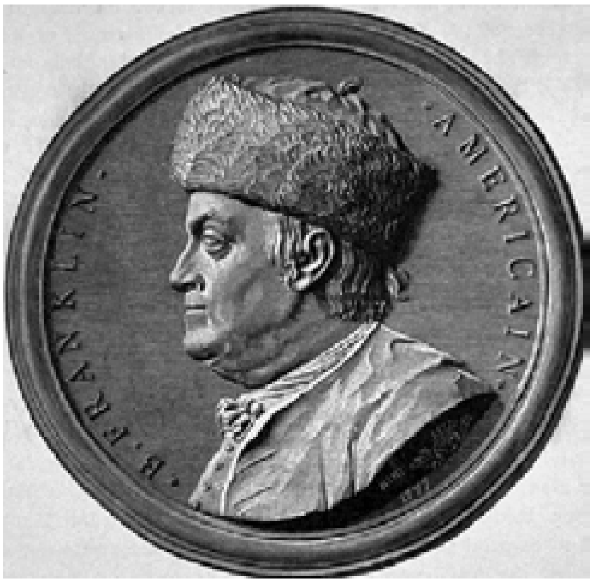
Informative resource relating to frankincense. It contains a detailed description of the tree and its habitat. There are also notes on the constituents of the plant, as well as information on the possible medicinal uses of frankincense, which include acting as a stimulant.

Franklin, Benjamin (1706-1790)

US scientist, inventor, statesman, diplomat, writer, printer, and publisher. He proved that lightning is a form of electricity, distinguished between positive and negative electricity, and invented the lightning conductor. He was the first US ambassador to France 1776-85, and negotiated peace with Britain in 1783. As a delegate to the Continental Congress from Pennsylvania 1785-88, he helped to draft the Declaration of Independence and the US Constitution. He was president of the first US abolitionist society in 1775 and was responsible for many improvements in American life, including a modernized postal system, and the first US fire and police departments, hospital, and insurance company.

Franklin was born in Boston, the son of a soap and candlemaker, and the 15th of 17 children. After two years at school he was apprenticed to a printer at the age of 12, being self-taught from that time. In 1723, he left Boston for Philadelphia and in 1724 sailed for England, where he worked for 18 months in a printer's office. He returned to Philadelphia in 1726, set up his own printing business, and bought the *Pennsylvania Gazette*. In 1737, he became deputy postmaster of Philadelphia, and was a member of the colony's legislative body 1751-64. As early as 1754, Franklin was advocating an inter-colonial union to improve the presentation of colonial claims to the British government.

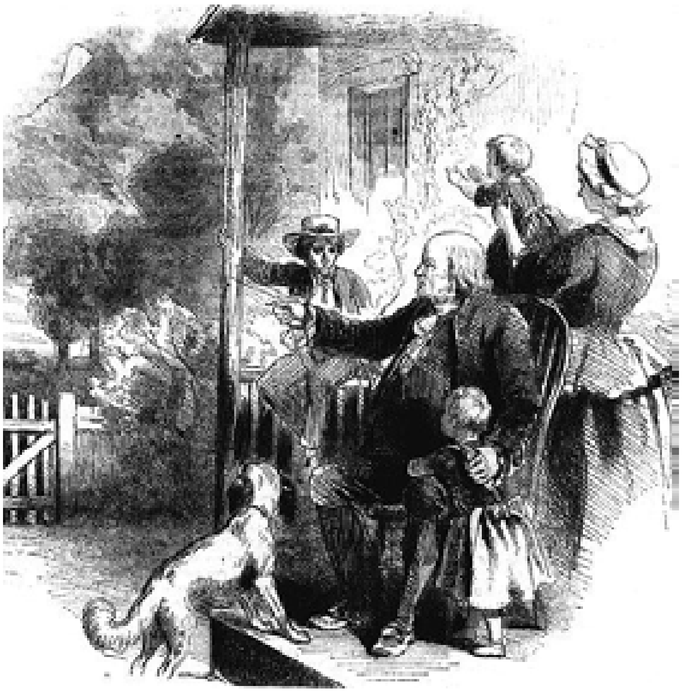
Franklin



(Image © Philip Sauvain Picture Collection)

American statesman and scientist Benjamin Franklin. He invented the lightning conductor and was a prominent negotiator in the American Declaration of Independence of 1773.

Franklin



(Image © Billie Love)

A portrait of the 18th-century US scientist and statesman Benjamin Franklin, conducting a dangerous experiment flying a kite during a thunderstorm, by which he proved the electrical nature of lightning. He also invented the lightning conductor.

Franklin Institute Science Museum

Go to site

Virtual museum of science with exhibits especially designed for online presentation. The topics include 'The circle of life', 'A robot zoo', 'The wind', 'The heart', 'Life in nature', and 'Man-made life'. An open-all-hours interactive museum which is rich in material, well-designed, and proof that learning can be fun and win over barriers of distance and nationality.

World of Benjamin Franklin

Go to site

Life and times of Benjamin Franklin. The site includes exhaustive biographical details, a family tree of Franklin and his family, and comprehensive information on his achievements in the many fields in which he was prominent. There is a video clip on the front page and certain other pages have audio clips attached to the articles.

Frasch process

process used to extract underground deposits of sulphur. Superheated steam is piped into the sulphur deposit and melts it. Compressed air is then pumped down to force the molten sulphur to the surface. The process was developed in the USA in 1891 by German-born Herman Frasch (1851-1914).

Fraunhofer, Joseph von (1787-1826)

German physicist who did important work in optics. The dark lines in the solar spectrum (**Fraunhofer lines**), which reveal the chemical composition of the Sun's atmosphere, were accurately mapped by him.

Fraunhofer determined the dispersion powers and refractive indices of different kinds of optical glass. In the process, he developed the spectroscope, and in 1821 he became the first to use a diffraction grating to produce a spectrum from white light.

---

freckles

in medicine, localized collections of brown spots that are often seen on the arms and faces of fair-skinned individuals. They are due to the excessive production of melanin following exposure to sunlight and they fade during the winter months.

free fall

the state in which a body is falling freely under the influence of gravity, as in freefall parachuting (skydiving). In a vacuum, a freely falling body accelerates at a rate of 9.806 m sec^{-2}/32.174 ft sec^{-2}; the value varies slightly at different latitudes and altitudes. A body falling through air accelerates until it reaches a maximum speed called the terminal velocity; thereafter, there is no further acceleration.

In orbit, astronauts and spacecraft are still held by gravity and are in fact falling freely toward the Earth. Because of their speed (orbital velocity), the amount they fall towards the Earth just equals the amount the Earth's surface curves away; in effect they remain at the same height, apparently weightless.

Free Fall and Air Resistance

Go to site

Detailed explanation of Newton's second law of motion, accompanied by diagrams and animations to help illustrate the concepts.

free radical

in chemistry, an atom or molecule that has an unpaired electron and is therefore highly reactive. Most free radicals are very short-lived. They are by-products of normal cell chemistry and rapidly oxidize other molecules they encounter. Free radicals are thought to do considerable damage. They are neutralized by protective enzymes.

Free radicals are often produced by high temperatures and are found in flames and explosions.

freesia

any of a South African group of plants belonging to the iris family, commercially grown for their scented, funnel-shaped flowers. (Genus *Freesia*, family Iridaceae.)

freeze-drying

method of preserving food; see food technology. The product to be dried is frozen and then put in a vacuum chamber that forces out the ice as water vapour, a process known as sublimation.

Many of the substances that give products such as coffee their typical flavour are volatile, and would be lost in a normal drying process because they would evaporate along with the water. In the freeze-drying process these volatile compounds do not pass into the ice that is to be sublimed, and are therefore largely retained.

freeze-thaw

form of physical weathering, common in mountains and glacial environments, caused by the expansion of water as it freezes. Water in a crack freezes and expands in volume by 9% as it turns to ice. This expansion exerts great pressure on the rock, causing the crack to enlarge. After many cycles of freeze-thaw, rock fragments may break off to form scree slopes.

For freeze-thaw to operate effectively the temperature must fluctuate regularly above and below 0°C/32°F. It is therefore uncommon in areas of extreme and perpetual cold, such as the polar regions.

freeze-thaw

(Image © Garret Nagle)

Active freeze-thaw on the chalk causes rockfalls on this section of the south Dorset coast, England. As the chalk is prized apart, it falls to the ground forming a scree slope. Active scree slopes are characterized by a very white colour (fresh chalk) as well as a lack of vegetation. In contrast, older freefalls and mass movements produce a darker colour and partly vegetated scree slopes.

freezing

change of state from liquid to solid, as when water becomes ice. For a given substance, freezing occurs at a definite temperature, known as the **freezing point**, that is invariable under similar conditions of pressure, and the temperature remains at this point until all the liquid is frozen; the freezing point and melting point of the substance are the same temperature. By measuring the temperature of a liquid against time as it cools a cooling curve can be plotted; on the cooling curve the temperature levels out at the freezing point.

The amount of heat per unit mass that has to be removed to freeze a substance is a constant for any given substance, and is known as the latent heat of fusion.

freezing point, depression of

lowering of a solution's freezing point below that of the pure solvent; it depends on the number of molecules of solute per unit volume of the solution. For a single solvent, such as pure water, all solute substances in the same molar concentration produce the same lowering of freezing point. The depression d produced by the presence of a solute of molar concentration C is given by the equation $d = KC$, where K is a constant (called the cryoscopic constant) for the solvent concerned.

Antifreeze mixtures for car radiators and the use of salt to melt ice on roads are common applications of this principle. Animals in arctic conditions, for example insects or fish, cope with the extreme cold either by manufacturing natural 'antifreeze' and staying active, or by allowing themselves to freeze in a controlled fashion, that is, they manufacture proteins to act as nuclei for the formation of ice crystals in areas that will not produce cellular damage, and so enable themselves to thaw out and become active again. Measurement of freezing-point depression is a useful method of determining the molecular weights of solutes. It is also used to detect the illicit addition of water to milk.

frequency

in physics, number of periodic oscillations, vibrations, or waves occurring per unit of time. The SI unit of frequency is the hertz (Hz), one hertz being equivalent to one cycle per second. Frequency is related to wavelength and velocity by the equation: $f = v/\lambda$ where f is frequency, v is velocity, and λ is wavelength. Frequency is the reciprocal of the period$T$: $f = 1/T$

The electrical mains supply in the UK is AC (alternating current) with a frequency of 50 Hz. Each time the current changes direction, the voltage falls to zero before increasing again as the current moves in the opposite direction. At 50 Hz, the current will change direction 100 times a second.

At one end of the electromagnetic spectrum are long radio waves with a frequency below 10^5 Hz and at the other extreme are gamma rays with a frequency beyond 10^{19} Hz.

Human beings can hear sounds from objects vibrating in the range 20–15,000 Hz. Ultrasonic frequencies

well above 15,000 Hz can be detected by such mammals as bats. Infrasound (low-frequency sound) can be detected by some mammals and birds. Pigeons can detect sounds as low as 0.1 Hz; elephants communicate using sounds as low as 1 Hz.
Frequency modulation (FM) is a method of transmitting radio signals in which the frequency of the **carrier wave** is changed and then decoded.

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frequency

in statistics, the number of times an event occurs. For example, in a survey carried out to find out a group of children's favourite colour of the rainbow, the colour red is chosen 26 times. This gives the colour red a frequency of 26. A table of the raw data collected, including the frequencies, is called a **frequency distribution**. It is usually presented in a **frequency table** or tally chart. The frequencies can also be shown diagrammatically using a **frequency polygon**.

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frequency modulation

see FM.

Frere, John (1740-1807)

English antiquary. A pioneering discoverer of the Palaeolithic era (Old Stone Age), he found flint weapons in association with large extinct animals 3.5 m/12 ft below ground in a brick pit at Hoxne, Suffolk, in 1797. He suggested (long before the English scientist Charles Darwin) that they predated the conventional biblical timescale.

Frere was high sheriff of Suffolk, member of Parliament for Norwich, and a Fellow of the Royal Society. His views were not taken seriously by his contemporaries, who believed in the creation as described in the Bible, and perhaps accepted the timescale formulated by the archbishop of Armagh, James Usher, in which humans were created on 23 October 4004 BC.

Fresnel, Augustin Jean (1788-1827)

French physicist who refined the theory of polarized light. Fresnel realized in 1821 that light waves do not vibrate like sound waves longitudinally, in the direction of their motion, but transversely, at right angles to the direction of the propagated wave.

Fresnel first had to confirm the wave theory of light. He demonstrated mathematically that the dimensions of light and dark bands produced by diffraction could be related to the wavelength of the light producing them if light consisted of waves. To explain double refraction, he then arrived at the theory of transverse waves.

Freud, Anna (1895-1982)

Austrian-born founder of child psychoanalysis in the UK. Her work was influenced by the theories of her father, Sigmund Freud. She held that understanding of the stages of psychological development was essential to the treatment of children, and that this knowledge could only be obtained through observation of the child.

Anna Freud and her father left Nazi-controlled Vienna in 1938 and settled in London. There she began working in a Hampstead nursery. In 1947 she founded the Hampstead Child Therapy Course and Clinic, which specialized in the treatment of children and the training of child therapists.

Freud, Sigmund (1856-1939)

Austrian physician who pioneered the study of the unconscious mind. He developed the methods of free association and interpretation of dreams that are basic techniques of psychoanalysis. The influence of unconscious forces on people's thoughts and actions was Freud's discovery, as was his controversial theory of the repression of infantile sexuality as the root of neuroses in the adult. His books include *Die Traumdeutung/The Interpretation of Dreams* (1900), *Jenseits des Lustprinzips/Beyond the Pleasure Principle* (1920), *Das Ich und das Es/The Ego and the Id* (1923), and *Das Unbehagen in der Kultur/Civilization and its Discontents* (1930). His influence has permeated the world to such an extent that it may be discerned today in almost every branch of thought.

From 1886 to 1938 Freud had a private practice in Vienna, and his theories and writings drew largely on case studies of his own patients, who were mainly upper-middle-class, middle-aged women. Much of the terminology of psychoanalysis was coined by Freud, and many terms have passed into popular usage, not without distortion. His theories have changed the way people think about human nature and brought about a more open approach to sexual matters. Antisocial behaviour is now understood to result in many cases from unconscious forces, and these new concepts have led to wider expression of the human condition in art and literature. Nevertheless, Freud's theories have caused disagreement among psychologists and psychiatrists, and his methods of psychoanalysis cannot be applied in every case.

Interpretation of Dreams (3rd edition) by Sigmund Freud

Go to site

A A Brill's 1911 translation of Freud's classic analysis of dreams. The section on typically recurring dreams is particularly interesting.

Sigmund Freud: The Father of Psychoanalysis

Go to site

Maintained in English by the Austrian National Tourist Office, the page provides a time line of biographical information about Freud, plus analyses of his ideas and the impact of his theories on his most notable followers.

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friction

in physics, the force that opposes the movement of two bodies in contact as they move relative to each other. The **coefficient of friction** is the ratio of the force required to achieve this relative motion to the force pressing the two bodies together.

Two materials with rough surfaces rubbing together will change kinetic energy into heat and sound energy. Friction is greatly reduced by the use of lubricants such as oil, grease, and graphite. A layer of lubricant between two materials reduces the contact, allowing them to slide over each other smoothly. For example, engine oil used in cars reduces friction between metal parts as they move against each other. Air bearings are now used to minimize friction in high-speed rotational machinery. In joints in the human body, such as the knee, synovial fluid plays a key role as a lubricant. In other instances friction is deliberately increased by making the surfaces rough – for example, brake linings, driving belts, soles of shoes, and tyres.

Friction is also used to generate static electric charges on different materials by rubbing the materials together.

Friends of the Earth

FoE or FOE

largest international network of environmental pressure groups, established in the UK in 1971, which aims to protect the environment and to promote rational and sustainable use of the Earth's resources. It campaigns on such issues as acid rain; air, sea, river, and land pollution; recycling; disposal of toxic wastes; nuclear power and renewable energy; the destruction of rainforests; pesticides; and agriculture. FoE has member groups in 68 countries.

Friends of the Earth Home Page

Go to site

Appeal for raised awareness of environmental issues, with masses of information and tips for action from Friends of the Earth (FoE). The site hosts lengthy accounts of several campaigns undertaken by FoE on climate, industry, transport, and sustainable development. It also maintains an archive of press releases from FoE on some of the most controversial environmental problems encountered in the course of last year around the world.

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frilled lizard

yellowish-brown Australian lizard with a large frill of skin to the sides of the neck and throat. The lizard is about 90 cm/35 in long.

When the lizard is angry or alarmed it erects its frill, which may be as much as 25cm/10 in in diameter, thus giving itself the appearance of being larger than it really is. Frilled lizards are generally tree-living but may spend some time on the ground, where they run with their forelimbs in the air.

classification

The frilled lizard *Chlamydosaurus kingi* belongs to the family Agamidae, suborder Sauria, order Squamata, class Reptilia.

Frisch, Karl von (1886-1982)

Austrian zoologist who was awarded the Nobel Prize for Physiology or Medicine in 1973 with Konrad Lorenz and Nikolaas Tinbergen for their work on animal behaviour patterns. Karl von Frisch specialized in bees, discovering how they communicate the location of sources of nectar by movements called 'dances'.

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fritillary

in botany, any of a group of plants belonging to the lily family. The snake's head fritillary (*F. meleagris*) has bell-shaped flowers with purple-chequered markings. (Genus *Fritillaria*, family Liliaceae.)

Fritillary, Common

Go to site

Detailed introduction to the common fritillary, including information on the plant itself, its habitat, and its propagation methods.

---

fritillary

in zoology, any of a large grouping of butterflies of the family Nymphalidae. Mostly medium-sized, fritillaries are usually orange and reddish with a black criss-cross pattern or spots above and with silvery spots on the underside of the hindwings.

They take their name from the Latin word *fritillus* ('dice box') because of their spotted markings.

---

frog

any amphibian of the order Anura (Greek 'tailless'). There are about 24 different families of frog, containing more than 3,800 species. There are no clear rules for distinguishing between frogs and toads.

Frogs usually have squat bodies, with hind legs specialized for jumping, and webbed feet for swimming. Most live in or near water, though as adults they are air-breathing. A few live on land or even in trees. Their colour is usually greenish in the genus *Rana*, but other Ranidae are brightly coloured, for instance black and orange or yellow and white. Many use their long, extensible tongues to capture insects. The eyes are large and bulging. Frogs vary in size from the North American little grass frog *Limnaoedus ocularis*, 12 mm/0.5 in long, to the giant aquatic frog *Telmatobius culeus*, 50 cm/20 in long, of Lake Titicaca, South America. Frogs are widespread, inhabiting all continents except Antarctica, and they have adapted to a range of environments including deserts, forests, grasslands, and even high altitudes, with some species in the Andes and Himalayas existing above 5,000 m/19,600 ft.

courtship and reproduction

In many species the males attract the females in great gatherings, usually by croaking. In some tropical species, the male's inflated vocal sac may exceed the rest of his body in size. Other courtship 'lures' include thumping on the ground and 'dances'.

Some lay eggs in large masses (spawn) in water. The jelly surrounding the eggs provides support and protection and retains warmth. Some South American frogs build mud-pool 'nests', and African tree frogs make foam nests from secreted mucus. In other species, the eggs may be carried in pockets on the mother's back, brooded by the male in his vocal sac or, as with the Eurasian midwife toad *Alytes obstetricans*, wrapped round the male's hind legs until hatching.

life cycle

The tadpoles hatch from the eggs in about a fortnight. At first they are fishlike animals with external gills and a long swimming tail, but no limbs. The first change to take place is the disappearance of the external gills and the development of internal gills, which are still later supplanted by lungs. The hind legs appear before the front legs, and the last change to occur is the diminution and final disappearance of the tail. The tadpole stage lasts about three months. At the end of this time the animal leaves the water. Some species, such as the edible frog, are always aquatic. By autumn the frog grows big and sluggish. It stores fat in a special gland in the abdomen; it is this fat that it lives on during hibernation.

species

Certain species of frog have powerful skin poisons (alkaloids) to deter predators. 'True frogs' are placed in the worldwide family Ranidae, with 800 species, of which the genus *Rana* is the best known. The North American bullfrog *Rana catesbeiana*, with a croak that carries for miles, is able to jump nine times its own length. The flying frogs, genus *Rhacophorus*, of Malaysia, using webbed fore and hind feet, can achieve a 12 m/40 ft glide. The hairy frog *Astylosternus robustus* is found in West Africa; it has long outgrowths on its flanks, which seem to aid respiration. A four-year rainforest study in eastern Madagascar revealed 106 new frog species in 1995. Indian zoologists discovered the first known leaf-eating frog in 1996, in Tamil Nadu, southern India. *R. hexadactyla* feeds mainly on leaves, flowers, and algae. New species are constantly being discovered. In 1997 a species *Eleutherodactylus pluvicanorus* was discovered in Bolivia; it is 4 cm long and ground-dwelling.

frog: development

Certain frogs do not spend time as tadpoles. The female of a species of tiny Brazilian frog lays a egg which hatches as a single froglet, rather than going through a tadpole phase first.

frog: lifespan

Common frogs can live for about six years but only about 1 in 10,000 will successfully evade predators and disease to live to this ripe old age.

frog: new species

One frog species is so tiny that it can sit comfortably on a human fingernail. The frog, *Psyllophryne didactyla*, was discovered in Cuba in 1996.

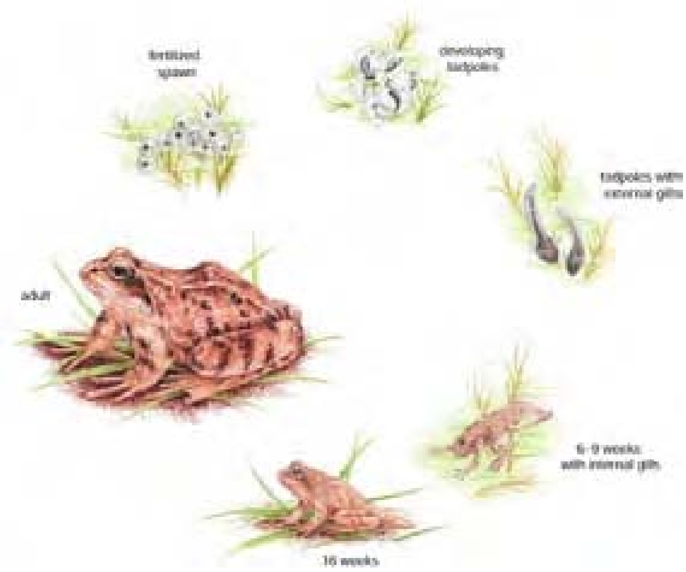
frog: poison

There is a species of frog found in Colombia that produces enough poison to kill 1,500 people. Pharmacologists are keen to see if the venom of *Phyllobates terribilis* might be the basis of a new painkiller.

frog: survival at low temperatures

The spring peeper frog *Pseudacris crucifer* can survive for three days at a temperature of -1.5°C/-29°F. It prevents all its body water from freezing by producing glucose, increasing concentration and reducing the formation of ice.

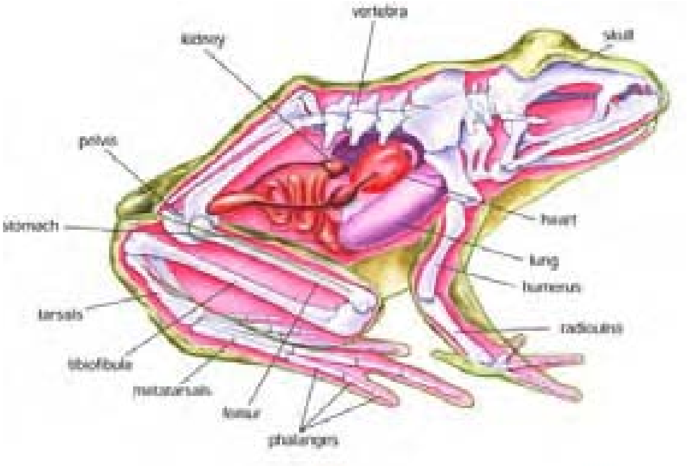
frog


fertilized
spawn
developing
tadpoles
tadpoles with
external gills
adult
6–9 weeks
with internal gills
16 weeks

(Image © Research Machines plc)

The life cycle of a frog. Frogs lay their eggs (spawn) in fresh, still water. The tadpoles hatch within about two weeks and then over the course of the next three months they grow larger and slowly develop legs and internal gills. By the time they lose their tails they resemble tiny adult frogs and can leave the water.

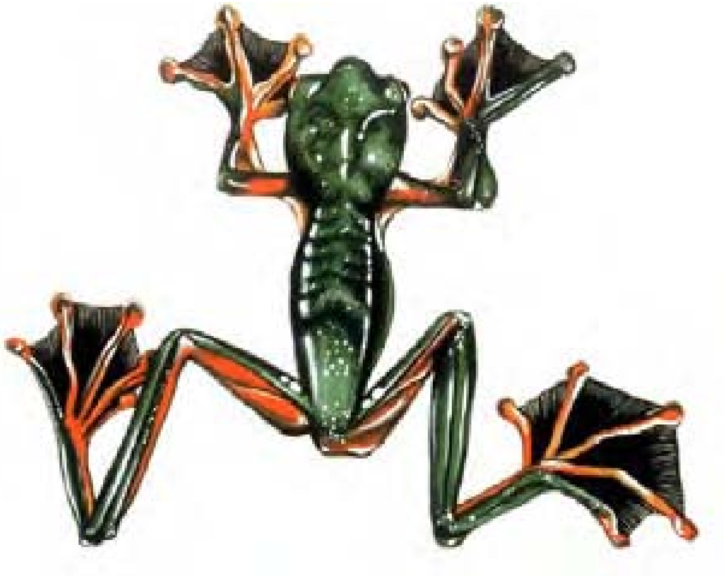
frog


vertebra
kidney
skull
pelvis
stomach
heart
lung
humerus
tarsals
radioulna
tibiofibula
metatarsals
femur
phalanges

(Image © Research Machines plc)

The frog is an unusual vertebrate in that it has no ribs.

frog



(Image © Research Machines plc)

Wallace's flying frog, found in the rainforest of South East Asia, glides from tree to tree. Its feet are greatly enlarged with webs between the toes. When launched into the air, it extends its toes to form parachutes. Flaps of skin along the body and limbs assist the glide.

Frogland

Go to site

Enthusiastic and informative personal home page devoted to frogs. Provides pictures, a guide to frogs around the world, tips on keeping frogs as pets, jokes, and a colouring book.

South American Ornate Horned Frog

Go to site

Illustrated guide to the South American ornate horned frog including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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froghopper

or spittlebug

leaping plant-bug, of the family Cercopidae, in the same order (Homoptera) as leafhoppers and aphids. Froghoppers live by sucking the juice from plants. The pale green larvae protect themselves (from drying out and from predators) by secreting froth ('cuckoo spit') from their anuses.

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frogmouth

nocturnal bird, related to the nightjar, of which the commonest species, the tawny frogmouth *Podargus strigoides*, is found throughout Australia, including Tasmania. Well camouflaged, it sits and awaits its prey.

Fromm, Erich (1900-1980)

German psychoanalyst who moved to the USA in 1933 to escape the Nazis. He believed that human beings experience a separation from nature and from other people which gives them the freedom to decide on the course their lives should take. This gives their lives meaning but also causes anxiety.

Fromm was influenced by Karl Marx and existentialism as much as by psychoanalysis. He stressed the role of culture in the formation of personality, a view that distinguished him from traditional psychoanalysts. He also described the authoritarian personality (the servile, obedient type of person who wants to accept authority), particularly to explain the success of Nazism.

Fromm's basic ideas are set out in *The Fear of Freedom* 1941 and *The Sane Society* 1955. He urged people to give up the materialistic way of life for one based on meaningful love in *The Art of Loving* 1956 and *To Have or to Be* 1976.

---

frond

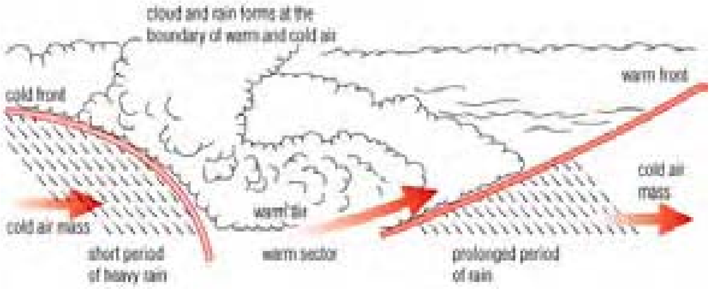
large leaf or leaflike structure; in ferns it is often pinnately divided. The term is also applied to the leaves of palms and less commonly to the plant bodies of certain seaweeds, liverworts, and lichens.

front

in meteorology, the boundary between two air masses of different temperature or humidity. A **cold front** marks the line of advance of a cold air mass from below, as it displaces a warm air mass; a **warm front** marks the advance of a warm air mass as it rises up over a cold one. Frontal systems define the weather of the mid-latitudes, where warm tropical air is continually meeting cold air from the poles.

Warm air, being lighter, tends to rise above the cold; its moisture is carried upwards and usually falls as rain or snow, hence the changeable weather conditions at fronts. Fronts are rarely stable and move with the air mass. An **occluded front** is a composite form, where a cold front catches up with a warm front and merges with it.

front



(Image © Research Machines plc)

The boundaries between two air masses of different temperature and humidity. A warm front occurs when warm air displaces cold air; if cold air replaces warm air, it is a cold front.

frontal lobotomy

operation on the brain. See leucotomy.

frost

condition of the weather that occurs when the air temperature is below freezing, 0°C/32°F. Water in the atmosphere is deposited as ice crystals on the ground or on exposed objects. As cold air is heavier than warm air and sinks to the ground, ground frost is more common than hoar (air) frost, which is formed by the condensation of water particles in the air.

frostbite

the freezing of skin or flesh, with formation of ice crystals leading to tissue damage. The treatment is slow warming of the affected area; for example, by skin-to-skin contact or with lukewarm water. Frostbitten parts are extremely vulnerable to infection, with the risk of gangrene. Sufferers of frostbite should always receive medical attention.

frost hollow

depression or steep-sided valley in which cold air collects on calm, clear nights. Under clear skies, heat is lost rapidly from ground surfaces, causing the air above to cool and flow downhill (as katabatic wind) to collect in valley bottoms. Fog may form under these conditions and, in winter, temperatures may be low enough to cause frost.

frost shattering

alternative name for freeze-thaw.

FRS

abbreviation for **Fellow of the Royal Society**.

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fructose

$C_6H_{12}O_6$

sugar that occurs naturally in honey, the nectar of flowers, and many sweet fruits; it is commercially prepared from glucose.

Fructose is a monosaccharide, whereas the more familiar cane or beet sugar is a disaccharide, made up of two monosaccharide units: fructose and glucose. It is sweeter than cane sugar and can be used to sweeten foods for people with diabetes.

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fruit

(from Latin frui 'to enjoy')

in botany, the ripened ovary in flowering plants that develops from one or more seeds or carpels and encloses one or more seeds. Its function is to protect the seeds during their development and to aid in their dispersal. Fruits are often edible, sweet, juicy, and colourful. When eaten they provide vitamins, minerals, and enzymes, but little protein. Most fruits are borne by perennial plants.

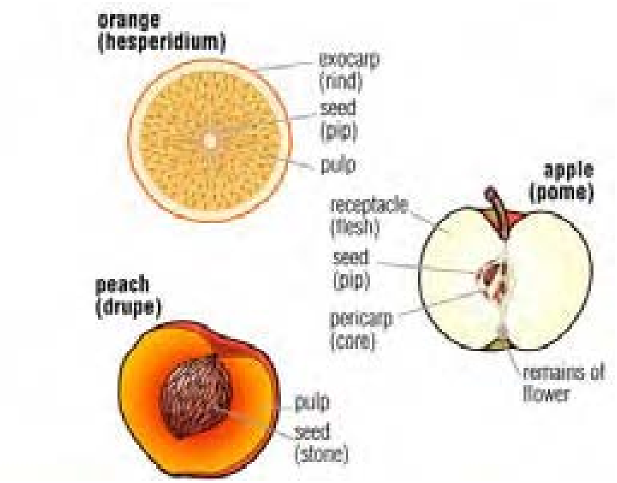
Fruits are divided into three agricultural categories on the basis of the climate in which they grow.
Temperate fruits require a cold season for satisfactory growth; the principal temperate fruits are apples, pears, plums, peaches, apricots, cherries, and soft fruits, such as strawberries.
Subtropical fruits require warm conditions but can survive light frosts; they include oranges and other citrus fruits, dates, pomegranates, and avocados.
Tropical fruits cannot tolerate temperatures that drop close to freezing point; they include bananas, mangoes, pineapples, papayas, and litchis. Fruits can also be divided botanically into **dry** (such as the capsule, follicle, schizocarp, nut, caryopsis, pod or legume, lomentum, and achene) and those that become **fleshy** (such as the drupe and the berry). The fruit structure consists of the pericarp or fruit wall, which is usually divided into a number of distinct layers. Sometimes parts other than the ovary are incorporated into the fruit structure, resulting in a false fruit or pseudocarp, such as the apple and strawberry. True fruits include the tomato, orange, melon, and banana. Fruits may be dehiscent, which open to shed their seeds, or indehiscent, which remain unopened and are dispersed as a single unit. Simple fruits (for example, peaches) are derived from a single ovary, whereas compositae or multiple fruits (for example, blackberries) are formed from the ovaries of a number of flowers. In ordinary usage, 'fruit' includes only sweet, fleshy items; it excludes many botanical fruits such as acorns, bean pods, thistledown, and cucumbers.

methods of seed dispersal

Efficient seed dispersal is essential to avoid overcrowding and enable plants to colonize new areas; the natural function of a fruit is to aid in the dissemination of the seeds which it contains. A great variety of dispersal mechanisms exist: winged fruits are commonly formed by trees, such as ash and elm, where they are in an ideal position to be carried away by the wind; some wind-dispersed fruits, such as clematis and cotton, have plumes of hairs; others are extremely light, like the poppy, in which the capsule acts like a pepperpot and shakes out the seeds as it is blown about by the wind. Some fruits float on water; the coconut can be dispersed across oceans by means of its buoyant fruit. Geraniums, gorse, and squirting cucumbers have explosive mechanisms, by which seeds are forcibly shot out at dehiscence. Animals often act as dispersal agents either by carrying hooked or sticky fruits (burs) attached to their bodies, or by eating succulent fruits, the seeds passing through the alimentary canal unharmed.

Recorded world fruit production in the mid-1980s was approximately 300 million tonnes per year. Technical advances in storage and transport have made tropical fruits available to consumers in temperate areas, and fresh temperate fruits available all year in major markets.

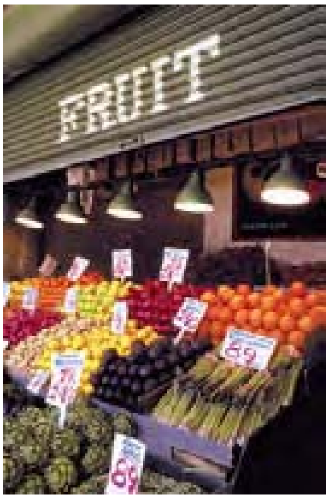
fruit


orange
(hesperidium)
exocarp
(rind)
seed
(pip)
pulp
apple
(pome)
receptacle
(flesh)
seed
(pip)
pericarp
(core)
remains of
flower
peach
(drupe)
pulp
seed
(stone)

(Image © Research Machines plc)

A fruit contains the seeds of a plant. Its outer wall is the exocarp, or epicarp; its inner layers are the mesocarp and endocarp. The orange is a hesperidium, a berry having a leathery rind and containing many seeds. The peach is a drupe, a fleshy fruit with a hard seed, or 'stone', at the centre. The apple is a pome, a fruit with a fleshy outer layer and a core containing the seeds.

fruit market



(Image © Corel)

Fresh fruit and vegetables contain many of the essential dietary minerals and vitamins that we require to stay healthy.

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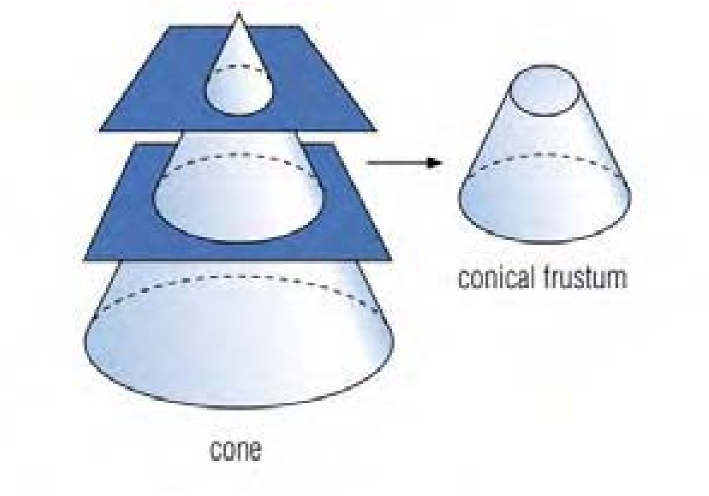
frustum

(from Latin 'a piece cut off')

in geometry, a 'slice' taken out of a solid figure by a pair of parallel planes. A conical frustum, for example, resembles a cone with the top cut off. The volume and area of a frustum are calculated by subtracting the volume or area of the 'missing' piece from those of the whole figure.

frustum



(Image © Research Machines plc)

The frustum, a slice taken out of a cone.

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f-stop

in photography, one of a series of numbers on the lens barrel designating the size of the variable aperture; it stands for the focal length and follows an internationally accepted scale.

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ft

symbol for **foot**, a measure of distance.

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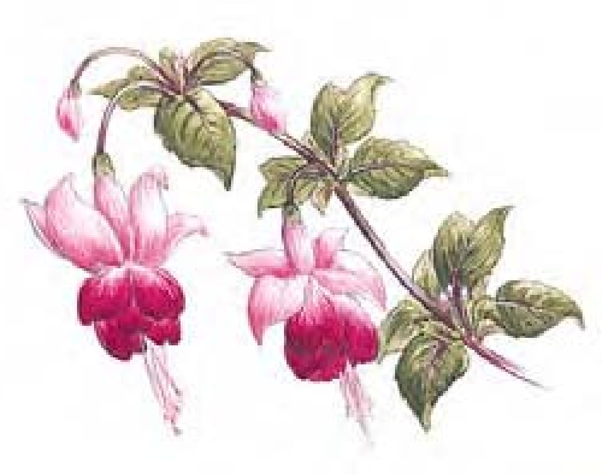
fuchsia

any shrub or herbaceous plant of a group belonging to the evening-primrose family. Species are native to South and Central America and New Zealand, and bear red, purple, or pink bell-shaped flowers that hang downwards. (Genus *Fuchsia*, family Onagraceae.)

The genus was named in 1703 after German botanist Leonhard Fuchs (1501–1566).

fuchsia



(Image © Research Machines plc)

Fuchsia flowers are bell-like and hang downwards. The flowers attract honey bees and the fruits are eaten by birds.

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fuel

any source of heat or energy, embracing the entire range of materials that burn in air (combustibles). A fuel is a substance that gives out energy when it burns. A **nuclear fuel** is any material that produces energy by nuclear fission in a nuclear reactor. Fossil fuels are formed from the fossilized remains of plants and animals.

Crude oil (unrefined petroleum) is purified at an oil refinery by fractional distillation into fuels such as gasoline and kerosine. The burning of fossil fuels for energy production contributes to environmental problems such as acid rain and the greenhouse effect.

---

fuel cell

cell converting chemical energy directly to electrical energy. It works on the same principle as a battery but is continually fed with fuel, usually hydrogen and oxygen. Fuel cells are silent and reliable (they have no moving parts) but expensive to produce. They are an example of a renewable energy source.

Hydrogen is passed over an electrode (usually nickel or platinum) containing a catalyst, which splits the hydrogen into electrons and protons. The electrons pass through an external circuit while the protons pass through a polymer electrolyte membrane to another electrode, over which oxygen is passed. Water is formed at this electrode (as a by-product) in a chemical reaction involving electrons, protons, and oxygen atoms. A current is generated between the electrodes. If the spare heat also produced is used for hot water and space heating, 80% efficiency in fuel is achieved.

Fuel cells can be used to power cars, replacing the internal combustion engine, and to produce electricity on spacecraft.

Batteries Not Included

Go to site

Part of the Why Files project published by the National Institute for Science Education (NISE) and funded by the National Science Foundation, this page touts the benefits of the fuel cell over the battery. Find out what makes the fuel cell a better, longer-lasting power source, and learn what the future may hold in store for the fuel cell.

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fuel injection

injecting fuel directly into the cylinders of an internal combustion engine, instead of by way of a carburettor. It is the standard method used in diesel engines, and is now becoming standard for petrol engines. In the diesel engine, oil is injected into the hot compressed air at the top of the second piston stroke and explodes to drive the piston down on its power stroke. In the petrol engine, fuel is injected into the cylinder at the start of the first induction stroke of the four-stroke cycle.

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fullerene

form of carbon, discovered in 1985, based on closed cages of carbon atoms. The molecules of the most symmetrical of the fullerenes are called buckminsterfullerenes (or buckyballs). They are perfect spheres made up of 60 carbon atoms linked together in 12 pentagons and 20 hexagons fitted together like those of a spherical football. Other fullerenes with 28, 32, 50, 70, and 76 carbon atoms, have also been identified.

Fullerenes can be made by arcing electricity between carbon rods. They may also occur in candle flames and in clouds of interstellar gas. Fullerene chemistry may turn out to be as important as organic chemistry based on the benzene ring. Already, new molecules based on the buckyball enclosing a metal atomhave been made.

Nobel Prize in Chemistry 1999

Go to site

Description of the scientific advances that led to the award of the 1999 Nobel Prize. The description on this page covers all the basic aspects of the 'studies of the transition states of chemical reactions using femtosecond spectroscopy', for which the prize was awarded.

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fuller's earth

soft, greenish-grey rock resembling clay, but without clay's plasticity. It is formed largely of clay minerals, rich in montmorillonite, but a great deal of silica is also present. Its absorbent properties make it suitable for removing oil and grease, and it was formerly used for cleaning fleeces ('fulling'). It is still used in the textile industry, but its chief application is in the purification of oils. Beds of fuller's earth are found in the southern USA, Germany, Japan, and the UK.

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fulmar

any of several species of petrels of the family Procellariidae, which are similar in size and colour to herring gulls. The northern fulmar *Fulmarus glacialis* is found in the North Atlantic and visits land only to nest, laying a single egg.

fulmar

The world's official oldest wild bird is over 50 years old. It is a female fulmar, which nests each year on an uninhabited Orkney island. She has been monitored for 46 years.

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fulminate

any salt of fulminic acid (ONCH), the chief ones being silver and mercury. The fulminates detonate (are exploded by a blow); see detonator. They are isomeric but distinct from the salts of cyanic acid (HOCN), the cyanates.

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fumigation

in medicine, the use of vapours, such as camphor, to destroy bacteria or vermin. The process was widely used in the past but it has been superseded by more effective disinfection procedures.

---

fumitory

any of a group of plants native to Europe and Asia. The common fumitory (*F. officinalis*) grows to 50 cm/20 in and produces pink flowers tipped with blackish red; it has been used in medicine for stomach and liver complaints. (Genus *Fumeria*, family Fumariaceae.)

Fumitory

Go to site

Informative resource relating to fumitory. It contains a detailed description of the plant and its habitat. There are also notes on the constituents of the plant, as well as information on the possible medicinal uses of fumitory, which include acting as a diuretic. A number of recipes are also included, showing how to use fumitory in making syrup, juice, and wine.

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function

in computing, a small part of a program that supplies a specific value – for example, the square root of a specified number, or the current date. Most programming languages incorporate a number of built-in functions; some allow programmers to write their own. A function may have one or more arguments (the values on which the function operates). A **function key** on a keyboard is one that, when pressed, performs a designated task, such as ending a program.

---

function

in mathematics, a function f is a non-empty set of ordered pairs (x, $f(x)$) of which no two can have the same first element. Hence, if $f(x) = x^2$ two ordered pairs are (-2,4) and (2,4). The set of all first elements in a function's ordered pairs is called the **domain**; the set of all second elements is the **range**. Functions are used in all branches of mathematics, physics, and science generally. For example, in the equation$y = 2x + 1$, y is a function of the symbol x. This can be written as $y = f(x)$.

In another example, the formula$t = 2\pi\surd(l/g)$ shows that for a simple pendulum, the time of swing t is a function of its length l and of no other variable quantity (π and g, the acceleration due to gravity, are constants).

---

functional group

in chemistry, a small number of atoms in an arrangement that determines the chemical properties of the group and of the molecule to which it is attached (for example, the carboxyl group COOH, or the amine group NH_2). Organic compounds can be considered as structural skeletons, with a high carbon content, with functional groups attached.

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fundamental constant

physical quantity that is constant in all circumstances throughout the whole universe. Examples are the electric charge of an electron, the speed of light, Planck's constant, and the gravitational constant.

Physical constants

Physical constants, or fundamental constants, are physical quantities that are constant in all circumstances throughout the whole universe.

Constant	Symbol	Value in SI units
acceleration of free fall	g	$9.80665\ m\ s^{-2}$

Avogadro's constant	N_A	6.0221367×10^{23} mol^{-1}
Boltzmann's constant	k	1.380658×10^{-23} J K^{-1}
elementary charge	e	$1.60217733 \times 10^{-19}$ C
electronic rest mass	m_e	$9.1093897 \times 10^{-31}$ kg
Faraday's constant	F	9.6485309×10^{4} C mol^{-1}
gas constant	R	8.314510 J K^{-1} mol^{-1}
gravitational constant	G	6.672×10^{-11} N m^{2} kg^{-2}
Loschmidt's number	N_L	2.686763×10^{25} m^{-3}
neutron rest mass	m_n	$1.6749286 \times 10^{-27}$ kg
Planck's constant	h	$6.6260755 \times 10^{-34}$ J s
proton rest mass	m_p	$1.6726231 \times 10^{-27}$ kg
speed of light in a vacuum	c	2.99792458×10^{8} m s^{-1}
standard atmosphere	atm	1.01325×10^{5} Pa
Stefan-Boltzmann constant	σ	5.67051×10^{-8} W m^{-2} K^{-4}

fundamental forces

see forces, fundamental.

fundamental particle

another term for **elementary particle**.

fungal infection

in medicine, infection with a fungus, such as the *Candida albicans*. Sites of infection are the mouth, skin folds, and vagina. These are treated by the use of suspensions, creams, and pessaries containing antifungal agents, such as nystatin and clotrimazole. More generalized candidiasis may occur in patients with damaged immune systems due to AIDS or to the use of immunosuppressive drugs. These infections can be severe and they are treated with intravenous infusions of amphotericin and other antifungal drugs.

Dermatophyte infections are due to fungi that infect the keratin tissues of the skin, hair, and nails. Such infections are usually superficial and they tend to occur in moist and warm situations. Examples are athlete's foot and ringworm. They often respond to local treatment with clotrimazole or miconazole. Oral antifungal agents, such as terbinafine, may be required to treat persistent infections. Therapy may need to be prolonged over several weeks due to low concentrations of the drug reaching the site of infection because of poor blood supply. This is a particular problem with nail infections.

fungicide

any chemical pesticide used to prevent fungus diseases in plants and animals. Inorganic and organic compounds containing sulphur are widely used.

fungus

plural fungi

any of a unique group of organisms that includes moulds, yeasts, rusts, smuts, mildews, mushrooms, and toadstools. There are around 70,000 species of fungi known to science, although there may be as many as 1.5 million actually in existence. They are not considered to be plants for three main reasons: they have no leaves or roots; they contain no chlorophyll (green colouring) and are therefore unable to make their own food by photosynthesis; and they reproduce by spores. Some fungi are edible but many are highly poisonous; they often cause damage and sometimes disease to the organic matter on which they live and feed, but some fungi are exploited in the production of food and drink (for example, yeasts in baking and brewing) and in medicine (for example, penicillin).

Fungi are either parasites, existing on living plants or animals, or saprotrophs, living on dead matter. Many of the most serious plant diseases are caused by fungi, and several fungi attack humans and animals. Athlete's foot, thrush, and ringworm are fungal diseases. Endophytes are fungi that live inside plants. Almost all plants have endophytes and many have large numbers, for example the grass fescue has 400 species.

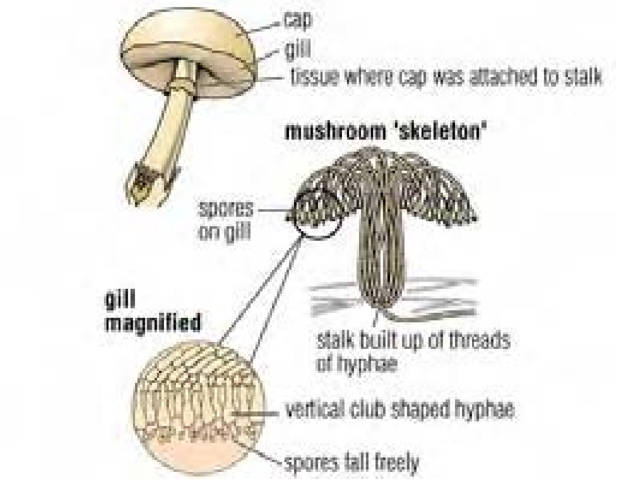
Before the classification Fungi came into use, they were included within the division Thallophyta, along with algae and bacteria. Two familiar fungi are bread mould, which illustrates the typical many-branched body (mycelium) of the organism, made up of threadlike chains of cells called hyphae; and mushrooms, which are the sexually reproductive fruiting bodies of an underground mycelium.

The mycelium of a true fungus is made up of many intertwined hyphae. When the fungus is ready to reproduce, the hyphae become closely packed into a solid mass called the fruiting body, which is usually small and inconspicuous but can be very large; mushrooms, toadstools, and bracket fungi are all examples of large fruiting bodies. These carry and distribute the spores. Most species of fungi reproduce both asexually (on their own) and sexually (involving male and female parents).

fungus

Fungi have twice the total biomass of all the Earth's animals.

fungus


cap
gill
tissue where cap was attached to stalk
mushroom 'skeleton'
spores on gill
gill magnified
stalk built up of threads of hyphae
vertical club shaped hyphae
spores fall freely

(Image © Research Machines plc)

Fungi grow from spores as fine threads, or hyphae. These have no distinct cellular structure. Mushrooms and toadstools are the fruiting bodies formed by the hyphae. Gills beneath the caps of these aerial structures produce masses of spores.

Fungi

Go to site

University-run network of hyperlinked pages on fungi, from their earliest fossil records to their current ecology and life cycles, from how they are classified systematically to how they are studied. Although this page is not shy of technical terms, there are clear explanations and pictures to help the uninitiated.

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funicular railway

railway with two cars connected by a wire cable wound around a drum at the top of a steep incline. Funicular railways of up to 1.5 km/1 mi exist in Switzerland.

In Britain, the system is used only in seaside cliff railways.

Funk, Casimir (1884-1967)

Polish-born US biochemist who pioneered research into vitamins. He was the first to isolate niacin (nicotinic acid, one of the vitamins of the B complex).

Funk proposed that certain diseases are caused by dietary deficiencies. In 1912 he demonstrated that rice extracts cure beriberi in pigeons. As the extract contains an amine, he mistakenly concluded that he had discovered a class of 'vital amines', a phrase soon reduced to 'vitamins'.

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fur

the hair of certain animals. Fur is an excellent insulating material and so has been used as clothing. This is, however, vociferously criticized by many groups on humane grounds, as the methods of breeding or trapping animals are often cruel. Mink, chinchilla, and sable are among the most valuable, the wild furs being finer than the farmed.

Fur such as mink is made up of a soft, thick, insulating layer called underfur and a top layer of longer, lustrous guard hairs.

Furs have been worn since prehistoric times and have long been associated with status and luxury (ermine traditionally worn by royalty, for example), except by certain ethnic groups like the Inuit. The fur trade had its origin in North America, where in the late 17th century the Hudson's Bay Company was established. The chief centres of the fur trade are New York, London, St Petersburg, and Kastoria in Greece. It is illegal to import furs or skins of endangered species listed by CITES (such as the leopard). Many synthetic fibres are widely used as substitutes.

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furlong

unit of measurement, originating in Anglo-Saxon England, equivalent to 220 yd (201.168 m).

A furlong consists of 40 rods, poles, or perches; 8 furlongs equal one statute mile. Its literal meaning is 'furrow-long', and refers to the length of a furrow in the common field characteristic of medieval farming.

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furnace

structure in which fuel such as coal, coke, gas, or oil is burned to produce heat for various purposes. Furnaces are used in conjunction with boilers for heating, to produce hot water, or steam for driving turbines - in ships for propulsion and in power stations for generating electricity. The largest furnaces are those used for smelting and refining metals, such as the blast furnace, electric furnace, and open-hearth furnace.

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furniture beetle

wood-boring beetle. See woodworm.

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furze

another name for gorse, a shrub.

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fuse

in electricity, a wire or strip of metal designed to melt (thus breaking the circuit) when excessive current passes through. It is a safety device that halts surges of current that would otherwise damage equipment and cause fires. In explosives, a fuse is a cord impregnated with chemicals so that it burns slowly at a predetermined rate. It is used to set off a main explosive charge, sufficient length of fuse being left to allow the person lighting it to get away to safety.

In an electrical fuse, current flow converts electrical energy into heat energy, increasing the temperature of the fuse material. As more current flows, the temperature of the material rises; at a certain current the material melts, thus interrupting the current flow.

Different types of electrical equipment require differently-rated fuses depending upon how much current can flow without damaging the equipment. For example, some equipment requires a 13 amp fuse and some a 3 amp fuse.

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fusel oil

liquid with a characteristic unpleasant smell, obtained as a by-product of the distillation of the product of any alcoholic fermentation, and used in paints, varnishes, essential oils, and plastics. It is a mixture of fatty acids, alcohols, and esters.

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fusion

in physics, the fusing of the nuclei of light elements, such as hydrogen, into those of a heavier element, such as helium. The resultant loss in their combined mass is converted into energy. Stars and thermonuclear weapons are powered by nuclear fusion.

Nuclear fusion takes place in the Sun, where hydrogen nuclei fuse at temperatures of about 10 million-°C/18 million-°F producing huge amounts of heat and light energy.

Fusion

Go to site

All-text site packed with information about fusion research and its applications. It is quite well organized and includes a glossary of commonly used terms to aid the uninitiated.

Fusion Energy and Plasma Physics Research at PPPL

Go to site

Outlines the work of the Princeton Plasma Physics Laboratory (PPPL). Updated with news from the laboratory, there are announcements of forthcoming meetings and pages detailing the educational programmes with which PPPL are involved.

Internet Plasma Physics Experience

Go to site

Operate your own virtual Tokamak fusion reactor and get a hands-on feel for this exciting branch of physics. This information-packed site explains the key physics concepts involved in nuclear fusion and plasma physics, such as matter, electricity and magnetism, and energy.

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fuzzy logic

in mathematics and computing, a form of knowledge representation suitable for notions (such as 'hot' or 'loud') that cannot be defined precisely but depend on their context. For example, a jug of water may be described as too hot or too cold, depending on whether it is to be used to wash one's face or to make tea.

The central idea of fuzzy logic is **probability of set membership**. For instance, referring to someone 175 cm/5 ft 9 in tall, the statement 'this person is tall' (or 'this person is a member of the set of tall people') might be about 70% true if that person is a man, and about 85% true if that person is a woman.

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g

symbol for **gram**.

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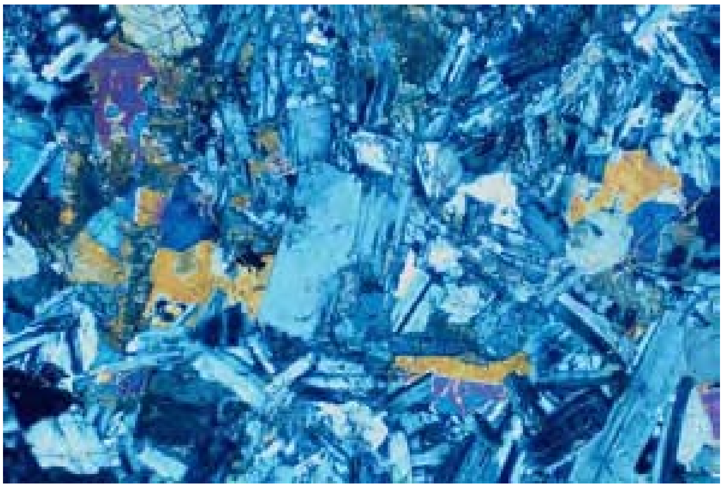
gabbro

mafic (consisting primarily of dark-coloured crystals) igneous rock formed deep in the Earth's crust. It contains pyroxene and calcium-rich feldspar, and may contain small amounts of olivine and amphibole. Its coarse crystals of dull minerals give it a speckled appearance.

Gabbro is the plutonic version of basalt (that is, derived from magma that has solidified below the Earth's surface), and forms in large, slow-cooling intrusions.

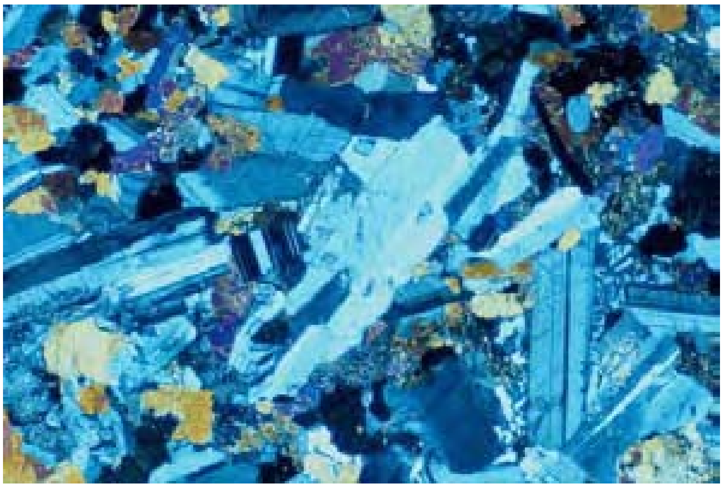
gabbro



(Image © Corel)

Gabbro through a polarized microscope. Gabbro is an igneous rock which forms in major plutonic intrusions.

olivine gabbro



(Image © Corel)

Olivine gabbro through a polarized microscope. Gabbro is a coarse-grained igneous rock.

Gabor, Dennis (1900-1979)

Hungarian-born British physicist. He was awarded the Nobel Prize for Physics in 1971 for his invention in 1947 of the holographic method of three-dimensional photography.

gadfly

fly that bites cattle, such as a botfly or horsefly.

gadolinium

chemical symbol Gd

silvery-white metallic element of the lanthanide series, atomic number 64, relative atomic mass 157.25. It is found in the products of nuclear fission and used in electronic components, alloys, and products needing to withstand high temperatures.

Gagarin, Yuri Alexeyevich (1934-1968)

Soviet cosmonaut who on 12 April 1961 became the first human in space, aboard the spacecraft *Vostok 1* (see *Vostok*). He completed one orbit of the Earth, taking 108 minutes from launch to landing. He died in a plane crash while training for the *Soyuz 3* mission.

Gagarin, Yuri

Go to site

Biography of the peasant's son who became 'the Columbus of the cosmos'. It traces Gagarin's education and training as a pilot prior to describing the courage with which he piloted *Vostok 1*.

Gaia hypothesis

theory that the Earth's living and nonliving systems form an inseparable whole that is regulated and kept adapted for life by living organisms themselves. The planet therefore functions as a single organism, or a giant cell. The hypothesis was elaborated by British scientist James Lovelock and first published in 1968.

Earthdance: Living Systems in Evolution

Go to site

Philosophical work by Elisabet Sahtouris, based on the Gaia hypothesis, published in 1995 with an introduction by James Lovelock. There are chapters on such topics as 'Problems for earthlife', 'Ecological ethics', and 'Survival: the sustainable society'.

gain

in electronics, the ratio of the amplitude of the output signal produced by an amplifier to that of the input signal. In a voltage amplifier the voltage gain is the ratio of the output voltage to the input voltage; in an inverting operational amplifier (op-amp) it is equal to the ratio of the resistance of the feedback resistor to that of the input resistor.

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gal

or galileo

unit of acceleration, used in geological surveying. One gal is one centimeter per second per second. The Earth's gravitational field often differs by several milligals (thousandths of a gal) in different places, because of the varying densities of the rocks beneath the surface.

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galactic coordinates

in astronomy, system for measuring the position of astronomical objects on the celestial sphere with reference to the galactic equator.

Galactic latitude (symbol b) is measured in degrees from the galactic equator (b = 0°) to the north (b = 90°) and south (b = - 90°) galactic poles.

Galactic longitude (symbol l) is measured in degrees eastward (l = 0° to 360°) from a fixed point in the constellation of Sagittarius that approximates to the centre of the Galaxy. Galactic coordinates are often used when astronomers are studying the distribution of material in the Galaxy.

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galactic halo

in astronomy, outer, sparsely populated region of a galaxy, roughly spherical in shape and extending far beyond the bulk of the visible stars. In our own Galaxy, the halo contains the globular clusters, and may harbour large quantities of dark matter.

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galactic plane

in astronomy, plane passing through the Sun and the centre of our Galaxy defining the mid-plane of the galactic disc. Projected onto the celestial sphere, the galactic plane is the galactic equator, a great circle marking the approximate centre line of the Milky Way.

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galaxy

grouping of millions or billions of stars, held together by gravity. There are billions of galaxies in the universe. There are different types, including spiral, barred spiral, and elliptical galaxies. Our own galaxy, the Milky Way, is about 100,000 light years across (a light year is the distance light travels in a year, about 9.5 trillion km/6 trillion mi; 1 trillion = 10^{12}), and contains at least 100 billion stars.

The galaxies are moving away from our own in all directions. The universe is thus expanding in all directions. The evidence for this comes from examining light from the galaxies by splitting the light into a spectrum. A feature known as the red shift appears, where the light is shifted towards the red end of the spectrum due to an increase in wavelength caused by the galaxies' recession.

For a prominent galaxy in the constellation Virgo, which is about 38 million light years away, the red shift indicates the galaxy is moving away from us at 1,200 km/730 mi per second, while another galaxy in the constellation Hydra, which is about 2,000 million light years away, is moving away from us at 56,000 km/35,000 mi per second.

Nearest galaxies

Name	Constellation	Type	Approximate distance (light-years)
Canis Major Dwarf	Canis Major	irregular	25,000
Virgo Stellar Stream	Virgo	spheroidal	30,000
Sagittarius Dwarf	Sagittarius	spheroidal	81,000
Large Magellanic Cloud (LMC)	Dorado/Mensa	irregular	168,000
Small Magellanic Cloud (SMC)	Tucana	irregular	200,000
Ursa Minor Dwarf	Ursa Minor	spheroidal	240,000
Sculptor Dwarf	Sculptor	spheroidal	254,000
Draco Dwarf	Draco	spheroidal	280,000
Sextans Dwarf	Sextans	spheroidal	320,000
Ursa Major Dwarf	Ursa Major	spheroidal	330,000

Galaxy Catalogue

Go to site

Magnificent photographic catalogue of 113 nearby galaxies imaged from the Palomar and Lowell observatories. After selecting a thumbnail, the user is prompted to choose a file format with which to view the full-size galaxy image.

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gale

strong wind, usually between force seven and ten on the Beaufort scale (measuring 45-90 km/28-56 mi per hour).

Galen (c. 129-c. 200)

Greek physician and anatomist whose ideas dominated Western medicine for almost 1,500 years. Central to his thinking were the threefold circulation of the blood and the theory of humours (blood, phlegm, choler/yellow bile, and melancholy/black bile) that contributed to mental and physical state. His *On Anatomical Procedures*, a detailed description of animal dissections when work on human corpses was forbidden, became a standard text on anatomy when rediscovered in Western Europe in the 16th century. He remained the highest medical authority until Andreas Vesalius and William Harvey exposed the fundamental errors of his system.

Galen postulated a circulation system in which the liver produced the natural spirit, the heart the vital spirit, and the brain the animal spirit. He also wrote about philosophy and believed that Nature expressed a divine purpose, a belief that became increasingly popular with the rise of Christianity (Galen himself was not a Christian). This helped to account for the enormous influence of his ideas.

On the Natural Faculties

Go to site

Text of this work by the Greek physician Galen.

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galena

mineral consisting of lead sulphide, PbS, the chief ore of lead. It is lead-grey in colour, has a high metallic lustre and breaks into cubes because of its perfect cubic cleavage. It may contain up to 1% silver, and so the ore is sometimes mined for both metals. Galena occurs mainly among limestone deposits in Australia, Mexico, Russia, Kazakhstan, the UK, and the USA.

Galileo (1564-1642)

born Galileo Galilei

Italian mathematician, astronomer, and physicist. He developed the astronomical telescope and was the first to see sunspots, the four main satellites of Jupiter, and the appearance of Venus going through phases, thus proving it was orbiting the Sun. Galileo discovered that freely falling bodies, heavy or light, have the same, constant acceleration and that this acceleration is due to gravity. He also determined that a body moving on a perfectly smooth horizontal surface would neither speed up nor slow down. He invented a thermometer, a hydrostatic balance, and a compass, and discovered that the path of a projectile is a parabola.

Galileo's work founded the modern scientific method of deducing laws to explain the results of observation and experiment, although the story of his dropping cannonballs from the Leaning Tower of Pisa is questionable. His observations were an unwelcome refutation of the Aristotelian ideas taught at universities, largely because they made plausible for the first time the Sun-centred theory of Polish astronomer Nicolaus Copernicus. Galileo's persuasive *Dialogo sopra i due massimi sistemi del mondo/Dialogues on the Two Chief Systems of the World* (1632) was banned by the church authorities in Rome and he was made to recant by the Inquisition.

astronomy and the invention of the telescope

In July 1609, hearing that a Dutch scientist had made a telescope, Galileo worked out the principles involved and made a number of telescopes. He compiled fairly accurate tables of the orbits of four of Jupiter's satellites and proposed that their frequent eclipses could serve as a means of determining longitude on land and at sea. His observations on sunspots and Venus going through phases supported Copernicus's theory that the Earth rotated and orbited the Sun. Galileo's results published in *Sidereus Nuncius/The Starry Messenger* (1610) were revolutionary.

He believed, however - following both Greek and medieval tradition - that orbits must be circular, not elliptical, in order to maintain the fabric of the cosmos in a state of perfection. This preconception prevented him from deriving a full formulation of the law of inertia, which was later to be attributed to the contemporary French mathematician René Descartes.

the pendulum

Galileo made several fundamental contributions to mechanics. He rejected the impetus theory that a force or push is required to sustain motion. While watching swinging lamps in Pisa Cathedral, Galileo determined that each oscillation of a pendulum takes the same amount of time despite the difference in amplitude, and recognized the potential importance of this observation to timekeeping. In a later publication, he presented his derivation that the square of the period of a pendulum varies with its length (and is independent of the mass of the pendulum bob).

mechanics and the law of falling bodies

Galileo discovered before Newton that two objects of different weights - an apple and a melon, for instance - falling from the same height would hit the ground at the same time. He realized that gravity not only causes a body to fall, but also determines the motion of rising bodies and, furthermore, that gravity extends to the centre of the Earth. Galileo then showed that the motion of a projectile is made up of two components: one component consists of uniform motion in a horizontal direction, and the other component is vertical motion under acceleration or deceleration due to gravity.

Galileo used this explanation to refute objections to Copernicus. It had been argued, against Copernicus, that a turning Earth would not carry along birds and clouds. Galileo explained that the motion of a bird, like a projectile, has a horizontal component that is provided by the motion of the Earth and that this horizontal component of motion always exists to keep such objects in position even though they are not attached to the ground.

Galileo came to an understanding of uniform velocity and uniform acceleration by measuring the time it takes for bodies to move various distances. He had the brilliant idea of slowing vertical motion by measuring the movement of balls rolling down inclined planes, realizing that the vertical component of this motion is a uniform acceleration due to gravity. It took Galileo many years to arrive at the correct expression of the law of falling bodies, which he presented in *Discorsi e dimostrazioni matematiche intorno a due nove scienze/Discourses and Mathematical Discoveries Concerning Two New Sciences* (1638) as:

$s=1/2at^2$

where s is speed, a is the acceleration due to gravity, and t is time. He found that the distance travelled by a falling body is proportional to the square of the time of descent.

A summation of his life's work, *Discourses* also included the facts that the trajectory of a projectile is a parabola, and that the law of falling bodies is perfectly obeyed only in a vacuum, and that air resistance always causes a uniform terminal velocity to be reached.

The Determination of Longitude

introduction

Being lost at sea was one of the greatest fears of the early navigators. Although the system of latitude and longitude had been used since the time of Ptolemy in the 2nd century, it was not until the late 18th century that navigation became a reliable art.

problem of measuring longitude

The problem is that while the latitude of any point of the Earth – its angular distance north or south of the Equator - can be determined by careful measurements of the altitude of the Sun or stars, longitude is a different matter. Longitude is measured east or west from an arbitrary prime meridian, connecting the Earth's poles. Until it settled on Greenwich in 1884, the prime meridian was often that of the ship's home port. To find longitude at sea, a navigator had to note the time when the Sun or a star appeared due south and compare it with the predicted time the same body appeared due south from the prime meridian. The difference in times (where 1 h of time is 15°), was the ship's longitude. Unfortunately, there were no clocks which could keep time on board ships. Throughout the great voyages of discovery from the 15th-18th centuries sailors were largely ignorant of their longitude, which is why Columbus, sailing westwards along a line of latitude, had no idea where he was when he landed in the New World in 1492.

using Jupiter's moons for navigation

In 1610, Galileo Galilei (1564-1642) discovered the four large moons of Jupiter. Every now and then the moons would pass in and out of the shadow of Jupiter and Galileo saw that these eclipses could provide a celestial clock for navigators. All that was needed were accurate predictions for the eclipses for a number of ports. By observing these eclipses, sailors would know the precise time at home and so be able calculate their longitude by noting which stars were then due south. Astronomers put a great deal of effort into studying the motions of Jupiter's moons (one such, Danish, astronomer Ole Römer (1644-1710), found that the times of eclipses deviated systematically from predictions with the varying distance of Jupiter from the Earth, and so made the first measurement of the speed of light). However, the method was only usable when Jupiter was above the horizon in a dark, clear sky and an eclipse was imminent.

problems without longitude

National observatories were founded in Paris (1667) and Greenwich (1675) with the prime purpose of developing astronomical methods of finding longitude. None the less, as the 18th century dawned no better method had come along and the increasing toll of lost ships and lives was causing growing concern. In a notorious accident in 1707, four Royal Navy ships, believing themselves to be in deeper water further east, were wrecked on the Scilly Isles with the loss of almost 2,000 lives. Other ideas showed how desperate this problem had become. One proposal in 1713 would have stationed signal boats at 600-mile intervals across the Atlantic, delivering time signals in the form of exploding cannon shells. Finally in 1714, under pressure from shipping and naval concerns, the British government set up a 'Board of Longitude' empowered to award a prize of £20,000 for a method of determining longitude at sea to a precision of half a degree.

sea-clocks

The idea of a sea-going clock had been revived on several occasions since the 16th century, and Dutch astronomer Christiaan Huygens (1629-1695) had built and tested one in 1664. Yet no clock had been devised that could keep good time on a rolling ship through changes of temperature, barometric pressure and gravity while enduring the rigours of life at sea. In 1735, a Lincolnshire clock-maker, John Harrison, presented his answer to the challenge. His sea-clock (known as H1) employed many novel features to ensure steady running and performed well in sea trials. Rather than claim the award, Harrison insisted on making an improved version, H2, which he delivered in 1741. An even better model, H3, was not completed until 1759, and in the intervening years another method was coming into contention.

using the Moon as a clock

The 'Board of Longitude' was dominated by astronomers who were hoping for a celestial rather than a mechanical solution. One such method, proposed as long ago as 1514, was to use the Moon as a clock. If the steadily shifting position of the Moon among the stars could be predicted, then precise measurements of its position should enable the time to be reckoned accurately enough for the determination of longitude. It was known as the lunar distance method. The problem was that the positions of the stars were poorly known, and sufficiently precise tables for the Moon's motion were not available. While Harrison laboured on his clocks, these problems were gradually overcome. In 1725, former Astronomer Royal John Flamsteed's (1646–1719) catalogue of 3000 star positions was published and in 1757, cartographer Johann Tobias Mayer (1723–1762) of Nuremberg delivered accurate tables of the Moon's motion to the 'Board of Longitude'. Together with the recently invented sextant, navigators now had everything they needed to make use of the lunar distance method.

H4

Shortly after completing H3, Harrison devised a dramatically different solution in the compact form of H4, an outsize pocket watch. H4 seemed to be the perfect solution to the longitude problem and performed exceedingly well in sea trials, losing only 5 s on its first transatlantic voyage in 1761. However, a leading advocate of the lunar distance method, astronomer Nevil Maskelyne (1732–1811), stalled the development of Harrison's clocks in the hope of gaining the award himself. In 1765, he became Astronomer Royal and took up his *ex officio* seat on the Board of Longitude. Under Maskelyne's influence, Harrison was denied his award for the next eight years while the Board prevaricated, demanding additional tests and the construction of more clocks. Finally, in faltering health, Harrison appealed directly to King George III who intervened with the Board and ensured in 1773 that Harrison was given his just reward, three years before his death. Between 1772 and 1779, James Cook (1728–1779) took several replicas of H4 on his voyages of discovery, and by the the turn of the century the 'marine chronometer' was in mass production by several clock-makers and had become a common sight on ocean-going ships.

Galileo

spacecraft launched from the space shuttle *Atlantis* on 18 October 1989 to explore the planet Jupiter. Galileo's probe entered the atmosphere of Jupiter in December 1995. It radioed information back to the orbiter for 57 minutes before the craft was destroyed by atmospheric pressure. The first pictures of Jupiter were transmitted in 1996. In 1997 Galileo completed two fly-bys of Jupiter's fourth-largest and icy moon Europa, and in February 2000 it passed within 200 km/125 mi of Jupiter's third-largest moon Io. In September 2003, with its mission completed, the orbiter was deliberately plunged into Jupiter's atmosphere to avoid any chance that it would crash onto a satellite and contaminate it.

The spacecraft flew past the planet Venus in February 1990 and passed within 970 km/600 mi of Earth in December 1990 and December 1992, using the gravitational fields of these two planets to increase its velocity. It flew past the asteroids Gaspra in 1991 and Ida in 1993, taking close-up photographs.

Galileo

(Image © NASA)

The Galileo spacecraft about to be detached from the Earth-orbiting space shuttle *Atlantis* at the beginning of its six-year journey to Jupiter.

Galileo: Journey to Jupiter

Go to site

Full details of the ground-breaking mission to the Solar System's largest planet. There are regularly updated reports on instructions being given to the probe by the Jet Propulsion Laboratory, Pasadena, California, and on data being received from Galileo. There are numerous images of Jupiter and its moons and an animation showing fluctuations in the Great Red Spot. If you cannot find an answer to your query in the Frequently Asked Questions, you may e-mail the project.

Galileo Project Information

Go to site

Site dedicated to the Galileo project and the opportunities it has offered scientists and astronomers to enhance our understanding of the universe. The site includes information about the mission's objectives, scientific results, images, and links to other relevant sites.

gall

abnormal outgrowth on a plant that develops as a result of attack by insects or, less commonly, by bacteria, fungi, mites, or nematodes. The attack causes an increase in the number of cells or an enlargement of existing cells in the plant. Gall-forming insects generally pass the early stages of their life inside the gall.

Gall wasps are responsible for the conspicuous bud galls forming on oak trees, 2.5–4 cm/1–1.5 in across, known as 'oak apples'. The organisms that cause galls are host-specific. Thus, for example, gall wasps tend to parasitize oaks, and sawflies willows.

gall bladder

small muscular sac, part of the digestive system of most, but not all, vertebrates. In humans, it is situated on the underside of the liver and connected to the small intestine by the bile duct. It stores bile from the liver.

Galle, Johann Gottfried (1812–1910)

German astronomer. He located the planet Neptune in 1846, close to the position predicted by French mathematician Urbain Leverrier and the English astronomer J C Adams.

galley

ship powered by oars, and usually also equipped with sails. Galleys typically had a crew of hundreds of rowers arranged in banks. They were used in warfare in the Mediterranean from antiquity until the 18th century.

France maintained a fleet of some 40 galleys, crewed by over 10,000 convicts, until 1748. The maximum speed of a galley is estimated to have been only four knots (7.5 kph/4.5 mph), because only 20% of the rower's effort was effective, and galleys could not be used in stormy weather because of their very low waterline.

gallium

chemical symbol Ga

grey metallic element, atomic number 31, relative atomic mass 69.72. It is liquid at room temperature. Gallium arsenide (GaAs) crystals are used for semiconductors in microelectronics, since electrons travel a thousand times faster through them than through silicon. The element was discovered in 1875 by Lecoq de Boisbaudran (1838–1912).

gallium arsenide

compound of gallium and arsenic, formula GaAs, used in lasers, photocells, and microwave generators. Its semiconducting properties make it a possible rival to silicon for use in microprocessors. Chips made from gallium arsenide require less electric power and process data faster than those made from silicon.

gall midge

minute and fragile long-legged flies, with longish hairy antennae. The larvae are small maggots, ranging in colour from white or yellow, to orange and bright red, that feed on developing fruits which become deformed and decay, and frequently produce galls on plants.

Some forms live within galls formed by other insects, such as beetles, or other species of Cecidomyiidae. The hessian fly of North America and New Zealand, is a pest of wheat. The **pearl midge** *Contarinia pyrivota* is a serious fruit pest in Europe.

classification

Gall midges are in the family Cecidomyiidae (suborder Nematocera) of the insect order Diptera, class Insecta, phylum Arthropoda.

Gallo, Robert Charles (1937-)

US scientist credited with identifying the virus responsible for AIDS. Gallo discovered the virus, now known as human immunodeficiency virus (HIV), in 1984; the French scientist Luc Montagnier of the Pasteur Institute, Paris, discovered the virus, independently, in 1983.

The sample in which Gallo discovered the virus was supplied by Montagnier, and it was alleged that this may have been contaminated by specimens of the virus isolated by Montagnier a few months earlier. Gallo was later exonerated of scientific fraud after a court case.

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gallon

unit of liquid measure, equal to 3.785 litres, and subdivided into four quarts or eight pints. The UK and Canadian imperial gallon is equivalent to 4.546 litres.

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gallstone

pebblelike, insoluble accretion formed in the human gall bladder or bile ducts from cholesterol or calcium salts present in bile. Gallstones may be symptomless or they may cause pain, indigestion, or jaundice. They can be dissolved with medication or removed, either by means of an endoscope or, along with the gall bladder, in an operation known as cholecystectomy.

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gall wasp

small (only a few millimetres long), dark-coloured insect with a compressed abdomen. Most gall wasps form galls, though a few live within the galls formed by other species; these are called **inquilines**. Others feed on gall-formers and inquilines.

classification

Gall wasps are in the family Cynipidae, order Hymenoptera, class Insecta, phylum Arthropoda.

The exact reactions which lead to gall formation in the host plant are little understood. Basically it is a reaction of the cells of the plant to the presence of the larva.

complex life history

The oak-apple gall is caused by species *Biorhiza pallida* and both winged males and wingless or vestigial-winged females emerge from these galls. After mating the females lay their eggs in the root of the same host plant, thus producing root galls. In the following spring only wingless females are produced. These females climb up the oak tree and produce the characteristic oak-apples, thus repeating the life cycle.

Rose galls are often produced by *Diplolepis rosae*. These gall wasps usually reproduce asexually; the females are about 4 mm/0.2 in long; parts of their abdomens and legs are yellow-red, while the rest of the body is black. Males of this species have been observed only rarely. The galls are a mass of reddish filaments within which are found a number of sealed chambers enclosing larvae. The larvae feed on the gall tissue.

Galois, Evariste (1811-1832)

French mathematician who originated the theory of groups and greatly extended the understanding of the conditions in which an algebraic equation is solvable.

Galois, Evariste

Go to site

Portrait and text-heavy biography of the 19th-century French mathematician. The site, run by St Andrews University, also includes excerpts from original works by Galois and details of his contemporaries.

Galton, Francis (1822-1911)

English scientist, inventor, and explorer who studied the inheritance of physical and mental attributes with the aim of improving the human species. He was the first to use twins to try to assess the influence of environment on development, and is considered the founder of eugenics (a term he coined).

Galton believed that genius was inherited, and was principally to be found in the British; he also attempted to compile a map of human physical beauty in Britain. He invented the 'silent' dog whistle, the weather map, a teletype printer, and forensic fingerprinting, and discovered the existence of anticyclones.

Galvani, Luigi (1737-1798)

Italian physiologist who discovered galvanic, or voltaic, electricity in 1762, when investigating the contractions produced in the muscles of dead frogs by contact with pairs of different metals. His work led quickly to Alessandro Volta's invention of the electrical cell, and later to an understanding of how nerves control muscles.

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galvanizing

process for rendering iron rust-proof, by plunging it into molten zinc (the dipping method), or by electroplating it with zinc.

The word, derived from the name of the pioneer of electrical studies, Luigi Galvani, originally referred to electrodeposition with any metal.

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galvanometer

instrument for detecting small electric currents by their magnetic effect.

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gamete

cell that functions in sexual reproduction by merging with another gamete to form a zygote. Examples of gametes include sperm and egg cells. In most organisms, the gametes are haploid (they contain half the number of chromosomes of the parent), owing to reduction division or meiosis.

In higher organisms, gametes are of two distinct types: large immobile ones known as eggs or egg cells and small ones known as sperm. They come together at fertilization. In some lower organisms the gametes are all the same, or they may belong to different mating strains but have no obvious differences in size or appearance.

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game theory

group of mathematical theories, developed in 1944 by German-born US mathematician Oscar Morgenstern and Hungarian-born US mathematician John Von Neumann, that seeks to abstract from invented game-playing scenarios and their outcome the essence of situations of conflict and/or cooperation in the real political, business, and social world.

A feature of such games is that the rationality of a decision by one player will depend on what the others do; hence game theory has particular application to the study of oligopoly (a market largely controlled by a few producers).

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gametophyte

the haploid generation in the life cycle of a plant that produces gametes; see alternation of generations.

---

gamma radiation

very high-frequency, high-energy electromagnetic radiation, similar in nature to X-rays but of shorter wavelength, emitted by the nuclei of radioactive substances during decay or by the interactions of high-energy electrons with matter. Cosmic gamma rays have been identified as coming from pulsars, radio galaxies, and quasars, although they cannot penetrate the Earth's atmosphere.

Gamma rays are stopped only by direct collision with an atom and are therefore very penetrating. They can, however, be stopped by about 4 cm/1.5 in of lead or by a very thick concrete shield. They are less ionizing in their effect than alpha and beta particles, but are dangerous nevertheless because they can penetrate deeply into body tissues such as bone marrow. They are not deflected by magnetic or electric fields.

Gamma radiation is used to kill bacteria and other micro-organisms, sterilize medical devices, and change the molecular structure of plastics to modify their properties (for example, to improve their resistance to heat and abrasion).

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gamma-ray astronomy

study of celestial objects that emit gamma rays (energetic photons with very short wavelengths). Much of the radiation detected comes from collisions between hydrogen gas and cosmic rays in our Galaxy. Some sources have been identified, including the Crab Nebula and the Vela pulsar (the most powerful gamma-ray source detected).

Gamma rays from space cannot be directly detected at ground level, but they can be studied indirectly by observing the secondary particles arriving at the ground after gamma-ray photons have collided with atoms of atmospheric gases. Gamma rays can be studied directly by use of balloon-borne detectors and artificial satellites. The first gamma-ray satellites were SAS II (1972) and COS-B (1975), although gamma-ray detectors were carried on the *Apollo 15* and *Apollo 16* missions, in 1971 and 1972, respectively. SAS II failed after only a few months, but COS-B continued working until 1982, carrying out a complete survey of the galactic disc.

Gamow, George (1904-1968)

born Georgi Antonovich Gamow

Russian-born US cosmologist, nuclear physicist, and popularizer of science. His work in astrophysics included a study of the structure and evolution of stars and the creation of the elements. He explained how the collision of nuclei in the solar interior could produce the nuclear reactions that power the Sun. With the 'hot Big Bang' theory, which he co-proposed in 1948, he indicated the origin of the universe.

Gamow predicted that the electromagnetic radiation left over from the universe's formation should, after having cooled down during the subsequent expansion of the universe, manifest itself as a microwave cosmic background radiation. He also made an important contribution to the understanding of protein synthesis.

---

ganglion

plural ganglia

solid cluster of nervous tissue containing many cell bodies and synapses, usually enclosed in a tissue sheath; found in invertebrates and vertebrates.

In many invertebrates, the central nervous system consists mainly of ganglia connected by nerve cords. The ganglia in the head (cerebral ganglia) are usually well developed and are analogous to the brain in vertebrates. In vertebrates, most ganglia occur outside the central nervous system.

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gangrene

death and decay of body tissue (often of a limb) due to bacterial action; the affected part gradually turns black and causes blood poisoning.

Gangrene sets in as a result of loss of blood supply to the area. This may be due to disease (diabetes, atherosclerosis), an obstruction of a major blood vessel (as in thrombosis), injury, or frostbite. Bacteria colonize the site unopposed, and a strong risk of blood poisoning often leads to surgical removal of the tissue or the affected part (amputation).

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gangue

part of an ore deposit that is not itself economically valuable; for example, calcite may occur as a gangue mineral with galena.

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gannet

any of three species of North Atlantic seabirds; the largest is *Sula bassana*. When fully grown, it is white with buff colouring on the head and neck; the beak is long and thick and compressed at the point; the wings are black-tipped with a span of 1.7 m/5.6 ft. It breeds on cliffs in nests made of grass and seaweed, laying a single white egg. Gannets feed on fish that swim near the surface, such as herrings and pilchards. (Family Sulidae, order Pelecaniformaes.)

Diving swiftly and sometimes from a considerable height upon their prey, they enter the water with closed wings and neck outstretched. They belong to the same family as the booby.

The gannets are the largest seabirds of the North Atlantic; they are found also in the southeast Pacific and in temperate waters off Africa.

Cape gannets

(Image © Corel)

A colony of Cape gannets gather along the coast of Namibia, southwest Africa.

Ganymede

in astronomy, largest moon of the planet Jupiter, orbiting every 7.2 days at a distance of 1.1 million km/700,000 mi. It is the largest moon in the Solar System, 5,260 km/3,270 mi in diameter (larger than the planet Mercury). Its surface is a mixture of extensively cratered and grooved terrain. Molecular oxygen was identified on Ganymede's surface in 1994. It is thought that Ganymede has a water ice crust and possibly a buried water ocean

The space probe Galileo detected a magnetic field around Ganymede in 1996; this suggests it may have a molten core. Galileo photographed Ganymede at a distance of 7,448 km/4,628 mi. The resulting images were 17 times clearer than those taken by Voyager 2 in 1979.

gardenia

any of a group of subtropical and tropical trees and shrubs found in Africa and Asia, belonging to the madder family, with evergreen foliage and flattened rosettes of fragrant waxen-looking flowers, often white in colour. (Genus *Gardenia*, family Rubiaceae.)

garfish

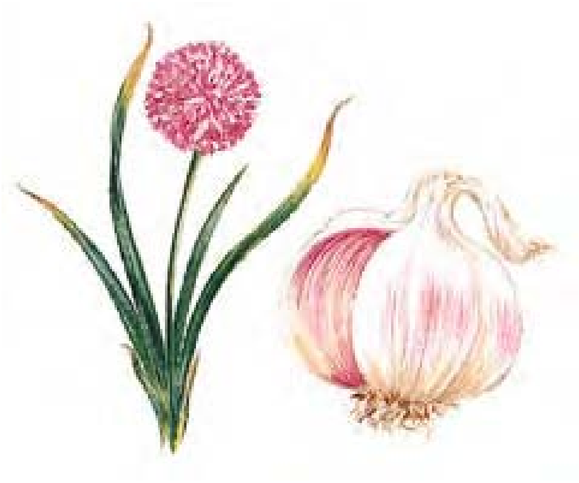
European marine fish with a long spearlike snout. The common garfish (*Belone belone*) has an elongated body measuring 75 cm/2.5 ft in length. (Family Belonidae, order Beloniformes.)

garlic

perennial Asian plant belonging to the lily family, whose strong-smelling and sharp-tasting bulb, made up of several small segments, or cloves, is used in cooking. The plant has white flowers. It is widely cultivated and has been used successfully as a fungicide in the cereal grass sorghum. It also has antibacterial properties. (*Allium sativum*, family Liliaceae.)

In tests carried out in 1994, US doctors found freshly pressed garlic extract killed a number of bacteria, including drug-resistant strains, even when diluted to one part in 250. Its effectiveness is probably due to allicin, a simple organic disulphide.

garlic



(Image © Research Machines plc)

Garlic is a perennial bulb of the onion family. It grows about 30 cm/12 in high, and has pale spherical flowers. It has been used since ancient Egyptian times as a herb. In the Middle Ages, it was thought to keep away vampires, perhaps because of the strong smell imparted to the breath of regular users.

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garnet

group of silicate minerals with the formula $X_3Y_3(SiO_4)_3$, where X is calcium, magnesium, iron, or manganese, and Y is usually aluminium or sometimes iron or chromium. Garnets are used as semi-precious gems (usually pink to deep red) and as abrasives. They occur in metamorphic rocks such as gneiss and schist.

Garnets consisting of neodymium, yttrium, and aluminium (referred to as Nd-YAG) produce infrared laser light when sufficiently excited. Nd-YAG lasers are inexpensive and used widely in industry and scientific research.

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gas

form of matter, such as air, in which the molecules move randomly in otherwise empty space, filling any size or shape of container into which the gas is put.

A sugar-lump sized cube of air at room temperature contains 30 trillion molecules moving at an average speed of 500 metres per second (1,800 kph/1,200 mph). Gases can be liquefied by cooling, which lowers the speed of the molecules and enables attractive forces between them to bind them together.

Chemical Stuff

Go to site

School-focused chemistry Web site, providing a lively discussion of concepts such as 'The nature of proof', a list of experiments on topics such as the nature of gases, and chemistry calculations as well as a links page.

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gas constant

in physics, the constant R that appears in the equation $PV = nRT$, which describes how the pressure P, volume V, and temperature T of an ideal gas are related (n is the amount of gas in moles). This equation combines Boyle's law and Charles's law.

R has a value of 8.3145 joules per kelvin per mole.

---

gas engine

internal-combustion engine in which a gas (coal gas, producer gas, natural gas, or gas from a blast furnace) is used as the fuel.

The first practical gas engine was built in 1860 by Jean Etienne Lenoir, and the type was subsequently developed by Nikolaus August Otto, who introduced the four-stroke cycle.

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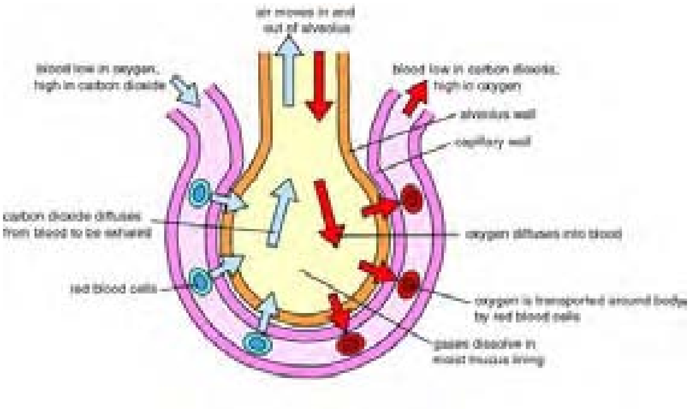
gas exchange

movement of gases between an organism and the atmosphere, principally oxygen and carbon dioxide. All aerobic organisms (most animals and plants) take in oxygen in order to burn food and manufacture ATP (adenosine triphosphate, which provides the energy for all cell reactions). The resultant oxidation reactions release carbon dioxide as a waste product to be passed out into the environment. Green plants also absorb carbon dioxide during photosynthesis, and release oxygen as a waste product.

It is a characteristic of living organisms that they exchange materials with the environment. As well as the exchange of oxygen and carbon dioxide during aerobic respiration, nutrients must be taken up from the environment to feed the organism. In humans, these include carbohydrates, proteins, minerals (see mineral salts), and vitamins. Water is another important substance that has to be absorbed. However, in plants, only carbon dioxide, water, and minerals are required. The carbon dioxide is used in photosynthesis, which then releases oxygen as a waste product. All oxygen gas in the air on Earth is believed to have been produced by photosynthesis.

Specialized respiratory surfaces have evolved during evolution to make gas exchange more efficient. In humans and other tetrapods (four-limbed vertebrates), gas exchange occurs in the lungs, aided by the breathing movements of the ribs. Many adult amphibia and terrestrial invertebrates can absorb oxygen directly through the skin. The bodies of insects and some spiders contain a system of air-filled tubes known as tracheae. Fish have gills as their main respiratory surface. In plants, gas exchange generally takes place via the stomata and the air-filled spaces between the cells in the interior of the leaf.

gas exchange


air moves in and out of alveolus
blood low in oxygen, high in carbon dioxide
blood low in carbon dioxide, high in oxygen
alveolus wall
capillary wall
carbon dioxide diffuses from blood to be exhaled
oxygen diffuses into blood
red blood cells
oxygen is transported around body by red blood cells
gases dissolve in moist mucus lining

(Image © Research Machines plc)

Gas exchange in the alveolus. Blood enters the lungs low in oxygen and high in carbon dioxide. The carbon dioxide diffuses from the blood to the alveolus, where carbon dioxide levels are low. Oxygen diffuses from the alveolus, where oxygen levels are high, into the blood where the level is low, so blood leaves the lungs high in oxygen and low in carbon dioxide.

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gas giant

in astronomy, any of the four large outer planets of the Solar System, Jupiter, Saturn, Uranus, and Neptune, which consist largely of gas and whose visible surfaces are not solid, though they have solid cores.

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gas laws

physical laws concerning the behaviour of gases. They include Boyle's law and Charles's law, which are concerned with the relationships between the pressure (P), temperature (T), and volume (V) of an ideal (hypothetical) gas. These two laws can be combined to give the **general** or **universal gas law**, which may be expressed as: PV/T = constant.

The laws state that gas pressure depends on the temperature and volume of the gas. If the volume of a gas is kept constant, its pressure increases with temperature. When a gas is squeezed into a smaller volume, its pressure increases. If the pressure of a gas is constant, its volume increases with temperature. Such behaviour of gases depends on the kinetic theory of matter, and particle theory, which states that all matter is composed of particles.

Gases

Go to site

Clear explanation of gases and the states of matter, part of an introductory chemistry site aimed at entry-level university students. Click on the sidebar for information on the properties of gases, gas laws, kinetic molecular theory, and deviation from the ideal gas law.

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gasohol

motor fuel that is 90% petrol and 10% ethanol (alcohol). The ethanol is usually obtained by fermentation, followed by distillation, using maize, wheat, potatoes, or sugar cane. It was used in early cars before petrol became economical, and its use was revived during the 1940s war shortage and the energy shortage of the 1970s, for example in Brazil.

gasoline

mixture of hydrocarbons derived from petroleum, whose main use is as a fuel for internal combustion engines. It is colorless and highly volatile.

In the UK, gasoline is called petrol.

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gasoline engine

or piston engine

the most commonly used source of power for motor vehicles, introduced by the German engineers Gottlieb Daimler and Karl Benz in 1885. The gasoline engine is a complex piece of machinery made up of about 150 moving parts. It is a reciprocating piston engine, in which a number of pistons move up and down in cylinders. A mixture of petrol and air is introduced to the space above the pistons and ignited. The gases produced force the pistons down, generating power. The engine-operating cycle is repeated every four strokes (upward or downward movement) of the piston, this being known as the four-stroke cycle. The motion of the pistons rotates a crankshaft, at the end of which is a heavy flywheel. From the flywheel the power is transferred to the car's driving wheels via the transmission system of clutch, gearbox, and final drive.

The parts of the gasoline engine can be subdivided into a number of systems. The **fuel system** pumps fuel from the petrol tank into the carburettor. There it mixes with air and is sucked into the engine cylinders. (With electronic fuel injection, the fuel goes directly from the tank into the cylinders by way of an electronic monitor.) The **ignition system** supplies the sparks to ignite the fuel mixture in the cylinders. By means of an ignition coil and contact breaker, it boosts the 12-volt battery voltage to pulses of 18,000 volts or more. These go via a distributor to the spark plugs in the cylinders, where they create the sparks. (Electronic ignitions replace these parts.) Ignition of the fuel in the cylinders produces temperatures of 700°C/1,300°F or more, and the engine must be cooled to prevent overheating. Most engines have a **water-cooling system**, in which water circulates through channels in the cylinder block, thus extracting the heat. It flows through pipes in a radiator, which are cooled by fan-blown air. A few cars and most motorcycles are air-cooled, the cylinders being surrounded by many fins to present a large surface area to the air. The **lubrication system** also removes some heat, but its main job is to keep the moving parts coated with oil, which is pumped under pressure to the camshaft, crankshaft, and valve-operating gear.

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gastritis

inflammation of the lining of the stomach. The term is a vague one, applied to a range of conditions.

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gastroenteritis

inflammation of the stomach and intestines, giving rise to abdominal pain, vomiting, and diarrhoea. It may be caused by food or other poisoning, allergy, or infection. Dehydration may be severe and it is a particular risk in infants.

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gastroenterology

medical speciality concerned with disorders of the digestive tract and associated organs such as the liver, gall bladder and pancreas.

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gastrolith

stone that was once part of the digestive system of a dinosaur or other extinct animal. Rock fragments were swallowed to assist in the grinding process in the dinosaur digestive tract, much as some birds now swallow grit and pebbles to grind food in their crop. Once the animal has decayed, smooth round stones remain - often the only clue to their past use is the fact that they are geologically different from their surrounding strata.

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gastropod

any member of a very large group of molluscs (soft-bodied invertebrate animals). Gastropods have a single shell (in a spiral or modified spiral form) and eyes on stalks, and they move on a flattened, muscular foot. They have well-developed heads and rough, scraping tongues called radulae. Some are marine, some freshwater, and others land creatures, but they all tend to live in damp places. (Class Gastropoda.)

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gastroscope

in medicine, instrument for viewing the interior of the stomach. It consists of a tube with a light and mirrors attached that is introduced into the stomach via the mouth and the oesophagus. A camera attachment allows photographs to be taken of the stomach interior.

Gastroscopy using fibreoptic technology allows the observation of images that are transmitted through a fibreoptic bundle or a small video camera. Flexibility of the instrument allows photographs of all areas of the stomach and tissue samples can be taken to assist in diagnosis when required.

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gas turbine

engine in which burning fuel supplies hot gas to spin a turbine. The most widespread application of gas turbines has been in aviation. All jet engines (see under jet propulsion) are modified gas turbines, and some locomotives and ships also use gas turbines as a power source.

They are also used in industry for generating and pumping purposes.

In a typical gas turbine a multivaned compressor draws in and compresses air. The compressed air enters a combustion chamber at high pressure, and fuel is sprayed in and ignited. The hot gases produced escape through the blades of (typically) two turbines and spin them around. One of the turbines drives the compressor; the other provides the external power that can be harnessed.

Gates, Bill (1955-)

born William Henry Gates, III

US computer entrepreneur. He co-founded Microsoft Corporation in 1975, with school friend and fellow entrepreneur Paul Allen, and has succeeded in converting a passion for computers into a globally dominant software business. Gates and Allen adapted a version of BASIC, an early computer language, and licensed the operating system MS-DOS to IBM for its first personal computer (PC) in 1981. US magazine *Forbes* estimated his net worth at US$90 billion in 1999 and, despite a reduction in his wealth due to a slump in technology shares, he remains the world's richest person. In 2003, the magazine put Gates's net worth at US$40.7 billion.

By 1983 MS-DOS was the dominant operating system, and Gates was able to use his enormous royalties to fund the development of the Windows graphical user interface, the mouse, and Microsoft applications (including Word and Excel) in the 1990s. However, Microsoft's position in the software market led to an antitrust court action. In 2000 the trial judge ruled that the company was a monopoly and ordered its break-up into two separate concerns. Although the ruling to break up the company was overturned on appeal in June 2001, the verdict that Microsoft had abused its monopoly with its Windows software was upheld in October 2001, forcing the company to accept penalties for breaking US competition laws.

Gates, Bill

Go to site

Part of a larger archive from *Time* exploring the most influential people of the 20th century, this article highlights the life and work of the US businessman and computer programmer Bill Gates. The profile also features a time line.

Gatling, Richard Jordan (1818-1903)

US inventor of a rapid-fire gun. Patented in 1862, the Gatling gun had ten barrels arranged as a cylinder rotated by a hand crank. Cartridges from an overhead hopper or drum dropped into the breech mechanism, which loaded, fired, and extracted them at a rate of 320 rounds per minute.

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gauge

any scientific measuring instrument - for example, a wire gauge or a pressure gauge. The term is also applied to the width of a railway or tramway track.

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gauge boson

or field particle

any of the particles that carry the four fundamental forces of nature (see forces, fundamental). Gauge bosons are elementary particles that cannot be subdivided, and include the photon, the graviton, the gluons, and the W^+, W^-, and Z particles.

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gauss

symbol Gs

centimetre-gram-second (*c*.g.s.) unit of magnetic induction or magnetic flux density, replaced by the SI unit, the tesla, but still commonly used. It is equal to one line of magnetic flux per square centimetre. The

Earth's magnetic field is about 0.5 Gs, and changes to it over time are measured in gammas (one gamma equals 10^{-5} gauss).

Gauss, Carl Friedrich (1777-1855)

German mathematician who worked on the theory of numbers, non-Euclidean geometry, and the mathematical development of electric and magnetic theory. A method of neutralizing a magnetic field, used to protect ships from magnetic mines, is called 'degaussing'.

In statistics, the normal distribution curve, which he studied, is sometimes known as the Gaussian distribution. Between 1800 and 1810 Gauss concentrated on astronomy. He developed a quick method for calculating an asteroid's orbit from only three observations and published this work - a classic in astronomy - 1809.

Gauss, Carl Friedrich

Go to site

Web site run by St Andrews University providing a portrait and detailed biography of the German physicist and mathematician. The site also contains details on Gauss's major works, including his work on the prime number theorem. Many literature references are also listed for further study.

Gay-Lussac, Joseph Louis (1778-1850)

French physicist and chemist who investigated the physical properties of gases, and discovered new methods of producing sulphuric and oxalic acids. In 1802 he discovered the approximate rule for the expansion of gases now known as Charles's law; see also gas laws.

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gazelle

any of a number of lightly built, fast-running antelopes found on the open plains of Africa and southern Asia. (Especially species of the genus *Gazella*.)

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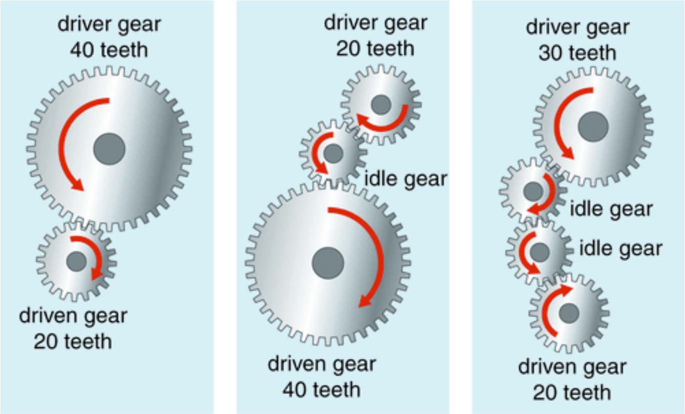
gear

toothed wheel that transmits the turning movement of one shaft to another shaft. Gear wheels may be used in pairs, or in threes if both shafts are to turn in the same direction. The gear ratio - the ratio of the number of teeth on the two wheels - determines the torque ratio, the turning force on the output shaft compared with the turning force on the input shaft. The ratio of the angular velocities of the shafts is the inverse of the gear ratio.

The common type of gear for parallel shafts is the **spur gear**, with straight teeth parallel to the shaft axis. The **helical gear** has teeth cut along sections of a helix or corkscrew shape; the double form of the helix gear is the most efficient for energy transfer.
Bevel gears, with tapering teeth set on the base of a cone, are used to connect intersecting shafts.

gear



ratio 1:2
(one turn of the driver to every two of the driven)

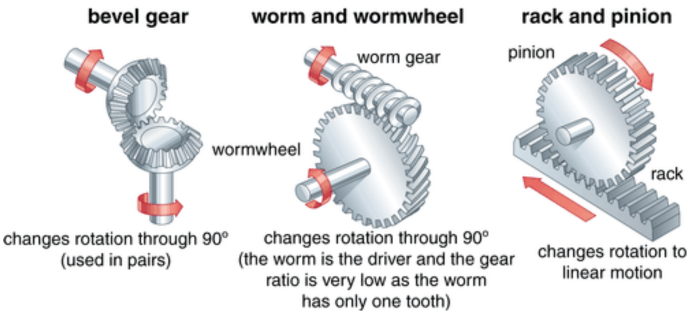
ratio 2:1
(two turns of the driver to every one of the driven)

ratio 2:3
(two turns of the driver to every three of the driven)

(Image © Research Machines plc)

Gear ratio is calculated by dividing the number of teeth on the driver gear by the number of teeth on the driven gear (gear ratio = driver/driven); the idler gears are ignored. Idler gears change the direction of rotation but do not affect speed. A high driven to driver ratio (middle) is a speed-reducing ratio.

gear


bevel gear
worm and wormwheel
rack and pinion
worm gear
pinion
wormwheel
rack
changes rotation through 90° (used in pairs)
changes rotation through 90° (the worm is the driver and the gear ratio is very low as the worm has only one tooth)
changes rotation to linear motion

(Image © Research Machines plc)

Different gears are used to perform different engineering functions depending on the change in direction of motion that is needed. Rack and pinion gears are the commonest gears and are used in car steering mechanisms.

Geber

Latin name of Arabic alchemist Jabir ibn Hayyan.

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gecko

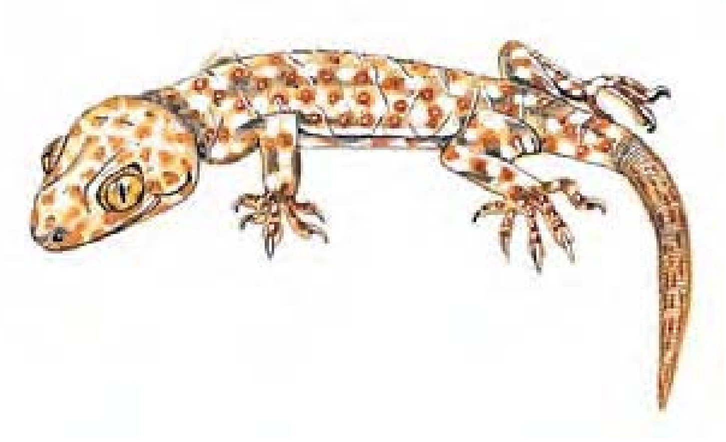
any lizard of the family Gekkonidae. Geckos are common worldwide in warm climates, and have large heads and short, stout bodies. Many have no eyelids. They are able to climb vertically and walk upside down on smooth surfaces in their search for flies, spiders, and other prey.

There are about 850 known species of gecko. There are 102 Australian species, 17 new species having been discovered there 1986–96. A new species of gecko *Tarentola mindiae* was identified in Egypt's Western Desert in 1997. In June 2000 US researchers explained the mechanism whereby geckos are able to walk across ceilings and up walls. Each foot is covered with nearly 5,000 tiny hairs less than a tenth of the diameter of human hair, called setae. Each seta is tipped with hundreds of spatula-shaped structures. The setae generate a force of over 10 kg/22 lb when clinging on, by force of attraction between molecules (explained by van der Waals' law).

gecko

One species of Hawaiian gecko reproduces without sex to create all-female populations. These females have fewer parasites (and thus better health) than their mixed-gender neighbours.

gecko



(Image © Research Machines plc)

The tokay gecko is one of the largest and most common geckos – 28 cm/11 in long. It is found in Asia and Indonesia and is thought to bring good luck to the houses in which it lives. It feeds on insects such as cockroaches, and on small lizards, mice, and even small birds.

Geiger, Hans (Wilhelm) (1882-1945)

German physicist who produced the Geiger counter. He spent the period 1906-12 in Manchester, England, working with Ernest Rutherford on radioactivity. In 1908 they designed an instrument to detect and count alpha particles, positively charged ionizing particles produced by radioactive decay.

In 1928 Geiger and Walther Müller produced a more sensitive version of the counter, which could detect all kinds of ionizing radiation.

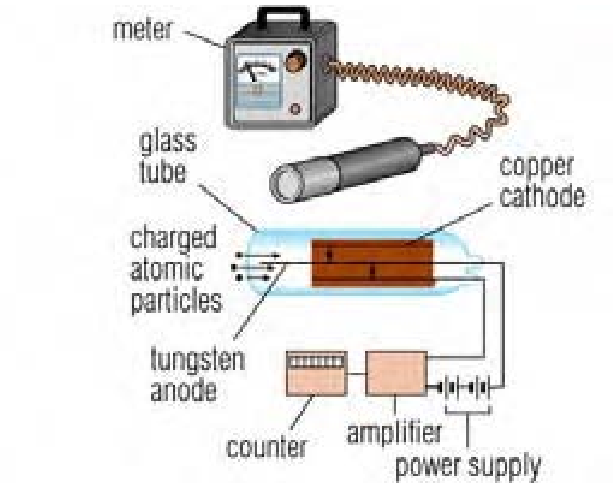
Geiger counter

any of a number of devices used for detecting nuclear radiation and measuring its intensity by counting the number of ionizing particles produced (see radioactivity). It detects the momentary current that passes between electrodes (anode and cathode) in a suitable gas (such as argon) when radiation causes the ionization of the gas. The electrodes are connected to electronic devices that enable the number of particles passing to be measured. The increased frequency of measured particles indicates the intensity of radiation. The device is named after the German physicist Hans Geiger.

The becquerel (Bq) is the unit used to measure radioactive decay. The number of particles emitted in one second by a radioactive source is known as the activity (or disintegration): 1 Bq = 1 disintegration per second.

The Geiger-Müller, Geiger-Klemperer, and Rutherford-Geiger counters are all devices often referred to loosely as Geiger counters.

Geiger counter



(Image © Research Machines plc)

A Geiger-Müller counter detects and measures ionizing radiation (alpha particles, beta particles, and gamma rays) emitted by radioactive materials. Any incoming radiation creates ions (charged particles) within the counter, which are attracted to the anode and cathode to create a measurable electric current.

gel

solid produced by the formation of a three-dimensional cage structure, commonly of linked large-molecular-mass polymers, in which a liquid is trapped. It is a form of colloid. A gel may be a jellylike mass (pectin, gelatin) or have a more rigid structure (silica gel).

gelignite

type of dynamite.

gem

mineral valuable by virtue of its durability (hardness), rarity, and beauty, cut and polished for ornamental use, or engraved. Of 120 minerals known to have been used as gemstones, only about 25 are in common use in jewellery today; of these, the diamond, emerald, ruby, and sapphire are classified as precious, and all the others semi-precious; for example, the topaz, amethyst, opal, and aquamarine.

Among the synthetic precious stones to have been successfully produced are rubies, sapphires, emeralds, and diamonds (first produced by General Electric in the USA in 1955). Pearls are not technically gems.

Birthstones

Month	Stone	Quality
January	garnet	constancy
February	amethyst	sincerity
March	aquamarine, bloodstone	courage

April	diamond	innocence
May	emerald	love
June	alexandrite, pearl	health and purity
July	ruby	contentment
August	peridot, sardonyx	married happiness
September	sapphire	clear thinking
October	opal, tourmaline	hope
November	topaz	fidelity
December	turquoise, zircon	wealth

Gems and semi-precious stones

Stone	Colour	Hardness	Composition
amethyst	purple or blue-violet	7.0	silica (quartz)
aquamarine	pale blue-green	7.5	beryl
carnelian	red or red-brown	7.0	silica (quartz)
citrine	yellow	7.0	silica (quartz)
diamond	colourless, yellow, green, or black	10.0	carbon
emerald	green	7.5	beryl
lapis lazuli	blue	5.5	lazurite
malachite	green	4.0	copper carbonate
moonstone	silver/blue opalescent	6.0-6.5	alkali feldspar
morganite	pink	7.5	beryl
opal	multicoloured	6.0	silica (amorphous)
pearl	white or black	3.5	calcium carbonate
peridot	olive-green	6.0-7.0	olivine
ruby	red	9.0	corundum
sapphire	blue, green, or yellow	9.0	corundum
topaz	green, blue, or yellow	8.0	complex silicate
tourmaline	dark green or pink	7.5	complex borosilicate
turquoise	blue	6.0	aluminium/copper phosphate
zircon	colourless or pink	6.5-7.5	zirconium silicate

Gemini

prominent zodiacal constellation in the northern hemisphere represented as the twins Castor and Pollux. Its brightest star is Pollux; Castor is a system of six stars. The Sun passes through Gemini from late June to late July. Each December, the Geminid meteors are seen, their trails giving the appearance of radiating from Gemini. In astrology, the dates for Gemini are between about 21 May and 21 June (see precession).

Gemini project

US space programme (1965-66) in which astronauts practised rendezvous and docking of spacecraft, and working outside their spacecraft, in preparation for the *Apollo* project Moon landings.

Gemini spacecraft carried two astronauts and were launched by Titan rockets. Flights were designated by the double name *Gemini-Titan*.

The meeting of *Gemini 7* with *Gemini 6* in 1965 was the first rendezvous between two spacecraft.

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gemma

plural gemmae

unit of vegetative reproduction, consisting of a small group of undifferentiated green cells. Gemmae are found in certain mosses and liverworts, forming on the surface of the plant, often in cup-shaped structures, or gemmae cups. Gemmae are dispersed by splashes of rain and can then develop into new plants. In many species, gemmation is more common than reproduction by spores.

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gemsbok

species of antelope that inhabits the desert regions of southern Africa. It stands about 1.2 m/4 ft in height, and its general colour is greyish. Its horns are just over 1 m/3.3 ft long.

classification

The gemsbok *Oryx gazella* is in family Bovidae, order Artiodactyla.

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gene

basic unit of inherited material, encoded by a strand of DNA and transcribed by RNA. In higher organisms, genes are located on the chromosomes. A gene consistently affects a particular character in an individual – for example, the gene for eye colour. Also termed a Mendelian gene, after Austrian biologist Gregor Mendel, it occurs at a particular point, or locus, on a particular chromosome and may have several variants, or alleles, each specifying a particular form of that character – for example, the alleles for blue or brown eyes. Some alleles show dominance. These mask the effect of other alleles, known as recessive. Genes can be manipulated using the techniques of genetic engineering (gene technology).

The inheritance of genes and the way genes work is studied in genetics. One gene carries the information that describes how one particular protein is made. This information is stored as a chemical code on a DNA molecule and the genes are found in sequence from one end of the molecule to the other. Each protein that is made helps to determine part of the characteristics of an organism. Between them, all the proteins determine all the inherited characteristics of an organism, though some of these characteristics can be modified by the environment. The DNA is located in the chromosomes in the nucleus of a cell. Many thousands of genes are present on each chromosome. The total number of genes in a human, according to estimates published in 2001 by the Human Genome Project, is thought to be between 27,000 and 40,000, distributed between the 46 chromosomes in each human cell. Occasionally, a gene or a larger part of a chromosome or the number of chromosomes becomes accidentally altered. Such a change is a mutation. Mutations can cause an individual to have a disease or disorder, such as Huntington's disease, cystic fibrosis, or sickle-cell anaemia. Gregor Mendel was the first to understand the mechanism of inheritance by genes, as a result of the study of plant breeding. He did not, however, know about the existence of DNA.

Genetic Technology

Go to site

Wry and thought-provoking look at genetic science. Starting with a dig at the morals of a past US president, who was posthumously exposed by developments in gene mapping, this Web site continues with an intelligent consideration of the potential offered by the human genome project, and the limitations of genetics.

Question of Genes: Inherited Risks

Go to site

Companion to a US Public Broadcasting Service (PBS) television programme, this page explores the controversial subject of genetic testing, emphasizing its social, ethical, and emotional consequences. It includes summaries of the seven case studies featured on the television programme, including video clips. There is also a section on the basics of genetic testing, which features the transcript of an interview with a genetic counsellor. You will also find a list of resources for further research and a forum for discussion.

Your Genes, Your Choices: Exploring the Issues Raised by Genetic Research

Go to site

Learn all about dominant genes and mutation, heredity, and the science behind the Human Genome Project. This site also considers the important ethical, legal, and social issues that are raised by the project.

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gene amplification

technique by which selected DNA from a single cell can be duplicated indefinitely until there is a sufficient amount to analyse by conventional genetic techniques.

Gene amplification uses a procedure called the polymerase chain reaction. The sample of DNA is mixed with a solution of enzymes called polymerases, which enable it to replicate, and with a plentiful supply of nucleotides, the building blocks of DNA. The mixture is repeatedly heated and cooled. At each warming, the double-stranded DNA present separates into two single strands, and with each cooling the polymerase assembles a new paired strand for each single strand. Each cycle takes approximately 30 minutes to complete, so that after 10 hours there is one million times more DNA present than at the start.

The technique can be used to test for genetic defects in a single cell taken from an embryo, before the embryo is reimplanted in in vitro fertilization.

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gene bank

collection of seeds or other forms of genetic material, such as tubers, spores, bacterial or yeast cultures, live animals and plants, frozen sperm and eggs, or frozen embryos. These are stored for possible future use in agriculture, plant and animal breeding, or in medicine, genetic engineering, or the restocking of wild habitats where species have become extinct. Gene banks may be increasingly used as the rate of extinction increases, depleting the Earth's genetic variety (biodiversity).

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gene pool

total sum of alleles (variants of genes) possessed by all the members of a given population or species alive at a particular time.

generate

in mathematics, to produce a sequence of numbers from either the relationship between one number and the next or the relationship between a member of the sequence and its position. For example, $u_{n+1} = 2u_n$ generates the sequence 1, 2, 4, 8, ... ; $a_n = n(n+1)$ generates the sequence of numbers 2, 6, 12, 20, .

generation

in computing, stage of development in computer electronics (see computer generation) or a class of programming language (see fourth-generation language).

generator

machine that produces electrical energy from mechanical energy, as opposed to an electric motor, which does the opposite. A simple generator (known as a dynamo in the UK) consists of a wire-wound coil (armature) that is rotated between the poles of a permanent magnet. As the coil rotates it cuts across the magnetic field lines and a current is generated. A dynamo on a bicycle is an example of a simple generator.

The current generated can be increased by using a stronger magnet, by rotating the armature faster, or by winding more turns of wire onto a larger armature.

gene shears

technique in genetic engineering which may have practical applications in the future. The gene shears are pieces of messenger RNA that can bind to other pieces of messenger RNA, recognizing specific sequences, and cut them at that point. If a piece of DNA which codes for the shears can be inserted in the chromosomes of a plant or animal cell, that cell will then destroy all messenger RNA of a particular type. Genetic shears may be used to protect plants against viruses which infect them and cause disease. They might also be useful against AIDS.

gene-splicing

see genetic engineering.

genet

any of several small, nocturnal, carnivorous mammals belonging to the mongoose and civet family. Most species live in Africa, but the common genet *G. genetta* is also found in Europe and the Middle East. It is about 50 cm/1.6 ft long with a 45 cm/1.5 ft tail, weighs up to 2 kg/4.4 lb, with the male slightly larger than the female, and is greyish yellow in colour with rows of black spots. It is a good climber. Females have up to four young that begin to fend for themselves after about the age of four months. (Genus *Genetta*, family Viverridae.)

gene therapy

medical technique for curing or alleviating inherited diseases or defects that are due to a gene malfunction, certain infections, and some types of cancer, in which a replacement of the faulty DNA is introduced into the body. The biggest challenge is to ensure that the replacement gene can enter the cells and insert itself into the genome without disrupting other genes.

The first human to undergo gene therapy, in 1990, was one of the so-called 'bubble babies' - a four-year-old American girl suffering from a rare enzyme (ADA) deficiency that cripples the immune system. Unable to fight off infection, such children are nursed in a germ-free bubble; they usually die in early childhood. See also severe combined immune deficiency.

Cystic fibrosis is the most common inherited disorder and the one most keenly targeted by genetic engineers; the treatment has been pioneered in patients in the USA and UK. Gene therapy is not the final answer to inherited disease; it may cure the patient but it cannot prevent him or her from passing on the genetic defect to any children. However, it does hold out the promise of a cure for various other conditions, including some forms of heart disease and some cancers; US researchers have successfully used a gene gun to target specific tumour cells.

genetically modified foods

or GM foods

foods produced using genetic engineering technology. Individual genes can be copied or transferred from one living organism to another, to incorporate particular characteristics into the organism or remove undesirable characteristics. The technology, developed in the 1980s, may be used, for example, to produce crops with higher yields, improved taste, resistance to pests, or a longer growing season. The first genetically modified (GM) food, the 'Flavr Savr' tomato, went on sale in the USA in 1994. GM ingredients appearing in foods on the market today include tomatoes, soya, and maize. However, there remain some doubts and reservations about GM products, and some companies and countries, including the UK, have taken steps to delay the growing of GM crops until risks have been assessed, and to introduce legislation forcing GM products to be declared as such.

The higher yields and increased nutritional content produced by the new technology may help in feeding the world's rapidly-increasing population, and it may be possible in future to produce health foods such as oil seeds that produce oils with lower saturated fat content. Other advantages are that higher yields mean less land will need to be given over to farmland in order to produce more food, and that reliance on pesticides will be reduced by creating crops that are themselves resistant to pests.

Genetically Modified Foods

introduction

Modifying the genetic composition of crop plants or farm animals by selective breeding has been an important part of agriculture for thousands of years. However, the modern technology of genetic engineering has massively increased the scope for changing the characteristics of crops and livestock. This direct modification of an organism's genetic material (genome) bypasses conventional breeding methods, producing totally novel genetic combinations which could never occur in nature. Artificial transfer between completely unrelated organisms is possible, because the genetic material in all organisms is made from DNA.

how does it work?

Genetic modification usually involves identifying the genes governing a desirable characteristic in one organism, and inserting them into another in the expectation that the trait will be transferred. For example, a gene from certain bacteria, which causes their production of the toxin Bt, has been inserted into a wide variety of crop plants, including cotton, apple and maize. Transformed plants produce Bt in their tissues, and are therefore less palatable to insect pests. Once the section of DNA containing the relevant gene has been identified, it is cut from the genome of the donor organism using specific enzymes, creating free fragments of the desired DNA. The standard method for inserting these fragments into another genome, first achieved in 1973, involves using another organism as a vector. Vectors are able to carry DNA into the host cell, and integrate it into the host's DNA. A bacterial plasmid (circles of DNA independent of the main bacterial chromosome) or a virus can be harnessed as a vector, because either may integrate into a foreign genome during their normal infective process. Therefore, the genetic engineer splices the desired gene into the chosen vector, and allows the modified plasmid or virus to integrate into the host genome, taking the extra gene. The vector is usually 'tagged' with a marker gene, such as one conferring antibiotic resistance, so that successfully transformed cells can be identified. A newer technique for gene insertion is the use of DNA bullets. Microscopic metal beads can be coated with DNA fragments, and then 'fired' from a miniature gun into the host cell, where the DNA may integrate into the genome. Genes conferring virus resistance have been introduced into rice plants by this method.

cheaper production and greater yield ..

The dramatic, rapid changes made possible by genetic engineering have a vast range of potential applications in the development of new foodstuffs. Genetically modified (GM) crops may offer farmers greater yields, pest and disease resistance, and tolerance to temperature extremes, drought, or salinity. Plants engineered to be resistant to general herbicides are easier and cheaper to farm, as a whole field can be sprayed with the herbicide, killing all plants except the resistant crop. Agricultural improvements such as these aim for greater efficiency of production, which may be increasingly important as food supplies come under greater pressure due to global population growth. To the consumer, genetically modified crops can offer enhanced nutritional qualities, such as a lower fat content, or increased levels of vitamins. Improved flavour, appearance, and longer shelf-life are other objectives. There is also the prospect of plants engineered to contain specific ingredients of medical benefit, such as vaccines.

... but at what cost?

However, some scientists have expressed concern about the risks of genetically engineered foodstuffs. There is evidence that GM crops can cross-pollinate with their wild relatives, introducing novel genetic combinations into the wider environment. This may have unknown ecological effects; for instance, some suggest that it could lead to the creation of 'superweeds', where weed plants acquire traits such as herbicide resistance from GM crops, or it could detrimentally affect the life cycles of insect pollinators. The introduction of GM organisms into the human food chain may also have unpredictable health effects. For example, there are fears that the widespread use of antibiotic-resistant vectors may allow the development of new lines of bacterial pathogens with antibiotic resistance. Risks such as these illustrate that genetic engineering is often not as precise a technology as may be assumed. Although the ability to isolate and transfer specific genes is an impressive feat, it is still not possible to predict exactly every effect of inserting a gene, nor its long-term stability in the genome. The actual extent of such potential problems should become clearer with time, and after more research.

on the shelves, behind the scenes

There are several GM foodstuffs on the market, ranging from tomatoes to salmon. Not all are sold in all countries; the US currently has the largest number on sale. The most important modified foods are soya and maize. These GM crops are usually mixed with normal crops after harvest for use as ingredients in a wide range of processed foods. Additionally, GM foods can be found as agents in the food production process, rather than as foodstuffs in their own right. Examples include GM chymosin, used to make vegetarian cheese, and artificial bovine somatotropin (BST), a version of a cattle hormone synthesized by GM bacteria, which can be injected into cows to boost milk yields. There are a great many more GM crops and types of livestock under development. Research is subject to a variety of legislation, particularly concerning the release of modified organisms into the environment or food chain. All foods produced using GM undergo legal scrutiny and testing before approval. Additionally, EU legislation implemented in the UK in April 1999 requires that some foods containing GM protein or DNA be labelled in restaurants and food shops. However, GM labelling is likely to be a topic of much legal debate, facing problems such as the increasing use of mixed GM/non-GM ingredients (like soya).

public fears and corporate control

Public opinion on GM foods is mixed, and there is a general uncertainty about the potential impacts of the technology. Some people hold ethical or religious objections to the very idea of manipulating the basis of inheritance, especially where animals are involved. Public concern about possible health risks has made genetic modification an important public health issue in Europe and North America. Resistance to transgenic plants increased in Britain in 1998, leading to activists destroying crops at many separate sites and the formation of numerous local groups to protest against genetic engineering within food and agriculture. There are also fears about the power of large biotechnology corporations to control agricultural markets. For example, some crops have been engineered to produce sterile seeds, forcing farmers to buy new seed every year; other herbicide-resistant strains are produced by the companies that manufacture the particular herbicide, making farmers dependent on buying more and more of one type of herbicide. This is a particular concern to rural economies in poorer nations, where there is scepticism about the potential of GM to ameliorate the world's food crisis. Such controversies have sparked unrest, such as the burning of GM cotton crops by protesting peasant farmers in India. It seems certain that GM foods, and modern biotechnology in general, will continue to attract controversy. It remains to be seen to what extent genetic engineering will gain acceptance and become a commonplace technology. It is sure to continue to be the subject of one of the most urgent debates about the relationship between science and society.

Genetically Modified Foods

introduction

Genetically modified (GM) foods are increasingly controversial as they become more widespread. They have met a barrage of criticism and protest, and public confidence in them is low. New legislation on labelling has been introduced, partly in response to the controversy. The companies with a stake in developing genetic modification have made substantial efforts to promote its claimed benefits, such as greater agricultural efficiency and cheaper, more nutritious, novel foodstuffs. Opponents of the technology press for a ban, claiming that genetic modifications endangers the environment, presents risks to human health, and threatens small and organic farmers by increasing the influence of large agricultural corporations. Modifying the genetic composition of crop plants or farm animals by selective breeding has been an important part of agriculture for thousands of years. However, the modern technology of genetic engineering has massively increased the scope for changing the characteristics of crops and livestock. This direct modification of an organism's genetic material (genome) bypasses conventional breeding methods, producing totally novel gene combinations that could never occur in nature. Artificial transfer between completely unrelated organisms is possible, because the genetic material in all organisms is built from DNA.

how does it work?

Genetic modification usually involves identifying the genes governing a desirable characteristic in one organism, and inserting them into another in the expectation that the trait will be transferred. For example, a gene from certain bacteria, which causes them to produce the toxin Bt, has been inserted into a wide variety of crop plants, including cotton, apples, and maize. The transgenic (genetically transformed) plants produce Bt in their tissues, and are therefore less attractive to insect pests. Once the section of DNA containing the relevant gene has been identified, it is cut from the genome of the donor organism using specific enzymes, creating free fragments of the desired DNA. The standard method for inserting these fragments into another genome, first achieved in 1973, involves using DNA from a third organism as a vector. A vector is an agent that can be made to bind to a DNA fragment and transport it into another cell, where the fragment (but not the vector itself) is inserted into the host's DNA. A bacterial plasmid (a circle of DNA independent of the main bacterial chromosome) or a virus can be harnessed as a vector, because either may integrate into a foreign genome during its normal infective process. Therefore, the genetic engineer splices the DNA representing the desired gene into the chosen vector, and allows the modified plasmid or virus to integrate into the host genome, taking the extra gene with it. The vector is usually 'tagged' with a marker gene, for example one conferring antibiotic resistance, so that successfully transformed cells can be identified. There are several mechanical techniques for inserting DNA into cells. The most spectacular involves the use of DNA 'bullets'. Microscopic metal beads can be coated with DNA fragments and propelled on a plastic pellet fired by a miniature gun into the host cell, where the DNA integrates into the genome. Genes have been introduced into the cells of various types of plant by this method.

cheaper production and greater yield)

The dramatic, rapid changes made possible by genetic engineering have a vast range of potential applications in the development of new marketable foodstuffs. GM crops may offer greater yields, pest and disease resistance, and tolerance to temperature extremes, drought, or salinity. Plants engineered to be resistant to general herbicides should be easier and cheaper to farm, as a whole field can be sprayed with a single herbicide, killing all plants except the resistant crop. Agricultural developments such as these aim for greater efficiency of production, which may be increasingly important as food supplies come under greater pressure from global population growth. To the consumer, GM foods may offer enhanced nutritional qualities, such as a lower fat content or increased levels of vitamins. Improved flavour, appearance, and longer shelf life are other objectives. There is also the prospect of plants engineered to contain specific ingredients of medical benefit, such as vaccines.

) but at what cost?

However, some scientists have expressed concern about the risks associated with transgenic foodstuffs. Their studies have been used by protesters to support assertions that genetic modification is an unpredictable threat to the environment and to food safety. There is good evidence that transgenic crops can cross-pollinate with their wild relatives, introducing novel genetic combinations into the wider environment. This may have unknown ecological effects; for instance, some suggest that it could lead to the creation of 'superweeds' (weed plants that have acquired traits such as herbicide resistance from GM crops). It could also disrupt the life cycles of insects. For example, a 1999 study found that pollen from GM maize slowed the growth of caterpillars of the monarch butterfly compared with caterpillars that fed only on non-GM pollen. The introduction of GM organisms into the human food chain may also have unpredictable health effects. For example, there are fears that the widespread use of antibiotic-resistant vectors may allow the development of new lines of bacterial pathogens with antibiotic resistance. There are also concerns that novel DNA in foods may cause unforeseen allergic reactions in some people. Risks such as these illustrate that genetic engineering is often not as precise a technology as may be assumed. Although the ability to isolate and transfer specific genes is an impressive feat, it is not possible to predict exactly every effect of inserting a gene, nor its long-term stability in the genome. The actual extent of such potential problems should become clearer with time, and after more research.

on the shelves, behind the scenes

Since their commercial introduction in 1996, several GM foodstuffs have come onto the market, ranging from tomato paste to salmon. Not all are sold in all countries; the USA currently has the largest number on sale. The most important modified foods are soya and maize. About 30% (21 million tonnes) of the 1998 US soya harvest came from modified plants, as did some 20% (40 million tonnes) of the total US maize crop. These GM crops are usually mixed with normal crops after harvest for use as ingredients in a wide range of processed foods. Additionally, GM foods can be found as agents in the food production process, rather than as foodstuffs in their own right. Examples include GM chymosin, used to make vegetarian cheese, and artificial bovine somatotropin (BST), a version of a cattle hormone synthesized by GM bacteria, which can be injected into cows to boost milk yields. Most processed foods may now either contain GM ingredients or use transgenic enzymes during production. All GM foods undergo legal scrutiny and testing before approval; assessment is based mainly on a comparison of a GM food with its conventional counterpart.

regulation and testing

There are a great many more GM foodstuffs under development. Research is subject to various legislation, particularly concerning the release of modified organisms into the environment or food chain. For example, only government-licensed trial plots of GM crops are currently permitted in the UK. However, the size and number of trials has increased as more crops are tested on farm-scale plots, each typically covering 10 hectares/25 acres. The Royal Society, which in 1998 concluded that GM plants offered potential benefits, retrenched in 2002, saying that more work was required on health and environmental issues. UK law requires that GM soya or maize be labelled in food shops and restaurants. Additionally, European Union regulations made in October 1999 extend the labelling requirements to the suppliers of restaurants and caterers, and permit accidental GM content in non-GM food up to a threshold level of 1%. In 2003, a Cabinet Office report stated that there was no financial or consumer benefit in growing GM crops in the UK 'at present'.

public fears and corporate control

There is still a general uncertainty about GM's potential impacts. Some people hold ethical objections to the very idea of manipulating the basis of inheritance or the patenting of living organisms, especially where animals are involved. Public concern about possible health risks has made genetic modification an important public health issue in Europe and North America, with opinion polls indicating a majority opposed to GM food. Resistance to transgenic plants increased in Britain in 1998 and 1999, leading to activists destroying crops at many separate sites. A series of high-profile direct actions against farm-scale trials began in the summer of 1999, with numerous arrests. Many local groups were formed to campaign against genetic engineering within food and agriculture. There are also fears about the power of large biotechnology corporations to control agricultural markets. For example, some crops have been engineered to produce sterile seeds, forcing farmers to buy new seed every year; other herbicide-resistant strains are produced by the companies that manufacture a particular herbicide, making farmers dependent on buying more and more of one type of herbicide. This is a particular concern to rural economies in poorer nations, where there is widespread scepticism about the potential of genetic modification to ameliorate the world's food crisis. Such controversies have sparked unrest, such as the burning of GM cotton crops by protesting peasant farmers in India. It is uncertain to what extent genetic engineering will gain widespread acceptance, either on the supermarket shelves of wealthy nations, or the farm fields of poorer lands. What is more certain is that this is one of the pivotal debates about the relationship between science, business, and society in the 21st century, especially with the announcement early in 2004 that the UK government gave the go-ahead to one variety of GM maize (for animal consumption), despite the opposition of large sections of the public, the environment select committee, The Soil Association, organic farmers, and concerned scientists.

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genetic code

way in which instructions for building proteins, the basic structural molecules of living matter, are 'written' in the genetic material DNA. This relationship between the sequence of bases (the subunits in a DNA molecule) and the sequence of amino acids (the subunits of a protein molecule) is the basis of heredity. The code employs codons of three bases each; it is the same in almost all organisms, except for a few minor differences recently discovered in some protozoa.

Following the discovery of the DNA double helix in 1953, which suggested that the sequence of nucleobases along the DNA strand encoded the amino acid sequence of proteins in some way, it took researchers more than a decade to 'decipher' the code.

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genetic counselling

in medicine, the establishment of a detailed family history of any genetic disorders for individuals who are at risk of developing them, or concerned that they may pass them on to their children, and discussion as to likely incidence and available options. Prenatal diagnosis may be available to those at risk of having a child affected by a particular disorder. Genetic counselling of individuals at risk of developing a genetic disorder in adult life can result in the individual taking action to prevent the disorder developing; for example, removal of the ovaries in women at high risk of developing ovarian cancer.

There is a great deal of variation in the mode of inheritance of genetic disorders. Some disorders, such as Huntington's chorea, are inherited as dominant genes and there is a 50% chance of the children of an affected person and a normal person being affected by the disorder. Other disorders, such as cystic fibrosis, are inherited as recessive genes. The possession of a recessive gene does not result in overt disease but the children of an affected person and a normal person have a 25% chance of being affected by the disorder. Other genetic diseases, such as haemophilia, are linked to the X chromosome. These diseases are only found in male children but female children can carry the gene. Other diseases, such as diabetes, schizophrenia, and some forms of cancer have complex genetic and environmental components and risk can be determined from population studies.

Genes associated with some genetic disorders have been isolated in recent years. These have resulted in the development of tests for certain disorders in which inheritance is important, such as Alzheimer's disease and certain forms of breast cancer. After receiving genetic counselling, individuals at risk can be tested to determine if they are likely to develop such diseases later in life.

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genetic disease

any disorder caused at least partly by defective genes or chromosomes. In humans there are some 3,000 genetic diseases, including cystic fibrosis, Down's syndrome, haemophilia, Huntington's chorea, some forms of anaemia, spina bifida, and Tay-Sachs disease.

Tay-Sachs Disorder

Go to site

Informative page outlining the nature of Tay-Sachs disease, a genetic disorder. There is also information about what factors would put you at a high risk of carrying the Tay-Sachs enzyme.

Understanding Gene Testing

Go to site

Comprehensive US Department of Health overview of all the issues involved in gene testing. Basic information about genetics is accompanied by an explanation of the diseases which can be predicted by testing. There is also a glossary explaining the terminology in readily understandable language.

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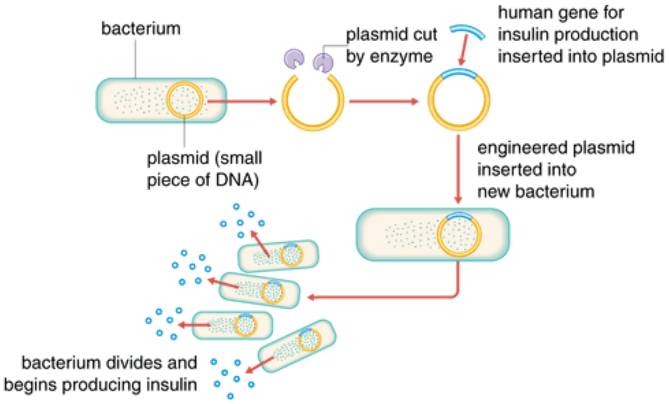
genetic engineering

all-inclusive term that describes the deliberate manipulation of genetic material by biochemical techniques. It is often achieved by the introduction of new DNA, usually by means of a virus or plasmid. This can be for pure research, gene therapy, or to breed functionally specific plants, animals, or bacteria. These organisms with a foreign gene added are said to be transgenic (see transgenic organism) and the new DNA formed by this process is said to be recombinant. In most current cases the transgenic organism is a micro-organism or a plant, because ethical and safety issues are limiting its use in mammals.

The breakthrough in this field came in 1973, when two biologists at the University of California succeeded in the recombination of two pieces of DNA from organisms that would not reproduce naturally. By the end of the 1970s, scientists were able to add genes to mice to create the first genetically modified (GM) mammal. They also were able to add human genes to bacteria and put this technology to commercial use in manufacturing human proteins for drugs. By early 1995 more than 60 plant species had been genetically engineered, and nearly 3,000 transgenic crops had been field-tested.

genetic engineering



(Image © Research Machines plc)

The genetic modification of a bacterium to produce insulin. The human gene for the production of insulin is collected from a donor chromosome and spliced into a vector plasmid (DNA found in bacteria but separate from the bacterial chromosomes). The plasmids and recipient bacteria are mixed together, during which process the bacteria absorb the plasmids. The plasmids replicate as the bacteria divide asexually (producing clones) and begin to produce insulin.

'What is Genetic Engineering'

Go to site

Essay by Dr Ricarda Steinbrecher which explains the concepts behind the controversial science of genetic engineering. The basic biology is clearly explained, although it should be pointed out that the author is opposed to the unregulated growth of biotechnology.

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genetic fingerprinting

or genetic profiling

technique developed in the UK by Professor Alec Jeffreys (1950–), and now allowed as a means of legal identification. It determines the pattern of certain parts of the genetic material DNA that is unique to each individual. Like conventional fingerprinting, it can accurately distinguish humans from one another, with the exception of identical siblings from multiple births. It can be applied to as little material as a single cell.

Genetic fingerprinting involves isolating DNA from cells, then comparing and contrasting the sequences of component chemicals between individuals. The DNA pattern can be ascertained from a sample of skin, hair, blood, or semen. Although differences are minimal (only 0.1% between unrelated people), certain regions of DNA, known as **hypervariable regions**, are unique to individuals.

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genetics

branch of biology concerned with the study of heredity and variation – inheritance. It aims to explain how characteristics of living organisms are passed on from one generation to the next. The science of genetics is based on the work of Austrian biologist Gregor Mendel whose experiments with the cross-breeding (hybridization) of peas showed that the inheritance of characteristics and traits takes place by means of discrete 'particles', now known as genes. These are present in the cells of all organisms and are the basic units of heredity. All organisms possess genotypes (sets of variable genes) and phenotypes (characteristics produced by certain genes). Modern geneticists investigate the structure, function, and transmission of genes.

Before the publication of Mendel's work in 1865, it had been assumed that the characteristics of both parents were blended during inheritance, but Mendel showed that the genes remain intact, although their combinations change. As a result of his experiments with the cultivation of the common garden pea, Mendel introduced the concept of hybridization (see monohybrid inheritance). Since Mendel, the study of genetics has advanced greatly, first through breeding experiments and light-microscope observations (classical genetics), later by means of biochemical and electron microscope studies (molecular genetics).

In 1909, Danish botanist Wilhelm Johannsen coined the term 'gene', from the Greek word *genos* meaning 'birth', to describe these particles. In 1911, he went on to make the distinction between 'genotype' and 'phenotype'. Genotype refers to the sets of genes carried by an organism that are capable of being passed on to the next generation, whereas phenotype refers to the physical traits or characteristics that the genes produce in an organism.

A major discovery in genetics came in 1944, when Canadian-born bacteriologist Oswald Avery, together with his colleagues at the Rockefeller Institute, Colin McLeod and Maclyn McCarty, showed that the carrier of hereditary information was deoxyribonucleic acid (DNA), and not protein or any other material as was previously thought. A further breakthrough was made in 1953 when James Watson and Francis Crick published their molecular model for the structure of DNA, the double helix, based on X-ray diffraction photographs. The following decade saw the cracking of the genetic code. The genetic code is said to be universal since the same code applies to all organisms from bacteria and viruses to higher plants and animals, including humans. Today the deliberate manipulation of genes by biochemical techniques, or genetic engineering, takes place.

Embryology: Early Observations

the first embryologist

The essence of science is systematic observation of the natural world. This may seem obvious to us, but it is a hard-won insight. Some appreciation of the value of observation stirred in Greece about 2,000 years ago, when Aristotle began to use experiments and scientific methods in the study of biology.

Hippocrates

The origins of animals and plants had been considered by Greek thinkers before Aristotle, beginning with Hippocrates in the 5th century BC. Did an organism form stage by stage or did it come into existence small but fully formed and then grow? The Hippocratic writings contain a clear suggestion for resolving the question:

'Take twenty eggs or more, and set them for brooding under two or more hens. Then on each day of incubation from the second to the last, that of hatching, remove one egg and open it for examination.'

Aristotle's experiments

There is no sign that the writer bothered to carry out the experiment; that was left to Aristotle, and he wrote a detailed description of what he saw. It seems that he extended the work to other birds, and that he understood something of the process which unfolded as the chick grew. He wrote:

'Generation from the egg proceeds in an identical manner with all birds, but the full periods from conception to birth differ. With the common hen after three days and three nights there is the first indication of the embryo; with larger birds the interval being longer, with smaller birds shorter. Meanwhile the yolk comes into being, rising towards the sharp end, where the primal element of the egg is situated, and where the egg gets hatched; and the heart appears, like a speck of blood, in the white of the egg. This point beats and moves as if endowed with life...'

On this Aristotle was wrong; the heart is not the first organ to develop. However, he correctly emphasizes that fetal development is closely linked to the development of blood vessels and membranes:

'...two vein-ducts with blood in them trend in a convoluted course... and a membrane carrying bloody fibres now envelops the yolk, leading off from the vein ducts. A little afterwards the body is differentiated, at first very small and white. The head is clearly distinguished, and in it the eyes, swollen out to a great extent.'

He understands correctly the role of the egg white and yolk:

'The life-element of the chick is in the white of the egg, and the nutrient comes through the navel-string out of the yolk.'

And the functions of the membranes surrounding the chick:

'The disposition of the several constituent parts is as follows. First and outermost comes the membrane of the egg, not that of the shell, but underneath it. Inside this membrane is a white liquid; then comes the chick, and a membrane round it, separating it off to keep the chick free from liquid; next after the chick comes the yolk, into which one of the two veins was described as leading, the other leading into the enveloping white substance.'

Day by day, Aristotle describes the development of the various organs:

'When the egg is now ten days old the chick and all its parts are distinctly visible. The head is still larger than the rest of its body, and the eyes are larger than the head, but still devoid of vision....At this time also the larger internal organs are visible, as also the stomach and the arrangement of the viscera; and the veins seen to proceed from the heart are now close to the navel.'

'About the twentieth day, if you open the egg and touch the chick, it moves inside and chirps; and it is already coming to be covered with down, when, after the twentieth day is past, the chick begins to break the shell. The head is situated over the right leg close to the flank, and the wing is placed over the head; and about this time is plain to be seen the membrane resembling an after-birth that comes next after the outermost membrane of the shell, into which membrane the one of the navel strings was described as leading ...'

He details the way the various membranes change, shrivel and detach during birth, ending with the observation:

'By and by the yolk, diminishing gradually in size, at length becomes entirely used up and comprehended within the chick (so that, ten days after hatching, if you cut open the chick, a small remnant of the yolk is still left in connection with the gut) ...'

modern embryology

Obviously, Aristotle believed in following up his experiments, seeking the unexpected. His description sounds like a modern scientist at work. For around 2,000 years, researchers could only refine the picture and correct a few small errors. Modern embryology is in the midst of an exciting revolution; we are beginning to understand the processes seen by Aristotle at molecular level – the level of genes. Genes control development and the same mechanisms are found in most animals. But the modern approach can still involve experiments on the embryo, and may mean opening chicken eggs and observing their development as Aristotle did.

The Role of Genetics in Conservation

introduction

Human population growth has led to increasing exploitation of our environment. It is now evident that active conservation measures are required to prevent the permanent loss of much of our flora and fauna. The genetic make-up of plant and animal populations is constantly changing through the effects of, for example, migration, inbreeding, and chance. Genetic analyses, therefore, form a key part of many conservation plans since the genetic composition of an organism can reveal a great deal of information about its past. Because distinct regions of DNA evolve at different rates, it is possible to trace the genetic history of an organism. For example, geneticists can identify parents and offspring, family groups, and ancestors and descendants. Conservationists use such information to decide whether particular organisms belong to the same species, breed, or family.

deciding what to conserve

One goal of conservation is preventing the loss of distinctive sets of organisms. However, deciding whether or not a particular group is unique or actually a mix of other less threatened groups is not always easy. Whilst it may seem obvious to use form and shape to characterize organisms, appearances can be deceptive. For example, the physique of the endangered red wolf was sufficiently different from that of other canine groups to warrant its protection. A genetic evaluation of living and museum specimens, however, provided good evidence that the red wolf is actually a hybrid between coyotes and grey wolves. Because the red wolf does not appear to be genetically distinct, there has been considerable debate as to whether the expensive recovery programme is justified. We can also use genetic information to clarify a situation where an organism is genetically similar throughout its geographic range but has a variable form; protection of such an organism would be unnecessary since it is not actually endangered. It is more common, however, to encounter genetically distinct organisms that cannot be identified from their appearance alone. The tuatara was originally believed to be the only surviving representative of an ancient group of reptiles. Genetic data, however, have provided evidence that there are at least three distinct groups, each of which needs its own conservation plan.

cross-breeding and genetic variation

Many zoos have greatly aided conservation by rearing rare plants and animals. However, some captive populations represent an unwanted mix of separate groups through unintentional cross-breeding. A survey of Asiatic lions in a zoo-based breeding programme found genes that had only been recorded from African animals, and many lions were removed from the project. Although the introduction of new individuals may be essential to prevent a serious decline in numbers, conservationists can maintain the genetic integrity of a group by carrying out a genetic study of potential donor organisms prior to breeding. For example, a genetic analysis has been used to identify animals suitable for breeding with the endangered Florida panther. Sometimes an endangered plant or animal is widely dispersed and thus, for economic or political reasons, it may not be possible to protect every individual. It is essential, therefore, to identify areas that are especially isolated or act as sources for other regions so that priority may be given to these populations. An analysis of genetic similarities between populations is a useful method of identifying probable migration routes. Where it is difficult to actually follow individual creatures, such as in the marine environment, a genetic approach may be the only method available to form management plans. While we can provide a safeguard to many organisms by stopping a decline in numbers or the destruction of their habitat, a species often depends upon its store of genetic variability to withstand a change in the environment. Lost genetic variation may never be regained, but we cannot be sure which genetic regions will be useful in the future. Many conservation strategies, therefore, use genetics to preserve a variety of plants or animals. Because of economic pressures many African breeds of livestock are being cross-bred with European animals. Consequently, many genetic adaptations to the local environment, such as resistance to disease or tolerance to drought, are likely to be lost as the native stocks become genetically diluted. At the Animal Genomics Laboratory in Liverpool and the International Livestock Research Institute in Nairobi, Kenya, genetic techniques are being used to characterize sheep and goat breeds from sub-Saharan Africa. This information will enable the conservation of distinct breeds and thus maintain genetic adaptations for use in times to come. In an effort to maintain diversity, breeding programmes have relied upon measurements of genetic variation to prevent breeding between related individuals. Simply breeding unrelated individuals, however, may not always reflect natural behaviour: social structure can be important and should be considered when planning breeding projects. For example, genetic studies have revealed that coalitions of male lions tend to be related and that their natural breeding behaviour differs from that of groups of unrelated male lions.

using genetics to protect animals and plants in the wild

Genetic signatures of species are used to identify products that illegally contain endangered organisms. Genetic markers have confirmed suspicions that minke whale meat legally sold in Japan also contains flesh from protected whale and dolphin species. Genetic markers may also be used to identify whether a protected organism has been bred from captivity or illegally taken from the wild.

looking ahead

The conservation of every endangered organism is impracticable and unfeasible. Genetic analyses provide a framework for decision-making and prioritizing suitable groups for conservation. They enable considerable time, effort, and money to be saved, essential considerations for maximizing the success of conservation efforts. There is, however, particular concern about the amount of genetic variation that needs to be maintained for future use, and while genetic variation may be preserved as sperm, eggs, or in seed banks, these methods are costly and have a limited lifespan. At present a large amount of DNA has been sequenced for many species, although the actual 'meaning' of most of this is unknown. Because DNA may be extracted from museum specimens, it is now possible to obtain the genetic code of extinct species.

Genetics: key events

1856	Austrian monk and botanist Gregor Mendel begins experiments breeding peas, research that will lead him to discover the laws of heredity.
1865	Gregor Mendel publishes a paper in the *Proceedings* of the Natural Science Society of Brünn that outlines the fundamental laws of heredity.
1869	Swiss biochemist Johann Miescher discovers a nitrogen and phosphorous material in cell nuclei that he calls nuclein but which is now known as the genetic material DNA.
1888	Dutch geneticist Hugo Marie de Vries uses the term 'mutation' to describe varieties that arise spontaneously in cultivated primroses.
1902	US geneticist Walter Sutton and German zoologist Theodor Boveri find the chromosomal theory of inheritance when they show that cell division is connected with heredity.
1906	English biologist William Bateson introduces the term 'genetics'.
1910	US geneticist Thomas Hunt Morgan discovers that certain inherited characteristics of the fruit fly *Drosophila melanogaster* are sex linked. He later argues that because all sex-related characteristics are inherited together they are linearly arranged on the X chromosome.
1934	Norwegian biochemist Asbjrn Fölling discovers the genetic metabolic defect phenylketonuria, which can cause retardation; his discovery stimulates research in biochemical genetics and the development of screening tests for carriers of deleterious genes.
1944	The role of deoxyribonucleic acid (DNA) in genetic inheritance is first demonstrated by US bacteriologist Oswald Avery, US biologist Colin MacLeod, and US biologist Maclyn McCarthy; it opens the door to the elucidation of the genetic code.
1945	Working in Japan, US geneticist Samuel G Salmon discovers Norin 10, a semidwarf wheat variety that grows quickly, responds well to fertilizer, does not fall over from the weight of the grains, and, when crossed with disease-resistant strains in the USA, results in a wheat strain that increases wheat harvests by more than 60% in India and Pakistan.

25 April 1953	English molecular biologist Francis Crick and US biologist James Watson announce the discovery of the double helix structure of DNA, the basic material of heredity. They also theorize that if the strands are separated then each can form the template for the synthesis of an identical DNA molecule. It is one of the most important discoveries in biology.
1954	Russian-born US cosmologist George Gamow suggests that the genetic code consists of the order of nucleotide triplets in the DNA molecule.
1958	US geneticists George Beadle, Edward Tatum, and Joshua Lederberg share the Nobel Prize for Physiology or Medicine: Beadle and Tatum for their discovery that genes act by regulating definite chemical events; and Lederberg for his discoveries concerning genetic recombination.
1961	French biochemists François Jacob and Jacques Monod discover messenger ribonucleic acid (mRNA), which transfers genetic information to the ribosomes, where proteins are synthesized.
1967	US scientist Charles Caskey and associates demonstrate that identical forms of messenger RNA produce the same amino acids in a variety of living beings, showing that the genetic code is common to all life forms.
1967	US biochemist Marshall Nirenberg establishes that mammals, amphibians, and bacteria all share a common genetic code.
October 1968	US geneticists Mark Ptashne and Walter Gilbert separately identify the first repressor genes.
1969	US geneticist Jonathan Beckwith and associates at Harvard Medical School isolate a single gene for the first time.
1969	The Nobel Prize for Physiology or Medicine is awarded jointly to US physiologists Max Delbrück, Alfred Hershey, and Salvador Luria for their discoveries concerning the replication mechanism and genetic structure of viruses.
1970	US geneticist Hamilton Smith discovers type II restriction enzyme that breaks the DNA strand at predictable places, making it an invaluable tool in recombinant DNA technology.
1970	US biochemists Howard Temin and David Baltimore separately discover the enzyme reverse transcriptase, which allows some cancer viruses to transfer their RNA to the DNA of their hosts turning them cancerous – a reversal of the common pattern in which genetic information always passes from DNA to RNA.
1972	US microbiologist Daniel Nathans uses a restriction enzyme that splits DNA molecules to produce a genetic map of the monkey virus (SV40), the simplest virus known to produce cancer; it is the first application of these enzymes to an understanding of the molecular basis of cancer.
1972	Venezuelan-born US immunologist Baruj Benacerraf and Hugh O'Neill McDevitt show immune response to be genetically determined.
1973	US biochemists Stanley Cohen and Herbert Boyer develop the technique of recombinant DNA. Strands of DNA are cut by restriction enzymes from one species and then inserted into the DNA of another; this marks the beginning of genetic engineering.
1975	The gel-transfer hybridization technique for the detection of specific DNA sequences is developed; it is a key development in genetic engineering.
1976	US biochemist Herbert Boyer and US venture capitalist Robert Swanson found Genentech in San Francisco, California, the world's first genetic engineering company.
28 August 1976	Indian-born US biochemist Har Gobind Khorana and his colleagues announce the construction of the first artificial gene to function naturally when inserted into a bacterial cell. This is a major breakthrough in genetic engineering.
1977	US biochemist Herbert Boyer, at Genentech, fuses a segment of human DNA into the bacterium *Escherichia coli*, which begins to produce the human protein somatostatin; this is the first commercially produced genetically engineered product.
1980	A new vaccine for the prevention of hepatitis B is tested in the USA. It is the first genetically engineered vaccine and has a success rate of 92%. It wins Federal Drug Administration approval in 1986.
16 June 1980	The US Supreme Court rules that a microbe created by genetic engineering can be patented.
1981	The US Food and Drug Administration grants permission to Eli Lilley and Co to market insulin produced by bacteria, the first genetically engineered product to go on sale.
1981	The genetic code for the hepatitis B surface antigen is discovered, creating the possibility of a bioengineered vaccine.
1981	US geneticists Robert Weinberg, Geoffrey Cooper, and Michael Wigler discover that oncogenes (genes that cause cancer) are integrated into the genome of normal cells.
1982	Using genetically engineered bacteria, the Swedish firm Kabivitrum manufactures human growth hormone.
1983	Geneticist James Gusella identifies the gene for Huntington's disease.
1984	British geneticist Alec Jeffreys discovers that a core sequence of DNA is almost unique to each person; this examination of DNA, known as 'genetic fingerprinting', can be used in criminal investigations and to establish family relationships.
1986	The US Department of Agriculture permits the Biological Corporation of Omaha to market a virus produced by genetic engineering; it is the first living genetically altered organism to be sold. The virus is used against a form of swine herpes.
1986	The US Department of Agriculture permits the first outdoor test of genetically altered high-yield plants (tobacco plants).
1987	German-born British geneticist Walter Bodmer and associates announce the discovery of a marker for a gene that causes cancer of the colon.
1987	The first genetically altered bacteria are released into the environment in the USA; they protect crops against frost.
1987	Foxes in Belgium are immunized against rabies by using bait containing a genetically engineered vaccine, dropped from helicopters. The success of the experiment leads to a large-scale vaccination programme.
April 1987	The US Patent and Trademark Office announces its intention to allow the patenting of animals produced by genetic engineering.
10 October 1987	The *New York Times* announces US geneticist Helen Donis-Keller's mapping of all 23 pairs of human chromosomes, allowing the location of specific genes for the prevention and treatment of genetic disorders.
April 1988	The US Patent and Trademark Office grants Harvard University a patent for a mouse developed by genetic engineering.
1989	Scientists in the UK introduce genetically engineered white blood cells into cancer patients, to attack tumours.

1990	The Human Genome Project to map the complete nucleotide sequence of human DNA is formally launched.
1991	British geneticists Peter Goodfellow and Robin Lovell-Badge discover the gene on the Y chromosome that determines sex.
1992	US biologist Philip Leder receives a patent for the first genetically engineered animal, the oncomouse, which is sensitive to carcinogens.
1993	US geneticist Dean Hammer and colleagues at the US National Cancer Institute publish the approximate location of a gene that could predispose human males to homosexuality.
1994	Trials using transfusions of artificial blood begin in the USA. The blood contains genetically engineered haemoglobin.
February 1994	The US Food and Drug Administration approves the use of genetically engineered bovine somatotropin (BST), which increases a cow's milk yield by 10-40%. It is banned in Europe.
May 1994	The first genetically engineered food goes on sale in the USA in California and Chicago, Illinois. The 'Flavr Savr' tomato is produced by the US biotechnology company Calgene.
1995	A genetically engineered potato is developed that contains the gene for Bt toxin, a natural pesticide produced by a soil bacterium. The potato plant produces Bt within its leaves.
1995	US embryologists Edward Lewis and Eric Wieschaus and German embryologist Christiane Nüsslein-Volhard are jointly awarded the Nobel Prize for Physiology or Medicine for their discoveries concerning the genetic control of early embryonic development.
1995	Australian geneticists produce a genetically engineered variety of cotton that contains a gene from soil bacteria that kills the cotton bollworm and native budworm.
1995	Trials begin in the USA to treat breast cancer by gene therapy. The patients are injected with a virus genetically engineered to destroy their tumours.
April 1995	US surgeons report the successful transplant of genetically altered hearts of pigs into baboons, a notable advance in trans-species operations.
July 1995	The US government approves experimentation of genetically altered animal organs in humans.
August 1995	The US Environmental Protection Agency approves the sale of genetically modified maize, which contains a gene from a soil bacterium that produces a toxin fatal to the European corn borer, a pest that causes approximately US$1 billion-worth of damages annually.
January 1996	The first genetically engineered salmon are hatched, at Loch Fyne in Scotland. The salmon contain genes from the ocean pout as well as a salmon growth hormone gene that causes them to grow five times as fast as other salmon.
9 May 1996	Scientists at the National Institute of Allergy and Infectious Disease discover a protein, fusin, that allows the HIV virus to fuse with a human immune system cell's outer membrane and inject genetic material. Its presence is necessary for the AIDS virus to enter the cell.
August 1996	US geneticists clone two rhesus monkeys from embryo cells.
27 February 1997	British researcher Ian Wilmut of the Roslin Institute in Edinburgh, Scotland, announces that British geneticists have cloned an adult sheep. A cell was taken from the udder of the mother sheep and its DNA combined with an unfertilized egg that had had its DNA removed. The fused cells were grown in the laboratory and then implanted into the uterus of a surrogate mother sheep. The resulting lamb, Dolly, came from an animal that was six years old. This is the first time cloning has been achieved using cells other than reproductive cells. The news is met with international calls to prevent the cloning of humans.
February 1997	US genetic scientist Don Wolf announces the production of monkeys cloned from embryos. It is a step closer to cloning humans and intensifies ethical debate.
16 May 1997	US geneticists identify a gene 'clock' in chromosome 5 in mice that regulates the circadian rhythm (the metabolic rhythm found in most organisms).
3 June 1997	US geneticist Huntington F Wilard constructs the first artificial human chromosome. He inserts telomeres (DNA and protein found on the tips of chromosomes) and centromeres (specialized regions of DNA within a chromosome) removed from white blood cells into human cancer cells. The cells are then assembled into chromosomes, which are about one-tenth the size of normal chromosomes. The artificial chromosome is successfully passed on to all daughter cells.
11 June 1997	English behavioural scientist David Skuse claims that boys and girls differ genetically in the way they acquire social skills. Girls acquire social skills intuitively and are 'pre-programmed', while boys have to be taught. This has important implications for education.
August 1997	US geneticist Craig Venter and colleagues publish the genome of the bacterium *Helicobacter pylori*, a bacterium that infects half the world's population and is the leading cause of stomach ulcers. It is the sixth bacterium to have its genome published, but is the most clinically important. It has 1,603 putative genes, encoded in a single circular chromosome that is 1,667,867 nucleotide base-pairs of DNA long. Complete genomes are increasingly being published as gene-sequencing techniques improve.
18 September 1997	US geneticist Bert Vogelstein and colleagues demonstrate that the *p53* gene, which is activated by the presence of carcinogens, induces cells to commit suicide by stimulating them to produce large quantities of poisonous chemicals, called 'reactive oxygen species' (ROS). The cells literally poison themselves. It is perhaps the human body's most effective way of combating cancer. Many cancers consist of cells with a malfunctioning *p53* gene.
November 1997	The US Food and Drug Administration approves Rituxan, the first anticancer monoclonal antibody made from genetically engineered mouse antibodies. The antibody binds itself to non-Hodgkin's lymphoma (a cancer of the lymph system) cells and triggers the immune system to kill the cells.
October 1998	US scientist French Anderson announces a technique that could cure inherited diseases by inserting a healthy gene to replace a damaged one. He calls for a full debate on the issue of gene therapy, which brings with it the dilemma of whether it is ethical to enable the choice of physical attributes such as eye colour and height.
8 December 1998	The Human Fertilization and Embryology Authority and the Human Genetics Advisory Commission publish a joint report in the UK on cloning. While they oppose cloning for reproductive purposes, they leave the door open for cloning for curing intractable diseases.
10 December 1998	In a joint effort by scientists around the world, the first genetic blueprint for a whole multicellular animal is completed. The 97 million-letter code, which is published on the Internet, is for a tiny worm called *Caenorhabditis elegans*. The study began 15 years ago and cost £30 million.

24 January 1999	US scientist Craig Venter of the Institute for Genomic Research in Maryland announces the possibility of creating a living, replicating organism from an artificial set of genes, at a meeting of the American Association for the Advancement of Science, in Anaheim, California. The experiment is put on hold until the moral question is discussed by religious leaders and ethicists at the University of Pennsylvania.
April 1999	European Union legislation is implemented in the UK, requiring that some foods containing genetically modified (GM) protein or DNA be labelled in restaurants and food shops. In September, the UK passes its own legislation to make labelling compulsory at all food outlets.
18 May 1999	A group of scientists at a specially convened Royal Society meeting finds that the experiments of Hungarian-born doctor Arpad Pusztai on GM foods were 'fundamentally flawed'. In August 1998, Pusztai claimed that his experiments demonstrated that genetically modified potatoes stunted the growth of laboratory rats, strengthening public opinion in the UK against genetically modified foods.
September 1999	A volunteer dies while participating in a gene therapy trial at the University of Pennsylvania, Philadelphia, USA. The Food and Drug Administration suspends all such trials at the university pending an investigation.
December 1999	Chromosome 22 is the first human chromosome to have its DNA sequence decoded, by scientists from the Sanger Institute.
May 2000	A team of German and Japanese scientists reveal they have sequenced chromosome 21, the second human chromosome to be decoded.
26 June 2000	A major scientific landmark is reached as the first draft of the complete human genome is completed. This is announced jointly by the publicly funded Human Genome Project and the commercial Celera Genomics, which have competed to produce the human DNA sequence first.
September 2000	Taco shells across the USA are found to contain GM StarLink corn, which is authorized for use as animal feed but not for human consumption. This prompts widespread product recalls.
14 December 2000	The entire DNA sequence of thale cress *Arabidopsis thaliana* is published. This completes five years of work by an international team, and is the first complete genome of a plant to be mapped.
11 January 2001	A team of US scientists led by Gerald Schatten announces the birth of the world's first genetically modified primate, a rhesus monkey dubbed Andi. The monkey's DNA includes a gene taken from a jellyfish included to act as a marker. This raises the possibility of using primates as models for the study of human genetic diseases. A fierce debate about the ethical implications of genetically modifying primates follows.
24 January 2001	The UK becomes the first country to legalize the cloning of human embryos for research purposes.
26 January 2001	Supermarket chains Tesco and Asda, which hold 42% of the UK grocery market between them, declare that all their meat and dairy products are to be sourced from animals fed a non-GM diet. This mirrors a general consumer mistrust of GM foods.
26 January 2001	Two corporations, Syngenta of Switzerland and Myriad Genetics of the USA, announce the publication of the complete genome of the rice plant. This is the first crop plant to be sequenced.
February 2001	Celera Genomics and the Human Genome Project publish their data on the human genetic code in different scientific publications. The most striking conclusion is that the genome consists of around 30,000 genes - much fewer than anticipated, and around the same number as a mouse.
August 2001	Researchers at the University of Abertay, Dundee, Scotland, announce that they have grown the world's first genetically modified elm trees, designed to be resistant to Dutch elm disease.
October 2001	Scientists publish the genetic code of the bacterium that causes typhoid fever.
November 2002	Molecular biologists working in the USA and South Korea announce that they have created a strain of rice that can withstand drought.
December 2002	Researchers announce the identification of 1,200 new human genes by deciphering the DNA code of the mouse.
April 2003	The scientific journal *New Scientist* reports that researchers have created mice that are completely immune to cancer.
August 2003	Scientists from six countries announce that they have sequenced the entire human genome to an accuracy of 99.999%.
August 2005	The first cloned dog is reported by scientists in South Korea
December 2005	Huge advances in research into stem cell cloning in South Korea are admitted to have been fabricated.

Designer Genes

Go to site

A very colourful Web site produced by a collaboration of high-school students from around the world. It provides plenty of easy-to-understand information about genetics and bioengineering, and, should you wish, you can even test your genetic knowledge with a quiz!

Gene CRC

Go to site

A very well laid out site that was developed for those who wish to keep up with accurate and up-to-date information on genetical research. As well as providing 'hot news' and discussion about ethical issues, it also contains a glossary, educational resources, and fun pages for children.

Natural History of Genetics

Go to site

Through a combination of scientific experts and teachers, this site offers an accessible and well-designed introduction to genetics. It includes several guided projects with experiments and explanations aimed initially at young teenage children. However, this site also includes 'Intermediate' and 'Expert' sections allowing this page to be used by a wide variety of ages and levels of expertise. In addition to the experiments, the site also includes sections on such topics as 'Core genetics', 'Teacher workshops', and 'Fun stuff'.

genetic screening

in medicine, the determination of the genetic make-up of an individual to determine if he or she is at risk of developing a hereditary disease later in life. Genetic screening can also be used to determine if an individual is a carrier for a particular genetic disease and, hence, can pass the disease on to his or her children. Genetic counselling should be undertaken at the same time as genetic screening of affected individuals. Diseases that can be screened for include cystic fibrosis, Huntington's chorea, and certain forms of cancer.

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genitalia

reproductive organs of sexually reproducing animals, particularly the external/visible organs of mammals: in males, the penis and the scrotum, which contains the testes, and in females, the clitoris and vulva.

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genome

full complement of genes carried by a single (haploid) set of chromosomes. The term may be applied to the genetic information carried by an individual or to the range of genes found in a given species.

The human genome is made up of around 3 billion basepairs, most of which were reported in draft genome sequences obtained in 2003 by the Human Genome Project and by a commercial sequencing initiative. Complete and final sequences for individual chromosomes have been reported since then, but the total number of human genes, now estimated to be close to 30,000, remains uncertain.

The first genomes of cellular organisms to be sequenced in full were those of the bacteria *Haemofilus influenzae* and *Mycoplasma genitalium*, in 1995. *Methanococcus jannaschii* was the first archaeon to be sequenced in full, in 1996, and the baker's yeast *Saccharomyces cerevisiae* the first eukaryote, in 1997. Dozens of other microbial genome sequences followed during the second half of the 1990s.

Landmark genome sequences of higher organisms included fruit fly (2000), mouse (2002), dog (2003), rat (2004), bee (2004), and chimpanzee (2005). The latter has proven a particularly useful reference for the study of human evolution, and as a reference point for the investigation of human population genetics.

DNA

The human genome contains between 27,000 and 40,000 genes, over 10,000 less than rice (which has the smallest number of genes of any cereal, at 50,000).

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genotype

particular set of alleles (variants of genes) possessed by a given organism. The term is usually used in conjunction with phenotype, which is the product of the genotype and all environmental effects.

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genus

plural genera

group of one or more species with many characteristics in common. Thus all doglike species (including dogs, wolves, and jackals) belong to the genus *Canis* (Latin 'dog').

Species of the same genus are thought to be descended from a common ancestor species. Related genera are grouped into families.

Humans belong to the genus *Homo*, while chimpanzees and bonobos form the genus *Pan*. Following the detailed insights gained from sequencing the genomes of both human and chimp, it is now generally believed by researchers that this distinction is biologically unfounded and that humans should share a genus with chimps and bonobos.

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geochemistry

science of chemistry as it applies to geology. It deals with the relative and absolute abundances of the chemical elements and their isotopes in the Earth, and also with the chemical changes that accompany geologic processes.

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geochronology

branch of geology that deals with the dating of rocks, minerals, and fossils in order to create an accurate and precise geological history of the Earth. The geological time scale is a result of these studies. It puts stratigraphic units in chronological order and assigns actual dates, in millions of years, to those units.

geode

in geology, a subspherical cavity into which crystals have grown from the outer wall into the centre. Geodes often contain very well-formed crystals of quartz (including amethyst), calcite, or other minerals.

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geodesic dome

hemispherical dome, a type of space-frame, whose surface is formed out of short rods arranged in triangles. The rods lie on geodesics (the shortest lines joining two points on a curved surface). This type of dome allows large spaces to be enclosed using the minimum of materials, and was patented by US engineer Buckminster Fuller in 1954.

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geodesy

science of measuring and mapping Earth's surface for making maps and correlating geological, gravitational, and magnetic measurements. Geodetic surveys, formerly carried out by means of various measuring techniques on the surface, are now commonly made by using radio signals and laser beams from orbiting satellites (see global positioning system).

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geography

study of the Earth's surface; its topography, climate, and physical conditions, and how these factors affect people and society. It is usually divided into **physical geography**, dealing with landforms and climates, and **human geography**, dealing with the distribution and activities of peoples on Earth.

history

Early preclassical geographers concentrated on map-making, surveying, and exploring. In classical Greece theoretical ideas first became a characteristic of geography. Aristotle and Pythagoras believed the Earth to be a sphere, Eratosthenes was the first to calculate the circumference of the world, and Herodotus investigated the origin of the Nile floods and the relationship between climate and human behaviour.

During the medieval period the study of geography progressed little in Europe, but the Muslim world retained much of the Greek tradition, embellishing the 2nd-century maps of Ptolemy. During the early Renaissance the role of the geographer as an explorer and surveyor became important once again.

The foundation of modern geography as an academic subject stems from the writings of Friedrich Humboldt and Johann Ritter, in the late 18th and early 19th centuries, who for the first time defined geography as a major branch of scientific inquiry.

Greatest Places

Go to site

Journey to seven of the most geographically dynamic locations on Earth. This site features stylish presentations with extensive pictures and cultural commentary.

National Geographic Online

Go to site

Large and lavishly illustrated Web site. Features include the *Map Machine Atlas*, which allows you to find maps, flags, facts, and profiles for the countries of the world, and discussion forums on a variety of subjects. Many articles and multimedia items can be accessed for free. Good for general reference.

Primary Geography Page

Go to site

A site of links to pages providing resources, including the author's own software, for teachers and pupils of Key Stages 1 and 2 geography.

Royal Geographical Society

Go to site

Mine of information for both geographers and non-specialists, including events organized by the RGS, online exhibitions, field expeditions and research projects, publications, and links to other geographical organizations.

The Geography Portal

Go to site

Extensive geographical resource, which includes outline maps in GIF format, and geographical photographs, both of which are freely available to download.

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geological time

time scale embracing the history of the Earth from its physical origin to the present day. Geological time is traditionally divided into eons (Archaean or Archaeozoic, Proterozoic, and Phanerozoic in ascending chronological order), which in turn are subdivided into eras, periods, epochs, ages, and finally chrons.

The terms eon, era, period, epoch, age, and chron are **geochronological units** representing intervals of geological time. Rocks representing an interval of geological time comprise a **chronostratigraphic** (or **time-stratigraphic**) **unit**. Each of the hierarchical geochronological terms has a chronostratigraphic equivalent. Thus, rocks formed during an eon (a geochronological unit) are members of an eonothem (the chronostratigraphic unit equivalent of eon). Rocks of an era belong to an erathem. The chronostratigraphic equivalents of period, epoch, age, and chron are system, series, stage, and chronozone, respectively.

geological periods

To remember the geological periods in descending order of age:

Camels **o**ften **s**it **d**own **c**arefully. **P**erhaps **t**heir **j**oints **c**reak? **E**arly **o**iling **m**ight **p**revent **p**ermanent **r**heumatism or **C**hina **o**wls **s**eldom **d**eceive **c**lay **p**igeons. **T**hey **j**ust **c**hase **e**ach **o**ther **m**aking **p**reposterous **p**uns

Cambrian, **O**rdovician, **S**ilurian, **D**evonian, **C**arboniferous, **P**ermian, **T**riassic, **J**urassic, **C**retaceous, **E**ocene, **O**ligocene, **M**iocene, **P**liocene, **P**leistocene (**R**ecent)

Geological eras, periods, and epochs

Eon	Era	Period	Epoch	Began	Stage of life
Phanerozoic	Cenozoic	Quaternary	Holocene	10,000 years ago	end of last ice age; civilization develops
			Pleistocene	1.64 million years ago	*Homo sapiens* evolves
		Tertiary	Pliocene	5.2 million years ago	earliest hominids evolve
			Miocene	23.5 million years ago	grasslands spread; hoofed mammals evolve
			Oligocene	35.5 million years ago	first anthropoid apes evolve
			Eocene	56.5 million years ago	predecessors of most modern mammals evolve
			Palaeocene	65 million years ago	mammals flourish
	Mesozoic	Cretaceous		146 million years ago	seed-bearing plants evolve; mass extinction (including dinosaurs) at end of period
		Jurassic		208 million years ago	birds evolve
		Triassic		245 million years ago	early dinosaurs; first mammals; mass plant extinction at end of period
	Palaeozoic	Permian		290 million years ago	mass extinction
		Carboniferous		360 million years ago	reptiles evolve
		Devonian		409 million years ago	amphibians and insects evolve
		Silurian		439 million years ago	land plants and jawed fishes evolve
		Ordovician		510 million years ago	reef-building algae and jawless fish evolve
		Cambrian		570 million years ago	invertebrate animals evolve
Precambrian	Proterozoic			2.5 billion years ago	first biological activity; bacteria and algae
	Archaean			4.6 billion years ago	none

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geology

science of the Earth, its origin, composition, structure, and history. It is divided into several branches, inlcuding **mineralogy** (the minerals of Earth), **petrology** (rocks), **stratigraphy** (the deposition of successive beds of sedimentary rocks), **palaeontology** (fossils) and **tectonics** (the deformation and movement of the Earth's crust), **geophysics** (using physics to study the Earth's surface, interior, and atmosphere), and **geochemistry** (the science of chemistry as it applies to biology).

Geology

introduction

The geological sciences have arisen in part from the need for further utilization of Earth's resources as well as from the ever-present desire to understand our origins.

The concept of time has been central to development of the geological sciences. The history of the development of geology, or earth sciences as it is more commonly known in recent times, is in most ways inseparable from historical progress in the other physical sciences, including chemistry, physics, and the allied field of biology. But it is the colossal time (in human terms) that initially confounded our understanding of Earth and it is this same element of time that often requires unique scientific perspectives.

antiquity

Scientific thinking about the Earth grew out of traditions of thought which took shape in the Middle East and the Eastern Mediterranean. Early civilization needed to adapt to the seasons, to deserts and mountains, volcanoes and earthquakes. Yet inhabitants of Mesopotamia, the Nile Valley, and the Mediterranean littoral had experience of only a fraction of the Earth. Beyond lay *terra incognita*. Hence legendary alternative worlds were conjured up in myths of burning tropics, lost continents, and unknown realms where the gods lived.

the Greeks

The first Greek philosopher about whom much is known was Thales of Miletus (*c.* 640-546 BC). He postulated water as the primary ingredient of material nature. Thales' follower, Anaximander, believed the universe began as a seed which grew; and living things were generated by the interaction of moisture and the Sun. Xenophanes (*c.* 570-475 BC) is credited with a cyclic worldview: eventually the Earth would disintegrate, returning to a watery state.

Like many other Greek philosophers, Empedocles (*c.* 500-*c.* 430 BC) was concerned with change and stability, order and disorder, unity and plurality. The terrestrial order was dominated by strife. In the beginning, the Earth had brought forth living structures more or less at random. Some had died out. The survivors became the progenitors of modern species.

The greatest Greek thinker was Aristotle. He considered the world was eternal. Aristotle drew attention to natural processes continually changing its surface features. Earthquakes and volcanoes were due to the wind coursing about in underground caves. Rivers took their origin from rain. Fossils indicated that parts of the Earth had once been covered by water.

Ptolemy and Pliny

In the 2nd century AD, Ptolemy composed a geography that summed up the Ancients' learning. Ptolemy accepted that the equatorial zone was too torrid to support life, but he postulated an unknown land mass to the south, the *terra australis incognita*. Antiquity advanced a 'geocentric' and 'anthropocentric' view. The planet had been designed as a habitat for humans. A parallel may be seen in the Judaeo-Christian cosmogony.

The centuries from Antiquity to the Renaissance accumulated knowledge on minerals, gems, fossils, metals, crystals, useful chemicals and medicaments, expounded in encyclopedic natural histories by Pliny (AD 23-79) and Isidore of Seville (AD 560-636). The great Renaissance naturalists were still working within this 'encyclopedic' tradition. The most eminent was Konrad Gesner, whose *On Fossil Objects* was published in 1565, with superb illustrations. Gesner saw resemblances between 'fossil objects' and living sea creatures.

the Christian view

At the same time, comprehensive philosophies of the Earth were being elaborated, influenced by the Christian revelation of Creation as set out in 'Genesis'. This saw the Earth as recently created. Bishop Ussher (1581-1656) in his *Sacred Chronology* (1660), arrived at a creation date for the Earth of 4004 BC. In Christian eyes, time was directional, not cyclical. God had made the Earth perfect but, in response to Original Sin, he had been forced to send Noah's Flood to punish people by depositing them in a harsh environment, characterized by the niggardliness of Nature. This physical decline would continue until God had completed his purposes with humans.

the scientific revolution

The 16th and 17th centuries brought the discovery of the New World, massive European expansion and technological development. Scientific study of the Earth underwent significant change. Copernican astronomy sabotaged the old notion that the Earth was the centre of the system. The new mechanical philosophy (Descartes, Gassendi, Hobbes, Boyle, and Hooke) rejected traditional macrocosm-microcosm analogies and the idea that the Earth was alive. Christian scholars adopted a more rationalist stance on the relations between Scripture and scientific truth. The possibility that the Earth was extremely old arose in the work of 'savants' like English physicist Robert Hooke (1635-1703). For Enlightenment naturalists, the Earth came to be viewed as a machine, operating according to fundamental laws.

The old quarrel as to the nature of fossils was settled. Renaissance philosophies had stressed the living aspects of Nature. Similarities between fossils and living beings seemed to prove that the Earth was capable of growth. Exponents of the mechanical philosophy denied these generative powers. Fossils were petrified remains, rather like Roman coins, relics of the past, argued Hooke. Such views chimed with Hooke's concept of major terrestrial transformations and of a succession of faunas and floras now perished. Some species had been made extinct in great catastrophes.

the significance of fossils

This integrating of evidence from fossils and strata is evident in the work of Danish naturalist Nicolaus Steno (1638-1686). He was struck by the similarity between shark's teeth and fossil *glossopetrae*. He concluded that the stones were petrified teeth. On this basis, he posited six successive periods of Earth's history. Steno's work is one of the earliest 'directional' accounts of the Earth's development that integrated the history of the globe and of life. Steno treated fossils as evidence for the origin of rocks.

the Enlightenment

Mining schools developed in Germany. German mineralogists sought an understanding of the order of rock formations which would be serviceable for prospecting purposes. Johann Gottlob Lehmann (1719-1776) set out his view that there were fundamental distinctions between the various *Ganggebergen* (masses formed of stratified rock). These distinctions represented different modes of origin, strata being found in historical sequence. Older strata had been chemically precipitated out of water, whereas more recent strata had been mechanically deposited.

German geologist Abraham Gottlob Werner (1749-1817) was appointed in 1775 to the Freiberg Akademie. He was the most influential teacher in the history of geology. Werner established a well-ordered, clear, practical, physically based stratigraphy. He proposed a succession of the laying down of rocks, beginning with 'primary rocks' (precipitated from the water of a universal ocean), then passing through 'transition', 'flútz' (sedimentary), and finally 'recent' and 'volcanic'. The oldest rocks had been chemically deposited; they were therefore crystalline and without fossils. Later rocks had been mechanically deposited. Werner's approach linked strata to Earth history.

the development of stratigraphy

Thanks to the German school, but also to French observers like botanist, palaeontologist, and stratigrapher Jean-Etienne Guettard, (1715-1786), chemist Antoine Lavoisier (1743-1794), and geologist Déodat Dolomieu (1750-1801), and to Swedish scientists like chemist and physicist Torbern Bergman (1735-1784), stratigraphy was beginning to emerge in the 18th century.

Of course, there were many rival classifications and all were controversial. In particular, battle raged over the nature of basalt: was it of aqueous or igneous origin? The Wernerian, or Neptunist, school saw the Earth's crust precipitated out of aqueous solution. The other, culminating in Hutton, asserted the formation of rock types from the Earth's central heat.

the ideas of Buffon and Hutton

A pioneer of this school was French naturalist Georges-Louis Buffon (1707-1778). He stressed ceaseless transfigurations of the Earth's crust produced by exclusively 'natural' causes. In his *Epochs of Nature* (1779) he emphasized that the Earth had begun as a fragment thrown off the Sun by a collision with a comet. Buffon believed the Earth had taken at least 70,000 years to reach its present state. Extinction was a fact, caused by gradual cooling. The seven stages of the Earth explained successive forms of life, beginning with gigantic forms, now extinct, and ending with humans.

Though a critic of Buffon, Scottish natural philosopher James Hutton (1726-1797) shared his ambitions. Hutton was a scion of the Scottish Enlightenment, being friendly with Adam Smith and James Watt. In his 'Theory of the Earth' (1795), Hutton demonstrated a steady-state Earth, in which natural causes had always been of the same kind as a present, acting with precisely the same intensity ('uniformitarianism'). There was 'no vestige of a beginning, no prospect of an end'. All continents were gradually eroded by rivers and weather. Debris accumulated on the sea bed, to be consolidated into strata and thrust upwards by the central heat to form new continents. Hutton thus postulated an eternal balance between uplift and erosion. All the Earth's processes were gradual. The Earth was incalculably old. His maxim was that 'the past is the key to the present'.

Hutton's theory was much attacked in its own day. Following the outbreak of the French Revolution in 1789, conservatives saw all challenges to the authority of the Bible as socially subversive. Their writings led to ferocious 'Genesis versus Geology' controversies in England.

the 19th century

New ideas about the Earth brought momentous social, cultural, and economic reverberations. Geology clashed with traditional religious dogma about Creation. Modern state-funded scientific education and research organizations emerged. German universities pioneered scientific education. The Geological Survey of Great Britain was founded, after English geologist Henry De la Beche (1796-1855) obtained state finance for a geological map of southwest England. De la Beche's career culminated in the establishment of a Mines Record Office and the opening in 1851 of the Museum of Practical Geology and the School of Mines in London.

Specialized societies were founded. The Geological Society of London dates from 1807. In the USA, the government promoted science, and various states established geological surveys, New York's being particularly productive. In 1870, Congress appointed US geologist John Wesley Powell (1834-1902) to lead a survey of the natural resources of the Utah, Colorado, and Arizona area. Powell would later become the second director of the US Geological Survey, which was founded in 1879.

the stratigraphical column

Building on Werner, the great achievement of early 19th-century geology lay in the stratigraphical column. After 1800, it was perceived that mineralogy was not the master key. Fossils became regarded as the indices enabling rocks of comparable age to be identified. Correlation of information from different areas would permit tabulation of sequences of rock formations, thereby displaying a comprehensive picture of previous geological epochs.

Britain

In Britain the pioneer was English geologist William 'Strata' Smith (1769-1839). Smith received little formal education and became a canal surveyor and mining prospector. By 1799 he set out a list of the secondary strata of England. This led him to the construction of geological maps. In 1815 he brought out *A Delineation of the Strata of England and Wales*, using a scale of five miles to the inch. Between 1816 and 1824 he published *Strata Identified by Organized Fossils*, which displayed the fossils characteristic of each formation.

France

Far more sophisticated were the Frenchmen zoologist and palaeontologist Georges Cuvier (1769-1832) and naturalist and geologist Alexandre Brongniart (1770-1837), who worked on the Paris basin. Cuvier's contribution lay in systematizing the laws of comparative anatomy and applying them to fossil vertebrates. He divided invertebrates into three phyla and conducted notable investigations into fish and molluscs. In *Researches on the Fossil Bones of Quadrupeds* (1812), he reconstructed such extinct fossil quadrupeds as the mastodon, applying the principles of comparative anatomy. Cuvier was the most influential palaeontologist of the 19th century.

Fossils, in Cuvier's and Brongniart's eyes, were the key to the identification of strata and Earth history. Cuvier argued for occasional wholesale extinctions caused by geological catastrophes, after which new flora and fauna appeared by migration or creation. Cuvier's *Discours sur les révolutions de la surface du globe* (1812) became the foundation text for catastrophist views.

older rock types

Classification of older rock types was achieved by English geologist Adam Sedgwick (1785-1873) and Scottish geologist Roderick Murchison (1792-1871). Sedgwick unravelled the stratigraphic sequence of fossil-bearing rocks in North Wales, naming the oldest of them the Cambrian period (now dated at 500-570 million years ago). Further south, Murchison delineated the Silurian system amongst the *grauwacke*. Above the Silurian, the Devonian was framed by Sedgwick, Murchison and De la Beche. Shortly afterwards, English geologist Charles Lapworth (1842-1920) developed the Ordovician.

uniformitarianism

Werner's retreating-ocean theory was quickly abandoned, as evidence accumulated that mountains had arisen not by evaporation of the ocean, but through processes causing elevation and depression of the surface. This posed the question of the rise and fall of continents. Supporters of 'catastrophes' argued that terrestrial upheavals had been sudden and violent. Opposing these views, Scottish geologist Charles Lyell (1797-1875) advocated a revised version of Hutton's gradualism. Lyellian uniformitarianism argued that both uplift and erosion occurred by natural forces.

Expansion of fieldwork undermined traditional theories based upon restricted local knowledge. The retreating-ocean theory collapsed as Werner's students travelled to terrains where proof of uplift was self-evident.

Geologists had to determine the Earth movements that had uplifted mountain chains. Chemical theories of uplift yielded to the notion that the Earth's core was intensely hot, by consequence of the planet commencing as a molten ball. Many hypotheses were advanced. In 1829, *Researches on Some of the Revolutions of the Globe* linked a cooling Earth to sudden uplift: each major mountain chain represented a unique episode in the systematic crumpling of the crust. The Earth was like an apple whose skin wrinkled as the interior shrank through moisture loss. The idea of horizontal (lateral) folding was applied in the USA by US mineralogist, crystallographer, and geologist James Dwight Dana (1813-1895) to explain the complicated structure of the Appalachians. Such views were challenged by Lyell in his bid to prove a steady-state theory. His classic *Principles of Geology* (1830-33) revived Hutton's vision of a uniform Earth that precluded cumulative, directional change in overall environment; Earth history proceeded like a cycle, not like an arrow. In *Principles of Geology*, Lyell thus attacked diluvialism and catastrophism by resuscitating Hutton's vision of an Earth subject only to changes currently discernible. Time replaced violence as the key to geomorphology.

Lyell discounted Cuvier's apparent evidence for the catastrophic destruction of fauna and flora populations. For over 30 years he opposed the transmutation of species, reluctantly conceding the point at last only in deference to his friend, English naturalist Charles Darwin(1809-1882), and the cogency of Darwin's *Origin of Species* (1859).

ice ages

Landforms presented a further critical difficulty. Geologists had long been baffled by beds of gravel and 'erratic boulders' strewn over much of Northern Europe and North America. Bold new theories in the 1830s attributed these phenomena to extended glaciation. Swiss palaeontologist Louis Agassiz (1807-1873) and others contended that the 'diluvium' had been moved by vast ice sheets covering Europe during an 'ice age'. Agassiz's *Studies on Glaciers* (1840) postulated a catastrophic temperature drop, covering much of Europe with a thick covering of ice that had annihilated all terrestrial life.

The ice-age hypothesis met opposition but eventually found acceptance through Scottish geologist James Geikie (1839-1915), Scottish physicist and geologist James Croll (1821-1890), and German geographer and geologist Albrecht Penck (1858-1945). Syntheses were required. The most impressive unifying attempt came from Austrian geologist Eduard Suess (1831-1914). His *The Face of the Earth* (1885-1909) was a massive work devoted to analysing the physical agencies contributing to the Earth's geographical evolution. Suess offered an encyclopedic view of crustal movement, the structure and grouping of mountain chains, of sunken continents, and the history of the oceans. He made significant contributions to structural geology.

Suess disputed whether the division of the Earth's relief into continents and oceans was permanent, thus clearing the path for the theory of *continental drift*. Around 1900, the US geologist and cosmologist Thomas C Chamberlin (1843-1928) proposed a different synthesis: the Earth did not contract; its continents were permanent. Continents, Chamberlin argued, were gradually filling the oceans and thereby permitting the sea to overrun the land.

the 20th century

At the start of the 20th century the tools for significant advancements in the geological sciences were being developed. Geophysics had already emerged as a distinct discipline in the late 19th century. Study of the Earth's magnetic and gravitational fields came to early prominence as did the application of chemistry to geological problems. Studies of the propagation of seismic waves through the Earth revealed the nature of the planet's interior. In 1919 the American Geophysical Union was formed, and 1957 was designated the International Geophysical Year. The modern term 'earth sciences', replacing geology as the name of the discipline, marks the triumph of geophysics. Application of breakthroughs in all of these subdisciplines gave rise to the development of plate tectonics, representing one of the great scientific achievements of the century.

the use of radioactivity for dating purposes

In the year 1900 the Earth was estimated to be about 90 million years old by comparing the amount of salt in the oceans to the rate at which salt was delivered to the oceans by rivers. In 1907 US chemist Bertram Boltwood (1870-1927) used the recent discovery that some forms of lead were the products of radioactive decay of the element uranium to demonstrate that some rocks were as old as 2,200 million years. The Earth was apparently much older than had been previously contemplated. In *The Age of the Earth* (1913), English geologist Arthur Holmes (1890-1965) pioneered the use of this new tool of radioactive decay methods for rock-dating.

measuring Earth's magnetic and gravitational fields

Mapping Earth's magnetic field was a major goal of the geological sciences in the early 20th century.

Deployment of the research sailing vessel *Carnegie* in 1909 was a manifestation of the desire for detailed geomagnetic surveys. The ship, operated by the Carnegie Institution of Washington, was built of non-magnetic materials for the purpose of measuring Earth's magnetic field as it sailed the oceans. It logged over 342,000 miles in this endeavour before being destroyed by fire in 1929.

By 1922 distortions in Earth's gravitational field were being used to locate salt domes in the Gulf of Mexico and the oil trapped adjacent them. Geophysics was proving to be an important tool for prospecting of economic resources.

seismology

In 1906 it was found that something lay at the centre of the Earth that blocked the path of seismic waves (sound waves transmitted through the Earth). By 1914 it was established that the object incapable of transmitting certain kinds of seismic waves was a molten core. Over the decades abrupt changes in the velocities of seismic waves were used to deduce further details of Earth's layered structure. Changes in density with depth as revealed by seismologists allowed physical chemists and mineral physicists to show that minerals have an entirely different structure at very high pressures in the Earth and in other terrestrial planets.

Toward the close of the 20th century three-dimensional imaging of Earth's structure was made possible through the use of global seismic tomography. Developed by geophysicists at Harvard University, this method is analogous to CAT scans of the human brain. With seismic tomography it is possible to follow the fate of great slabs of Earth's crust as they descend into the mantle, and it is also possible to find the sources of sustained volcanism such as that that created the Hawaiian Islands in the Pacific Ocean.

the physics and chemistry of Earth's deep interior

In order to explain the structure of Earth and other rocky bodies of the Solar System, scientists began to study the behaviour of materials at extreme pressures and temperatures. Rock deep in a planet is subjected to crushing pressures of many thousands of atmospheres. At the turn of the century the maximum pressure that could be achieved in the laboratory was about 2,000 atmospheres. In 1910, Nobel laureate and US physicist Percy Bridgman (1882–1961) invented a device that allowed him to squeeze all manner of materials to pressures of 20,000 atmospheres. This enabled scientists to examine the nature of rock, as well as other materials like water, to pressures corresponding to the base of Earth's crust. Toward the close of the century it is now possible to investigate materials at pressures of several millions of atmospheres, corresponding to the centre of our planet, using diamond anvils. The advent of the laser has allowed earth scientists to heat materials to extreme temperatures even as they are being squeezed to crushing pressures. In so doing it is possible to simulate conditions that exist in Earth's core. Fundamental information about Earth's deep interior are still being investigated with these methods. The temperatures of the core is one such problem that has thus far eluded precise determination.

With the capability for investigating matter at very high pressures and temperature has come a better understanding of not only Earth, Mars, and the other rocky planets, but also the structures of the gaseous, hydrogen-rich giant planets Jupiter and Saturn and the icy planets Uranus and Neptune as well. It is in these bodies of the Solar System that materials that we think of as gases turn to metals and ultimately to exotic materials that we can not yet classify as solids, gases, or liquids. Indeed the disciplines of geology and stellar physics are beginning to overlap as mineral physicists contemplate the nature of matter in objects that span the transition from giant planet to star.

the origin of life

The latter half of the 20th century saw renewed focus on the issue of how life began on Earth. Traditionally, fossils comprised the contribution of the geological sciences to the question of the origin of life. Widespread acceptance of the existence of ancient pre-animal (pre-metazoan) life came from the discovery in 1954 of numerous kinds of microscopic fossil organisms in the Gunflint rocks along the shores of Lake Superior in the USA. The Gunflint find showed that life was prevalent 2,000 million years ago.

Through their studies of fossil life forms, earth scientists have contributed to the concepts of evolution. Mass extinctions, in which large proportions of all of Earth's species die out, have been a particular source of intrigue in the 1980s and 1990s. This intrigue was stimulated in 1980 by the suggestion of Nobel prizewinning physicist Luis Alvarez (1911–1988) and his colleagues that the dinosaurs and 70% of all other species of the Earth were killed off 65 million years ago by the impact of an asteroid or comet. Others suggested that profuse volcanism in India at that time was responsible for the so-called 'KT' mass extinction. Testing of these hypotheses has promoted dialogue between meteoriticists, biologists, geochemists, and cosmochemists, and the boundaries of what is called earth science has been once again blurred toward the close of the century.

The suggestion in 1996 by the US National Aeronautics and Space Administration (NASA) researchers that the SNC meteorite ALH84001, thought to be a piece of Mars, contains evidence for bacterial life is arguably the principal motivation for the renewed interest in the origin of life (SNC is the name given to a class of meteorites named after the original members Shergotty, Nakhla, and Chassigny; ALH reflects the discovery of the sample in the Alan Hills of Antarctica). Indeed, it has even been suggested by some scientists that life on Earth could have originated on Mars and spread here by exchange of planetary fragments like the SNC meteorites. But another motivation is the realization that the organic and inorganic worlds are not as separate and distinct as was once believed. It has been demonstrated recently that the amount of biological material in ocean surface water is partly controlled by the amount of the element iron, an inorganic metal. Metals are now recognized as important to the functioning of cells in living things and earth scientists are beginning to study the movements of these important life-giving inorganic substances within Earth's hydrosphere, atmosphere, and rocky regolith.

The chemistry and global cycle of nitrogen is also proving to be instrumental in understanding the possible origins of life. Nitrogen is an essential component of amino acids (the constituents of proteins) and nucleic acids (DNA, RNA), the very building blocks of life. Earth scientists, including mineral physicists and biogeochemists, are studying how the element nitrogen could have found its way from inert forms, such as the nitrogen in our atmosphere, to more reactive states suitable for forming amino acids and nucleic acids. Results suggest the critical reactions occurred on the ocean floor along the great mid-ocean ridges where ocean water is heated by underlying volcanic magma. To simulate the pressures exerted by the water in the deep ocean basins, mineral physicists employ some of the same tools once used for studying the behaviour of rocks and minerals deep in Earth's crust.

continental drift

Several scientists of the 19th and 20th centuries had suggested that the continents were once joined and then drifted apart, but German geologist Alfred Wegener (1880–1930) went further and declared that continental rafts might actually slither horizontally across the Earth's face. Wegener published his ideas of 'Die Verschiebun der Kontinente', or continental displacement, from 1913 to 1924. His ideas became known as continental drift. Empirical evidence for continental drift lay, he thought, in the close jigsaw-fit between coastlines on either side of the Atlantic, and notably in palaeontological similarities between Brazil and Africa. Wegener was also convinced that geophysical factors would corroborate wandering continents.

Wegener supposed that a united supercontinent, Pangaea, had existed in the Mesozoic. This had developed numerous fractures and had drifted apart, some 200 million years ago. During the Cretaceous, South America and Africa had largely been split, but not until the end of the Quaternary had North America and Europe finally separated. Australia had been severed from Antarctica during the Eocene.

the causes of continental drift

What had caused continental drift? Wegener offered a choice of possibilities. One was a westwards tidal force caused by the Moon. The other involved a centrifugal effect propelling continents away from the poles towards the Equator (the 'flight from the pole'). In its early years, drift theory won few champions, and in the English-speaking world reactions were especially hostile. A few geologists were intrigued by drift, especially the South African, Alexander Du Toit (1878–1948), who adumbrated the similarities in the geologies of South America and South Africa, suggesting they had once been contiguous. In *Our Wandering Continents* (1937), Du Toit maintained that the southern continents had formed the supercontinent of Gondwanaland.

The most ingenious support for drift came, however, from the English geophysicist Arthur Holmes. Assuming radioactivity produced vast quantities of heat, Holmes argued for convection currents within the crust, in 1929. Radioactive heating caused molten magma to rise to the surface, which then spread out in a horizontal current before descending back into the depths when chilled. Such currents provided a new mechanism for drift.

The real breakthrough required diverse kinds of evidence accumulated during the 1940s, especially through studies in oceanography and palaeomagnetism.

Sonar, developed as part of the World War II war effort, became available for mapping the topography of the ocean floor. The result was discovery of the semi-continuous mid-ocean ridge, a mountain chain 50,000 km/31,250 mi in length beneath the oceans. In addition US geologist William Maurice Ewing (1906–1974) ascertained that the crust under the ocean is much thinner than the continental shelf.

The US geologist Harry Hess (1906–1969), in an unpublished manuscript in 1959, suggested that new crust was produced in mid-ocean ridges, whereas deep-ocean trenches marked the sites where old crust descended into the depths of the mantle. Hess's concept, eventually published in 1962, was that the ocean crust was like a giant conveyor belt. This concept was termed 'seafloor spreading' and was shortly thereafter confirmed by palaeomagnetic studies of the ocean floor. In 1963, English geophysicists Fred Vine (1939–) and Drummond Matthews (1931–), showed that reversal in Earth's magnetic field had left a record of seafloor spreading in the form of stripes on the ocean floor. The stripes were defined by the direction of magnetism locked in to the rocks as they were formed at the ridges.

Seafloor spreading constituted the great breakthrough in understanding the dynamics of the Earth. Continents were seen to be gliding across the surface as passive passengers on great plates bounded by mid-ocean ridges and deep oceanic trenches. Constantly being formed and destroyed, the ocean floors were young; only continents – too light to be drawn down by the current – would preserve testimony of the remote geological past. Support came from J Tuzo Wilson (1908–1993), a Canadian geologist, who provided backing for the seafloor spreading hypothesis.

Seafloor spreading led to the formal development of the theory of 'plate tectonics' in the late 1960s by English geophysicist Dan McKenzie (1942–) and French geophysicist Xavier Le Pichon (1937–), then at the Lamont Observatory in New York, USA.

The majority of Earth scientists accepted the new plate tectonics model with remarkable rapidity. In the mid-1960s, a full account of plate tectonics was expounded. The Earth's surface was divided into six major plates, the borders of which could be explained by way of the convection-current theory. Deep earthquakes were produced where one section of crust was driven beneath another, the same process also causing volcanic activity in zones like the Andes. Mountains on the western edge of the North and South American continents arose from the fact that the continental 'raft' is the leading edge of a plate, having to face the oncoming material from other plates being forced beneath them. The Alps and Himalayas are the outcome of collisions of continental areas, each driven by a different plate system.

Geologists of the late 1960s and 1970s undertook immense reinterpretation of their traditional doctrines. Well-established stratigraphical and geomorphological data had to be redefined in terms of the new forces operating in the crust. Tuzo Wilson's *A Revolution in Earth Science* (1967) was a persuasive account of the plate tectonics revolution.

Geology is remarkable for having undergone such a dramatic and comprehensive conceptual revolution within recent decades. The fact that the most compelling evidence for the new theory originated from the new discipline of ocean-based geophysics has involved considerable reassessment of skills and priorities within the profession. Above all, the ocean floor now appears to be the key to understanding the Earth's crust, in a way that Wegener never appreciated.

satellite observations

In recent years Earth-observation satellites have measured continental movements with unprecedented accuracy. The surface of the Earth can be measured using global positioning geodesy (detecting signals from satellites by Earth-based receivers), satellite laser ranging (in which satellites reflect signals from ground transmitters back to ground receivers), and very long-baseline interferometry, which compares signals received at ground-based receivers from distant extraterrestrial bodies. These techniques can measure distances of thousands of kilometres to accuracies of less than a centimetre. Movements of faults can be measured, as can the growth of tectonic plates. Previously, such speeds were calculated by averaging displacements measured over decades or centuries. The results show that in the oceanic crust, plate growth is steady: from 12 mm/0.05 in per year across the Mid-Atlantic Ridge to 160 mm/6.5 in per year across the East Pacific Rise. The major continental faults seem to be very irregular in their movement; the Great Rift Valley has remained stationary for 20 years, when long-term averages suggest that it would have opened up about 100 mm/4 in in that time.

the future

At the start of the new millennium earth sciences is a field in transition. Increasingly, the field of geology, that was once focused on studies of Earth's near-surface, is giving way to a broader discipline in which the Earth is studied in the context of its interplanetary environs. New methods are being devised to study not only Earth's unseen, deep interior, but also to examine rocky bodies throughout the Solar System. Discovery of extra-solar giant planets in the past several years has hastened the desire to understand how planets like Earth might form around other stars, and if life is an inevitable consequence of such terrestrial planet formation. Scientists now consider that the best way to gain answers to these questions is to understand the phenomena of planets and life in our Solar System as a whole. Thus, where earth scientists once studied the structure of our own planet, they now compare Earth to Mars and the other planets of the inner Solar System. Where they once concerned themselves with the evolution of life on Earth, now they steer their research towards understanding the origin of life in general, wherever and however it may have started. An example is the state of water on other planets. In 1999 geologists are contemplating the role that glaciers may have had on the form of the largest volcano in the Solar System, Olympus Mons on Mars.

Adventures in the Learning Web

Go to site

Huge range of online educational geological resources, including sections on 'Finding your way with map and compass', 'Monitoring active volcanoes', and 'This dynamic earth'. The site is run by the US Geological Survey, so some of the material is US-specific. However, a whole host of more general earth science topics are covered on this site in clear, well-illustrated sections. This site is regularly updated with information on any natural disasters as and when they happen.

Essential Guide to Rocks

Go to site

Entertaining and informative site based on the British Broadcasting Corporation's (BBC) television series of the same name. This site shows in particular how geology and the earth sciences can be seen within cities, the home, and even the bathroom. Another feature is a series of 'virtual walks' showing rocks and minerals in surprising places in London, England, and other cities.

Lunar and Planetary Institute

Go to site

Wonderful, extremely well-organized site, which includes information about planetary exploration and transcripts from astronauts' lunar field trips. The site also includes lots of materials for teachers.

US Geological Survey

Go to site

US Geological Survey (USGS) site includes information on almost every aspect of earth science you can think of. It is well-organized and contains a useful search engine to make finding things very easy.

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geometric mean

in mathematics, the nth root of the product of n positive numbers. The geometric mean m of two numbers p and q is such that $m = \surd(p \times q)$. For example, the geometric mean of 2 and 8 is $\surd(2 \times 8) = \surd 16 = 4$.

---

geometric progression

or geometric sequence

in mathematics, a sequence of terms (progression) in which each term is a constant multiple (called the **common ratio**) of the one preceding it. For example, 3, 12, 48, 192, 768, ... is a geometric progression with a common ratio 4, since each term is equal to the previous term multiplied by 4. Compare arithmetic progression.

The sum of n terms of a **geometric series**

$1 + r + r^2 + r^3 + \ldots + r^{n-1}$

is given by the formula

$S_n = (1 - r^n)/(1 - r)$ for all $r \neq 1$.

For mod $r < 1$ (see absolute value), the geometric series can be summed to infinity:

$S_\infty = 1/(1 - r)$.

In nature, many single-celled organisms reproduce by splitting in two so that one cell gives rise to 2, then 4, then 8 cells, and so on, forming a geometric sequence 1, 2, 4, 8, 16, 32, ..., in which the common ratio is 2.

---

geometry

branch of mathematics concerned with the properties of space, usually in terms of plane (two-dimensional, or 2D) and solid (three-dimensional, or 3D) figures. The subject is usually divided into **pure geometry**, which embraces roughly the plane and solid geometry dealt with in Greek mathematician Euclid's *Stoicheia/Elements*, and **analytical** or **coordinate geometry**, in which problems are solved using algebraic methods. A third, quite distinct, type includes the non-Euclidean geometries.

pure geometry

This is chiefly concerned with properties of figures that can be measured, such as lengths, areas, and angles and is therefore of great practical use. An important idea in Euclidean geometry is the idea of **congruence**. Two figures are said to be congruent if they have the same shape and size (and area). If one figure is imagined as a rigid object that can be picked up, moved and placed on top of the other so that they exactly coincide, then the two figures are congruent. Some simple rules about congruence may be stated: two line segments are congruent if they are of equal length; two triangles are congruent if their corresponding sides are equal in length or if two sides and an angle in one is equal to those in the other; two circles are congruent if they have the same radius; two polygons are congruent if they can be divided into congruent triangles assembled in the same order.

The idea of picking up a rigid object to test congruence can be expressed more precisely in terms of elementary 'movements' of figures: a translation (or glide) in which all points move the same distance in the same direction (that is, along parallel lines); a rotation through a defined angle about a fixed point; a reflection (equivalent to turning the figure over).

Two figures are congruent if one can be transformed into the other by a sequence of these elementary movements. In Euclidean geometry a fourth kind of movement is also studied; this is the enlargement in which a figure grows or shrinks in all directions by a uniform scale factor. If one figure can be transformed into another by a combination of translation, rotation, reflection, and enlargement then the two are said to be similar. All circles are similar. All squares are similar. Triangles are similar triangles if corresponding angles are equal.

coordinate geometry

A system of geometry in which points, lines, shapes, and surfaces are represented by algebraic expressions. In plane (two-dimensional) coordinate geometry, the plane is usually defined by two axes at right angles to each other, the horizontal x-axis and the vertical y-axis, meeting at O, the origin. A point on the plane can be represented by a pair of Cartesian coordinates, which define its position in terms of its distance along the x-axis and along the y-axis from O. These distances are, respectively, the x and $y$coordinates of the point.

Lines are represented as equations; for example, $y = 2x + 1$ gives a straight line, and $y = 3x^2 + 2x$ gives a parabola (a curve). The graphs of varying equations can be drawn by plotting the coordinates of points that satisfy their equations, and joining up the points. One of the advantages of coordinate geometry is that geometrical solutions can be obtained without drawing but by manipulating algebraic expressions. For example, the coordinates of the point of intersection of two straight lines can be determined by finding the unique values of x and y that satisfy both of the equations for the lines, that is, by solving them as a pair of simultaneous equations. The curves studied in simple coordinate geometry are the conic sections (circle, ellipse, parabola, and hyperbola), each of which has a characteristic equation.

Geometry probably originated in ancient Egypt, in land measurements necessitated by the periodic inundations of the River Nile, and was soon extended into surveying and navigation. Early geometers were the Greek mathematicians Thales, Pythagoras, and Euclid. Analytical methods were introduced and developed by the French philosopher René Descartes in the 17th century. From the 19th century, various non-Euclidean geometries were devised by Carl Friedrich Gauss, János Bolyai, and Nikolai Lobachevsky. These were later generalized by Bernhard Riemann and found to have applications in the theory of relativity.

Areas and Volumes

Go to site

Introduction to area and volume, with advice on good exam technique. Area is defined first, along with some equations for the areas of common shapes. Volume is then defined, along with the equations for calculating the surface areas and volumes of three-dimensional solids.

Similar Triangles

Go to site

Similar triangles and the ratios between their sides are covered by this concise page. It defines how triangles can be similar, and shows a worked example complete with a diagram. Links at the top of the page lead to other maths sections on the project GCSE Web site.

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geomorphology

branch of geology developed in the late 19th century, dealing with the morphology, or form, of the Earth's surface; nowadays it is also considered to be an integral part of physical geography. Geomorphological studies investigate the nature and origin of surface landforms, such as mountains, valleys, plains, and plateaux, and the processes that influence them. These processes include the effects of tectonic forces, weathering, running water, waves, glacial ice, and wind, which result in the erosion, mass movement (landslides, rockslides, mudslides), transportation, and deposition of rocks and soils. In addition to the natural processes that mould landforms, human activity can produce changes, either directly or indirectly, and cause the erosion, transportation, and deposition of rocks and soils, for example by poor land management practices and techniques in farming and forestry, and in the mining and construction industries.

Geomorphology deals with changes in landforms from the present to the geologic past, and in spatial scales ranging from microscale to mountains. For example, the formation of mountain ranges takes place over millions of years, as the Earth's crust cools and solidifies and the resulting layers, or plates, are folded, uplifted or deformed by the seismic activity of the underlying magma (see plate tectonics). The gouging out of river valleys by glacial erosion is a gradual process that takes place over thousands of years. Conversely, volcanic eruptions, by the ejection of rocks and gases and the rapid flow of molten lava down a mountainside, create rapid changes to landforms, as with the volcanic eruptions on the island of Montserrat in the West Indies. Similarly, the eruption of undersea volcanoes can result in the sudden birth of islands, while the consequent and rapidly moving tidal waves (tsunamis), can produce the unexpected inundation and destruction of low-lying coastal regions in their path.

Landforms and Bodies of Water

Go to site

Providing a comprehensive list of different types of landforms, such as capes, islands, and plateaux, this page acts as a starting point for definitions and locations of landforms throughout the world. Each sub-page contains a basic definition, locations where such landforms can be found, pictures, and case study style descriptions. A good resource for revision, or building geography case studies.

Models of Landform Development

Go to site

Discussion of the four types of landform to be found on Earth, and how they develop. Part of a much larger site, Fundamentals of Physical Geography, set up by a Canadian university, the text is supported by a graphical model explaining the relationship between geomorphic processes and landform types.

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geophysics

branch of earth science using physics (for instance gravity, seismicity, and magnetism) to study the Earth's surface, interior, and atmosphere. Geophysics includes several sub-fields such as seismology, paleomagnetism, and remote sensing.

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geostationary orbit

or geostationary Earth orbit

circular path 35,900 km/22,300 mi above the Earth's Equator on which a satellite takes 24 hours, moving from west to east, to complete an orbit, thus appearing to hang stationary over one place on the Earth's surface. Geostationary orbits are used particularly for communications satellites and weather satellites. Their use for communications satellites was first suggested by the English space writer Arthur C Clarke. A geosynchronous orbit lies at the same distance from Earth but is inclined to the Equator.

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geothermal energy

energy extracted for heating and electricity generation from natural steam, hot water, or hot dry rocks in the Earth's crust. It is a form of renewable energy. Water is pumped down through an injection well where it passes through joints in the hot rocks. It rises to the surface through a recovery well and may be converted to steam or run through a heat exchanger. Steam may be directed through turbines to produce electrical energy. It is an important source of energy in volcanically-active areas such as Iceland and New Zealand. The Earthseverals internal heat is produced by the decay of radioactive substances in the rocks.

Energy Resources

introduction

Humans are using up the world's energy resources in a way no other animal has ever done. We use them to provide light and heating in our homes, to plough the land, to cook our food, to travel, to run our factories, and in countless other ways. Whether we are rural workers in a developing country or urban workers in a wealthy industrial country, we all need energy, although the sources of the energy and the amounts used vary greatly from one society to another.

sources of energy

There are different forms or types of energy. Fuels such as coal, oil (petroleum), and wood contain chemical energy. When these fuels are burnt, the chemical energy changes to heat and light energy. Electricity is the most important form of energy in the industrialized world, because it can be transported over long distances via cables and transmission lines. It is also a very convenient form of energy, since it can power a wide variety of household appliances and industrial machinery. It is produced by converting the chemical energy from coal, oil, or natural gas in power stations. Energy resources fall into two broad groups: renewable and nonrenewable. Renewable resources are those which replenish themselves naturally and will either always be available - hydroelectric power, solar energy, wind and wave power, tidal energy, and geothermal energy - or will continue to be available provided supplies are given sufficient time to replenish themselves - peat and firewood. Nonrenewable resources are those of which there are limited supplies and which once used are gone forever. These include coal, oil, natural gas, and uranium.

fossil fuels

Coal, oil, and natural gas are called fossil fuels because they are the fossilized remains of plants and animals that lived hundreds of millions of years ago. Burning fossil fuels releases chemicals that cause acid rain, and is gradually increasing the carbon dioxide in the atmosphere, causing global warming. Fossil fuel resources are not evenly distributed around the world. Over half the world's known oil reserves are in the Middle East; about 40% of the reserves of natural gas are in the Commonwealth of Independent States (CIS), and 25% in the Middle East. About two-thirds of the world's coal is shared between North America, the CIS, and China.

uranium

Uranium is a radioactive metallic element and a very concentrated source of energy; large reserves are found in Australia, North America, and South Africa. Used to produce electricity in a nuclear power station, a single ton of uranium can produce as much energy as 15,000 tons of coal, or 10,000 tons of oil. Used in the type of nuclear power station now in operation, the world's known uranium supplies have about the same energy content as the known oil reserves. However, these power stations, known as thermal stations or reactors, use only a small part of the energy available in uranium. The next generation of reactors, known as fast or breeder reactors, release virtually all its energy. These reactors would increase the world's uranium energy reserves by sixty times. However, although nuclear power stations do not produce carbon dioxide or cause acid rain, they do produce radioactive waste that is dangerous and difficult to process or store safely.

solar energy

Many renewable resources take advantage of the energy in sunlight. The Sun's energy can be tapped directly by photovoltaic cells that convert light into electricity. Other solar energy plants use mirrors to direct sunlight onto pipes containing a liquid. The liquid boils and is used to drive an electricity generator. The Sun's energy also drives the wind and waves, so energy produced by wind farms and wave-driven generators is also derived from the Sun.

gravitational energy

Hydroelectricity and tidal power stations make use of gravitational forces. The Earth's gravity pulls water downward through the turbines in a hydroelectric power station. In a tidal power station, the Moon's gravity lifts water as the tides rise, giving the water potential energy (energy due to position) which is released as the water flows through a turbine. Geothermal energy (the heat energy of hot rocks deep beneath the Earth's surface) is due to gravity compressing and heating the rocks when the Earth formed.

the worldwide energy pie

Globally, the largest contributions to current energy resources come from oil (31%), coal (26%), and natural gas (19%). Renewable energy currently supplies about 20% of the world's energy needs, with hydroelectricity supplying 6% of the world's needs and traditional biofuels (firewood, crop wastes, peat, and dung) supplying 12%. A small contribution is made by new renewables, such as the conversion of crops such as sugar into alcohol fuel and the burning of waste material. The contribution solar, wave, tidal, and geothermal power can make to the world's energy resources is currently limited. This is because renewable energy depends on the development of means of capturing and concentrating it. In addition, renewable energy is not always available when needed - rivers can dry up, the wind does not always blow.

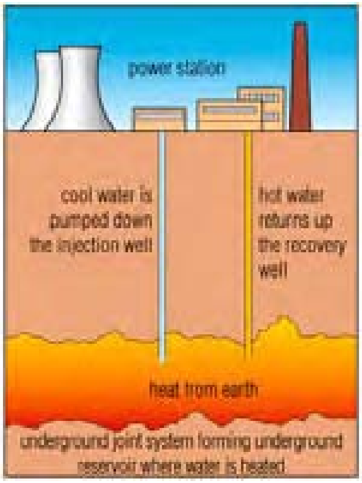
future demands

It is clear that, in the future, demand for energy will be higher than at present, due to population growth and increased industrialization. Furthermore, the energy available must be at a reasonable cost or economic growth will be held back. This is especially important for developing countries, where the inability to meet high energy costs hinders development.

future solutions

In principle, known resources of nonrenewable energy should be sufficient for several hundred years or more. At the present rate of consumption, oil reserves will last about 40 years; gas reserves will last about 60 years; coal reserves will last about 250 years; and uranium reserves, if used in fast reactors, would last for more than 1,000 years. It is also likely that further fossil-fuel reserves will be discovered as currently known supplies run out. However, in practice, the outlook is uncertain. Increasing concern about pollution might make dirty coal-fired power stations unacceptable in the future. One alternative is to make greater use of nuclear power, moving to fast reactors and then developing nuclear fusion plants that would mimic the power production process found in the Sun. However, anxiety about safety and waste disposal is already limiting the use of nuclear energy, so it is unlikely to provide an answer in the future. There is considerable room for development in the use of renewable resources, but with most of the world's energy production based around nonrenewable fuel supplies, the widespread introduction of efficient renewable energy will require a complete restructuring of the ways we produce and use energy.

geothermal energy


power station
cool water is pumped down the injection well
hot water returns up the recovery well
heat from earth
underground joint system forming underground reservoir where water is heated

(Image © Research Machines plc)

Geothermal energy is derived from the natural heat present below the surface of the Earth. Cool water is pumped down where it is heated up in large underground reservoirs before being pumped back to the surface.

geothermal energy

(Image © Garret Nagle)

Nesjavellir geothermal power station, Thingvellir, Iceland. Geothermal energy is a form of renewable energy that uses the natural heat of the Earth to heat water. The hot water or steam can then be converted into electricity. Nesjavellir is situated in an area of volcanic activity and has higher than normal rock temperatures near to the surface.

Geothermal Information Office

Go to site

Large resource of geothermal energy information. Included here are an introduction that explains the basics of geothermal energy, an article on geothermal energy's relation to the environment, and also a glossary and list of 'Frequently Asked Questions'.

Geothermal Technologies

Go to site

Interesting geothermal home page of the US Department of Energy. There is a description of various geothermal energy sources and technologies being developed to exploit them. There is information about a number of energy authorities across the world tapping geothermal energy.

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geranium

or cranesbill, plant of the genus *Geranium*, family Geraniaceae, which contains about 400 species. The plants are named after the long, beaklike process attached to the seed vessels.

When ripe, this splits into coiling spirals, which jerk the seeds out, assisting in their distribution.

gerbil

any of numerous rodents with elongated back legs, good at hopping or jumping. Gerbils range from mouse- to rat-size, and have hairy tails. Many of the 13 genera live in dry, sandy, or sparsely vegetated areas of Africa and Asia. (Family Cricetidae.)

The Mongolian jird or gerbil (*Meriones unguiculatus*) is a popular pet.

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geriatrics

medical speciality concerned with diseases and problems of the elderly.

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germ

colloquial term for a micro-organism that causes disease, such as certain bacteria and viruses. Formerly, it was also used to mean something capable of developing into a complete organism (such as a fertilized egg, or the embryo of a seed).

VTXT: Contributor added the following 072006, but not currently in database.

See also germ line.

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germanium

chemical symbol Ge

brittle, grey-white, weakly metallic (metalloid) element, atomic number 32, relative atomic mass 72.6. It belongs to the silicon group, and has chemical and physical properties between those of silicon and tin. Germanium is a semiconductor material and is used in the manufacture of transistors and integrated circuits. The oxide is transparent to infrared radiation, and is used in military applications. It was discovered in 1886 by German chemist Clemens Winkler (1838–1904).

In parts of Asia, germanium and plants containing it are used to treat a variety of diseases, and it is sold in the West as a food supplement despite fears that it may cause kidney damage.

German measles

or rubella

mild, communicable virus disease, usually caught by children. It is marked by a sore throat, pinkish rash, and slight fever, and has an incubation period of two to three weeks. If a woman contracts it in the first three months of pregnancy, it may cause serious damage to the unborn child.

Childhood Infections - Rubella

Go to site

Useful information about rubella, or German measles. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

German shepherd

or Alsatian

breed of dog. It is about 63 cm/25 in tall and has a wolflike appearance, a thick coat with many varieties of colouring, and a distinctive way of moving. German shepherds are used as police dogs because of their courage and intelligence.

They were introduced from Germany into Britain and the USA after World War I.

German Shepherd Dog

Go to site

Everything there is to know about Alsatians from the American Kennel Club. There is a history of the breed, agreed breed standards, and some photos. There are links to other German shepherd sites.

German silver

or nickel silver

silvery alloy of nickel, copper, and zinc. It is widely used for cheap jewellery and the base metal for silver plating. The letters EPNS on silverware stand for **e**lectro**p**lated **n**ickel **s**ilver.

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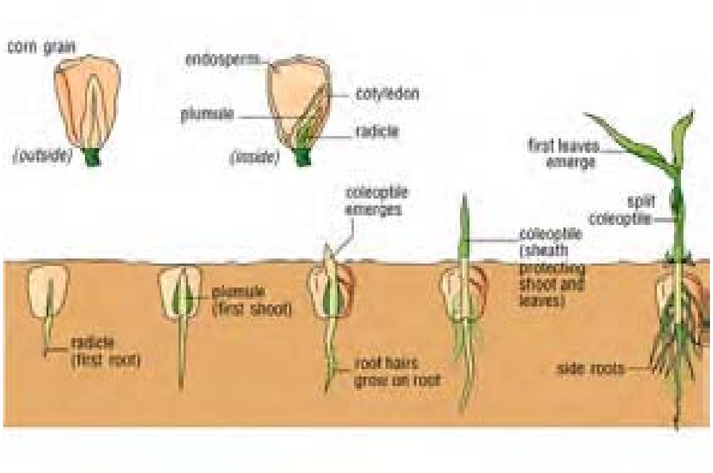
germination

in botany, the initial stages of growth in a seed, spore, or pollen grain. Seeds germinate when they are exposed to favourable external conditions of moisture, light, and temperature, and when any factors causing dormancy have been removed.

The process begins with the uptake of water by the seed. The embryonic root, or radicle, is normally the first organ to emerge, followed by the embryonic shoot, or plumule. Food reserves, either within the endosperm or from the cotyledons, are broken down to nourish the rapidly growing seedling. Germination is considered to have ended with the production of the first true leaves.

germination



(Image © Research Machines plc)

The germination of a corn grain. The plumule and radicle emerge from the seed coat and begin to grow into a new plant. The coleoptile protects the emerging bud and the first leaves.

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germ layer

in embryology, a layer of cells that can be distinguished during the development of a fertilized egg. Most animals have three such layers: the inner, middle, and outer. These differentiate to form the various body tissues.

The inner layer (**endoderm**) gives rise to the gut, the middle one (**mesoderm**) develops into most of the other organs, while the outer one (**ectoderm**) gives rise to the skin and nervous system. Simple animals, such as sponges, lack a mesoderm.

Gerson therapy

in alternative medicine, radical nutritional therapy for degenerative diseases, particularly cancer, developed by German-born US physician Max Gerson (1881-1959).

Numerous cures of chronic cases were achieved by Gerson, but his opposition to orthodox cancer treatment, and the stringency of his alternative approach, have resulted in the therapy not being widely practised today, although the evidence for its effectiveness, both in relieving the suffering and drug-dependence of most patients and in achieving the recovery of many others, is substantial.

Gestalt

(German 'form')

concept of a unified whole that is greater than, or different from, the sum of its parts; that is, a complete structure whose nature is not explained simply by analysing its constituent elements. A chair, for example, will generally be recognized as a chair despite great variations between individual chairs in such attributes as size, shape, and colour.

Gestalt psychology regards all mental phenomena as being arranged in organized, structured wholes, as opposed to being composed of simple sensations. For example, learning is seen as a reorganizing of a whole situation (often involving insight), as opposed to the behaviourists' view that it consists of associations between stimuli and responses. Gestalt psychologists' experiments show that the brain is not a passive receiver of information, but that it structures all its input in order to make sense of it, a belief that is now generally accepted; however, other principles of Gestalt psychology have received considerable criticism.

The term 'Gestalt' was first used in psychology by the Austrian philosopher and psychologist Christian von Ehrenfels in 1890. Max Wertheimer, Wolfgang Köhler, and Kurt Koffka (1886-1941) were cofounders of Gestalt psychology.

Classics In The History Of Psychology - Laws of Organization in Perceptual Forms

Go to site

Transcript of Max Wertheimer's 1923 paper *Laws of Organization in Perceptual Forms*. This paper outlined the principles of Gestalt psychology, and therefore formed the basis for much of the development in the science in the early part of this century.

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gestation

in all mammals except the monotremes (platypus and spiny anteaters), the period from the time of implantation of the embryo in the uterus to birth. This period varies among species; in humans it is about 266 days, in elephants 18-22 months, in cats about 60 days, and in some species of marsupial (such as opossum) as short as 12 days.

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geyser

natural spring that intermittently discharges an explosive column of steam and hot water into the air due to the build-up of steam in underground chambers. One of the most remarkable geysers is Old Faithful, in Yellowstone National Park, Wyoming, USA. Geysers also occur in New Zealand and Iceland.

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g-force

force experienced by a pilot or astronaut when the craft in which he or she is travelling accelerates or decelerates rapidly. The unit g denotes the acceleration due to gravity, where 1 g is the ordinary pull of gravity.

Early astronauts were subjected to launch and re-entry forces of up to 6 g or more; in the space shuttle, more than 3 g is experienced on lift-off. Pilots and astronauts wear g-suits that prevent their blood pooling too much under severe g-forces, which can lead to unconsciousness.

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giant star

member of a class of stars located at the top right pf the Hertzsprung-Russell diagram, characterized by great size and luminosity. Giants have exhausted their supply of hydrogen fuel and derive their energy from the fusion of helium and heavier elements. They are roughly 10-300 times bigger than the Sun with 30-1,000 times the luminosity. The cooler giants are known as red giants.

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gibberellin

plant growth substance (see also auxin) that promotes stem growth and may also affect the breaking of dormancy in certain buds and seeds, and the induction of flowering. Application of gibberellin can stimulate the stems of dwarf plants to additional growth, delay the ageing process in leaves, and promote the production of seedless fruit (parthenocarpy).

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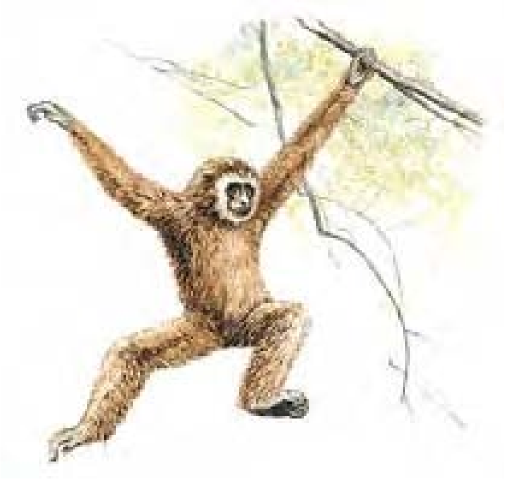
gibbon

any of a group of several small southern Asian apes. The **common** or **lar gibbon** (*H. lar*) is about 60 cm/2 ft tall, with a body that is hairy except for the buttocks, which distinguishes it from other types of apes. Gibbons have long arms and no tail. They spend most of their time in trees and are very agile when swinging from branch to branch. On the ground they walk upright, and are more easily caught by predators. (Genus *Hylobates*, including the subgenus *Symphalangus*.)

The **siamang** (*S. syndactylus*) is the largest of the gibbons, growing to 90 cm/36 in tall; it is entirely black. Gibbons are found from Assam through the Malay peninsula to Borneo, but are becoming rare, with certain species classified as endangered.

gibbon



(Image © Research Machines plc)

There are nine species of these lesser, tail-less apes found in South East Asian rainforests and monsoon forests. They eat mainly fruit and move with great agility through the trees by swinging from branch to branch suspended by their long arms – this is known as brachiation. On stronger branches, gibbons will also walk in an upright posture. The largest gibbon, the siamang, may reach lengths of 90 cm/3 ft.

Gibbs, Josiah Willard (1839-1903)

US theoretical physicist and chemist who developed a mathematical approach to thermodynamics and established vector methods in physics. He devised the phase rule and formulated the Gibbs adsorption isotherm.

Gibbs showed how many thermodynamic laws could be interpreted in terms of the results of the movements of enormous numbers of bodies such as molecules. His ensemble method equated the behaviour of a large number of systems at once to that of a single system over a period of time.

Gibbs, Josiah

Go to site

Photograph and biography of the 19th-century US mathematician and chemist. This site, run by St Andrews University, also provides information on Gibbs's constant along with literature references for further study.

Giffard, Henri (1825-1882)

French inventor of the first passenger-carrying powered and steerable airship, called a dirigible, built in 1852. The hydrogen-filled airship was 43 m/144 ft long, had a 2,200-W/3-hp steam engine that drove a three-bladed propeller, and was steered using a saillike rudder. It flew at an average speed of 5 kph/3 mph.

giga-

prefix signifying multiplication by 10^9 (1,000,000,000 or 1 billion), as in **gigahertz**, a unit of frequency equivalent to 1 billion hertz.

gigabyte

in computing, a measure of memory capacity, equal to 1,024 megabytes. It is also used, less precisely, to mean 1,000 billion bytes.

gila monster

lizard native to the southwestern USA and Mexico. It is one of the only two existing venomous lizards, the other being the Mexican beaded lizard of the same genus. It has poison glands in its lower jaw, but its bite is not usually fatal to humans. (Species *Heloderma suspectum*.)

Dr Seward's Gila Monster Web Page

Go to site

Comprehensive guide to *Heloderma suspectum*. The well-arranged contents include a description of the two subspecies, information on habit, behaviour, diet, reproduction in the wild, and the challenges of captive breeding. There are many pictures of gilas.

Gilbert, Walter (1932-)

US molecular biologist who studied genetic control, seeking the mechanisms that switch genes on and off. By 1966 he had established the existence of the lac repressor, a molecule that suppresses lactose production. He was awarded the Nobel Prize for Chemistry in 1980 for his work on the sequencing of DNA nucleotides. He shared the award with Frederick Sanger and Paul Berg.

Gilbert, William (1540-1603)

English scientist who studied magnetism and static electricity, deducing that the Earth's magnetic field behaves as if a bar magnet joined the North and South poles. His book on magnets, published in 1600, is the first printed scientific book based wholly on experimentation and observation.

Gilbert was the first English scientist to accept Nicolas Copernicus's idea that the Earth rotates on its axis and revolves around the Sun. He also believed that the stars are at different distances from the Earth and might be orbited by habitable planets, but erroneously thought that the planets were held in their orbits by magnetic forces.

gill

in biology, the main respiratory organ of most fishes and immature amphibians, and of many aquatic invertebrates. In all types, water passes over the gills, and oxygen diffuses across the gill membranes into the circulatory system, while carbon dioxide passes from the system out into the water.

In aquatic insects, these gases diffuse into and out of air-filled canals called tracheae.

gill

imperial unit of volume for liquid measure, equal to one-quarter of a pint or four fluid ounces (0.118 liter). It is used in selling alcoholic drinks.

ginger

southeast Asian reedlike perennial plant; the hot-tasting spicy underground root is used as a food flavouring and in preserves. (*Zingiber officinale*, family Zingiberaceae.)

Ginger

Go to site

Informative resource relating to ginger. It contains a detailed description of the plant and its habitat. There are also notes on the constituents of the plant, as well as information on the possible medicinal uses of ginger, which include acting as a stimulant.

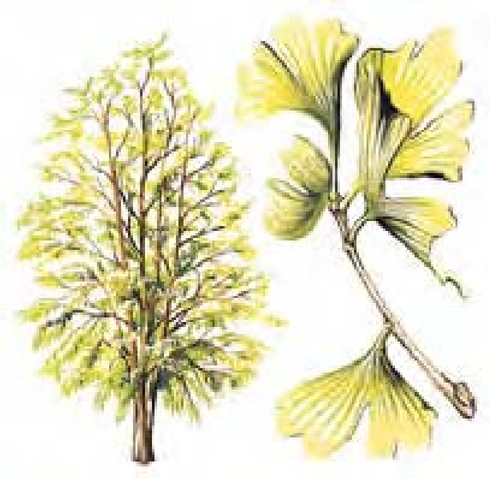
ginkgo

or maidenhair tree

tree belonging to the gymnosperm (or naked-seed-bearing) division of plants. It may reach a height of 30 m/100 ft by the time it is 200 years old. (*Ginkgo biloba*.)

The only living member of its group (Ginkgophyta), widespread in Mesozoic times (245-65 million years ago), it has been cultivated in China and Japan since ancient times, and is planted in many parts of the world. Its leaves are fan-shaped, and it bears fleshy, yellow, foul-smelling fruit enclosing edible kernels.

ginkgo



(Image © Research Machines plc)

The ginkgo tree has existed virtually unchanged for at least 160 million years. The bright green leaves resemble those of the maidenhair fern and give the ginkgo its common name, the maidenhair tree.

ginseng

plant with a thick forked aromatic root used in alternative medicine as a tonic. (*Panax ginseng*, family Araliaceae.)

Asian ginseng *Panax ginseng* was placed on the Convention on International Trade in Endangered Species (CITES) Appendix 2, which controls, but does not completely ban, trade in the species. Although cultivation is widespread, the wild plant is vulnerable, particularly in Russia.

Ginseng

Go to site

Extract from the *Modern Herbal* by Mrs M Grive, first published in 1931. This site gives a thorough description of the ginseng plant, its cultivation, harvesting, and the uses to which it is put. Some substitutes for the plant are also described.

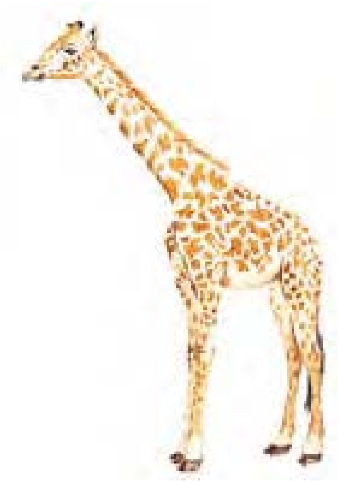
Giotto

space probe built by the European Space Agency to study Halley's Comet. Launched by an Ariane rocket in July 1985, Giotto passed within 600 km/375 mi of the comet's nucleus on 13 March 1986. On 2 July 1990, it flew within 23,000 km/14,000 mi of the Earth, which diverted its path to encounter another comet, Grigg-Skjellerup, on 10 July 1992.

giraffe

world's tallest mammal. It stands over 5.5 m/18 ft tall, the neck accounting for nearly half this amount. The giraffe has two to four small, skin-covered, hornlike structures on its head and a long, tufted tail. The fur has a mottled appearance and is reddish brown and cream. Giraffes are found only in Africa, south of the Sahara Desert. They eat leaves and vegetation that is out of reach of smaller mammals, and are ruminants; that is, they chew the cud. (Species *Giraffa camelopardalis*, family Giraffidae.)

giraffe



(Image © Research Machines plc)

The giraffe is a specialized offshoot of the deer family. The giraffe family is now restricted to two species: the okapi and the giraffe itself. The irregular coloration of the giraffe varies greatly, both geographically and between individuals. Some animals are almost white or black, or have few markings.

Rothchild's giraffe

(Image © Corel)

Rothschild's giraffe, in Kenya. Both male and female giraffes have two to four permanent skin-covered horns.

Giraffe

Go to site

Illustrated guide to the giraffe including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

gizzard

muscular grinding organ of the digestive tract, below the crop of birds, earthworms, and some insects, and forming part of the stomach. The gizzard of birds is lined with a hardened horny layer of the protein keratin, preventing damage to the muscle layer during the grinding process. Most birds swallow sharp grit which aids maceration of food in the gizzard.

glacial deposition

laying-down (deposition) of sediment once carried by a glacier. When ice melts, it deposits the material that it has been carrying. The material deposited by a glacier is called till, or in Britain **boulder clay**. It comprises angular particles of all sizes from boulders to clay that are unsorted and lacking in stratification (layering).

Unstratified till can be moulded by ice to form drumlins (egg-shaped hills). At the snout of the glacier, till piles up to form a ridge called a terminal moraine. Glacial deposits occur in many different locations - beneath the ice (subglacial), inside it (englacial), on top of it (supraglacial), at the side of it (marginal), and in front of it (proglacial).

Stratified till that has been deposited by meltwater is termed **fluvioglacial**, because it is essentially deposited by running water. Meltwater flowing away from a glacier will carry some of the till many kilometres away. This sediment will become rounded (by the water) and, when deposited, will form a gently sloping area called an **outwash plain**. Several landforms owe their existence to meltwater (**fluvioglacial landforms**) and include the long ridges called eskers, which form parallel to the direction of the ice flow. Meltwater may fill depressions eroded by the ice to form **ribbon lakes**. Small depositional landforms may also result from glacial deposition, such as **kames** (small mounds) and **kettle holes** (small depressions, often filled with water).

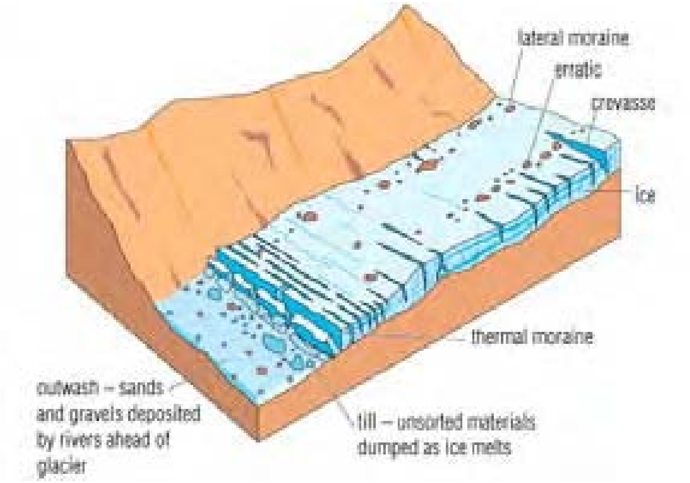
In periglacial environments on the margins of an icesheet, freeze-thaw weathering (the alternate freezing and thawing of ice in cracks in the rock) etches the outlines of rock outcrops, exploiting joints and areas of weakness, and results in aprons of scree.

glacial deposition

(Image © Garret Nagle)

Braided stream south of the Myrdalsjokull glacier, in southern Iceland. A braided stream or river is one that splits into many channels, leaving lots of bars or islands between the channels. At Myrdalsjokull the melt water river emerging from the glacier carries a huge load of sediment. It flows underneath the glacier under high-pressure conditions. As it escapes from the glacier it is suddenly able to spread out. As the height and velocity of the river is reduced, its energy drops. It begins to deposit its load, the heaviest particles first.

glacial deposition


lateral moraine
erratic
crevasse
ice
thermal moraine
outwash – sands and gravels deposited by rivers ahead of glacier
till – unsorted materials dumped as ice melts

(Image © Research Machines plc)

A glacier picks up large boulders and rock debris from the valley and deposits them at the snout of the glacier when the ice melts. Some deposited material is carried great distances by the ice to form erratics.

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glacial erosion

wearing-down and removal of rocks and soil by a glacier. Glacial erosion forms impressive landscape features, including glacial troughs (U-shaped valleys), arêtes (steep ridges), corries (enlarged hollows), and pyramidal peaks (high mountain peaks with three or more arêtes).

Erosional landforms result from abrasion and plucking of the underlying bedrock. Abrasion is caused by the rock debris carried by a glacier, wearing away the bedrock. The action is similar to that of sandpaper attached to a block of wood. The results include the polishing and scratching of rock surfaces to form powdered rock flour, and scratches or striations which indicate the direction of ice movement. Plucking is a form of glacial erosion restricted to the lifting and removal of blocks of bedrock already loosened by freeze-thaw activity.

The most extensive period of recent glacial erosion was the Pleistocene epoch (1.6 million to 10,000 years ago) in the Quaternary period (last 2 million years) when, over a period of 2 to 3 million years, the polar icecaps repeatedly advanced and retreated. More ancient glacial episodes are also preserved in the geological record, the earliest being in the middle Precambrian era (4.6 billion to 570 million years ago) and the most extensive in Permo-Carboniferous times.

glacial erosion

(Image © Garret Nagle)

The Gap of Dunloe, Killarney, County Kerry, Ireland, shows signs of the passage of a glacier during the last glacial phase. Upland areas favour the accumulation of snow and ice owing to their lower temperatures. Small cirque glaciers and larger valley glaciers flow along pre-existing river valleys, widening and deepening the valley. In some cases the glacier cuts through a mountain range, forming a col or gap. These are now often used as transport routes.

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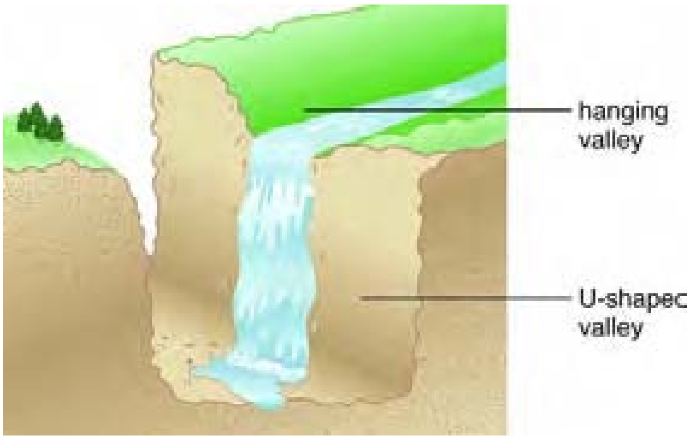
glacial trough

or U-shaped valley

steep-sided, flat-bottomed valley formed by a glacier. The erosive action of the glacier and of the debris carried by it results in the formation not only of the trough itself but also of a number of associated features, such as hanging valleys (smaller glacial valleys that enter the trough at a higher level than the trough floor). Features characteristic of glacial deposition, such as drumlins, are commonly found on the floor of the trough, together with long lakes called ribbon lakes.

glacial trough



(Image © Research Machines plc)

Cross section of a glacial trough with a hanging valley (a smaller glacial trough). Glacial troughs are U-shaped and carved out by glaciers.

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glacier

body of ice, originating in mountains in snowfields above the snowline, that moves slowly downhill and is constantly built up from its source. The geographic features produced by the erosive action of glaciers (erosion) are characteristic and include glacial troughs (U-shaped valleys), corries, and arêtes. In lowlands, the laying down of debris carried by glaciers (glacial deposition) produces a variety of landscape features, such as moraines and drumlins.

Glaciers form where annual snowfall exceeds annual melting and drainage. The area at the top of the glacier is called the zone of **accumulation**. The lower area of the glacier is called the ablation zone. In the zone of accumulation, the snow compacts to ice under the weight of the layers above and moves downhill under the force of gravity. As the ice moves, it changes its shape and structure. Partial melting of ice at the base of the glacier also produces sliding of the glacier, as the ice travels over the bedrock. In the ablation zone, melting occurs and glacial till is deposited.

Columbia Icefield

(Image © Corel)

A glacier in the Columbia Icefield, viewed from the Icefields Parkway, Alberta, Canada. The Parkway is a 230 km/143 mi stretch of highway in the Canadian Rockies, between Jasper and Banff.

glacier

(Image © Research Machines plc)

Glacier in Patagonia, Argentina. Deep cracks known as crevasses can be seen in the ice. These are formed when a glacier moves over an uneven surface. When the glacier reaches the sea, or as in this picture, a lake, the crevasses will fracture the ice to form icebergs.

glacier

(Image © Research Machines plc)

Glacier in the northern Himalayas, Tibet. Glacial erosion produces a great variety of geographic features and landscapes.

glacier

(Image © Research Machines plc)

Glacier on Mount Kilimanjaro, Tanzania. The main peaks of Kilimanjaro, the highest mountain in Africa, are three extinct volcanoes: Kibo, Mawensi, and Shira. Glaciers on Kibo's southwestern slopes terminate at 4,270 m/14,000 ft.

glacier

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Riggs Glacier, at one end of Muir Inlet, which is an extension of Glacier Bay, southeastern Alaska. The area lies within the Glacier Bay National Park and Preserve, to which the only access is by seaplane, tourist cruise-liner, or private yacht. The larger and better known Muir Glacier is a few kilometres to the northeast.

Saskatchewan glacier

(Image © Corel)

The Saskatchewan Glacier in the Columbia Icefield, Alberta, Canada. The Columbia Icefield contains about thirty glaciers, and covers an area of 325 sq km/125 sq mi.

Glacier

Go to site

Find out about the coldest, windiest place on Earth, and the geological processes behind its formation. Full of detail about what it is really like to go on an expedition to Antarctica, this well-designed site has ample information on ice and glaciers, and explains why the ice-sheet that covers all but 2% of Antarctica has expanded and contracted throughout its history.

Glaciers

Go to site

Comprehensive information about glaciers from the US National Snow and Ice Data Centre. There are explanations of why glaciers form, the different kinds of glaciers, and what they may tell us about climate change. There are a number of interesting facts and a bibliography about the compacted tongues of ice that cover 10% of the land surface of our planet.

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gladiolus

any plant of a group of southern European and African cultivated perennials belonging to the iris family, with brightly coloured funnel-shaped flowers borne on a spike; the swordlike leaves spring from a corm (swollen underground stem). (Genus *Gladiolus*, family Iridaceae.)

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gland

specialized organ of the body that manufactures and secretes enzymes, hormones, or other chemicals. In animals, glands vary in size from small (for example, tear glands) to large (for example, the pancreas), but in plants they are always small, and may consist of a single cell. Some glands discharge their products internally, endocrine glands, and others externally, exocrine glands. Lymph nodes are sometimes wrongly called glands.

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glass

transparent or translucent substance that is physically neither a solid nor a liquid. Although glass is easily shattered, it is one of the strongest substances known. It is made by fusing certain types of sand (silica); this fusion occurs naturally in volcanic glass (see obsidian).

In the industrial production of common types of glass, the type of sand used, the particular chemicals added to it (for example, lead, potassium, barium), and refinements of technique determine the type of glass produced. Types of glass include: soda glass; flint glass, used in cut-crystal ware; optical glass; stained glass; heat-resistant glass; and glasses that exclude certain ranges of the light spectrum. Blown glass is either blown individually from molten glass (using a tube up to 1.5 m/4.5 ft long), as in the making of expensive crafted glass, or blown automatically into a mould – for example, in the manufacture of light bulbs and bottles; pressed glass is simply pressed into moulds, for jam jars, cheap vases, and light fittings; while sheet glass, for windows, is made by putting the molten glass through rollers to form a 'ribbon', or by floating molten glass on molten tin in the 'float glass' process; fibreglass is made from fine glass fibres. Metallic glass is produced by treating alloys so that they take on the properties of glass while retaining the malleability and conductivity characteristic of metals.

CMCC - Glass Works

Go to site

Canadian-based site covering all aspects of glass. Out of the ten sections available, the ones of most interest are 'What is glass?', 'Natural glass', 'Making glass', and 'The glass of science and medicine'. Each section contains a detailed explanation of the ways in which glass is used, or processed, and photographs of products.

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glass-reinforced plastic

GRP

a plastic material strengthened by glass fibres, sometimes erroneously called fibreglass. Glass-reinforced plastic is a favoured material for boat hulls and for the bodies and some structural components of high-performance cars and aircraft; it is also used in the manufacture of passenger cars.

Products are usually moulded, mats of glass fibre being sandwiched between layers of a polyester plastic, which sets hard when mixed with a curing agent.

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glass snake

or glass lizard

any of a worldwide group of legless lizards. Their tails are up to three times the head-body length and are easily broken off. (Genus *Ophisaurus*, family Anguidae.)

Glauber, Johann Rudolf (1604-1670)

German chemist who in about 1625 discovered the salt known variously as **Glauber's salt** and '*sal mirabile* ' (sodium sulphate). He made his living selling patent medicines and used the salt to treat almost any complaint.

Glauber's salt

crystalline sodium sulphate decahydrate $Na_2SO_4.10H_2O$, produced by the action of sulphuric acid on common salt. It melts at 31°C/87.8°F; the latent heat stored as it solidifies makes it a convenient thermal energy store. It is used in medicine as a laxative.

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glaucoma

condition in which pressure inside the eye (intraocular pressure) is raised abnormally as excess fluid accumulates. It occurs when the normal outflow of fluid within the chamber of the eye (aqueous humour) is interrupted. As pressure rises, the optic nerve suffers irreversible damage, leading to a reduction in the field of vision and, ultimately, loss of eyesight.

The most common type, **chronic glaucoma**, usually affects people over the age of 40, when the trabecular meshwork (the filtering tissue at the margins of the eye) gradually becomes blocked and drainage slows down. The condition cannot be cured, but, in many cases, it is controlled by drug therapy. Laser treatment to the trabecular meshwork often improves drainage for a time; surgery to create an artificial channel for fluid to leave the eye offers more long-term relief. A tiny window may be cut in the iris during the same operation.

Acute glaucoma is a medical emergency. A precipitous rise in pressure occurs when the trabecular meshwork suddenly becomes occluded (blocked). This is treated surgically to remove the cause of the obstruction. Acute glaucoma is extremely painful. Treatment is required urgently since damage to the optic nerve begins within hours of onset.

During routine eye examinations, the 'air puff' test serves to measure the the intraocular pressure and detect glaucoma at an early stage.

Glaucoma Research Foundation

Go to site

Source of well-presented information on glaucoma. There is an informative list of frequently asked questions about the disease and the latest research findings. There are also links to a number of optometric and opthalmological organizations and to a search engine.

Glenn, John Herschel, Jr (1921-)

US astronaut and politician. On 20 February 1962, he became the first US astronaut to orbit the Earth, doing so three times in the spacecraft *Friendship 7*. The flight lasted 4 hours 55 minutes. On 29 October 1998, Glenn became the oldest person in space when, at the age of 77, he embarked on a nine-day mission aboard the shuttle *Discovery*.

Glenn was elected to the US Senate as a Democrat from Ohio in 1974; and re-elected in 1980 and 1986.

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global positioning system

GPS

US satellite-based navigation system, a network of more than 24 satellites in six orbits, each circling the Earth twice every 24 hours. Each satellite sends out a continuous time signal, plus an identifying signal. To fix position, a user needs to be within range of four satellites, one to provide a reference signal and three to provide directional bearings. The user's receiver can then calculate the position from the difference in time between receiving the signals from each satellite.

The position of the receiver can be calculated to within 0.5 m/1.6 ft, although only the US military can tap the full potential of the system. Other users can obtain a position to within 15 m/50 ft. This is accurate enough to be of use to boats, walkers, and motorists, and suitable receivers are on the market.

Frequently Asked Questions About GPS

Go to site

Good description of the navigational aid known as the global positioning system. There is information on the history of the navigation system, how it works, where to learn more about it, and the acronyms used to describe it.

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global warming

increase in average global temperature of approximately 0.5°C/0.9°F over the past century. Much of this is thought to be related to human activity. Global temperature has been highly variable in Earth history and many fluctuations in global temperature have occurred in historical times, but this most recent episode of warming coincides with the spread of industrialization, prompting the suggestion that it is the result of an accelerated greenhouse effect caused by atmospheric pollutants, especially carbon dioxide gas. The melting and collapse of the Larsen Ice Shelf, Antarctica, since 1995, is a consequence of global warming. Melting of ice is expected to raise the sea level in the coming decades.

Natural, perhaps chaotic, climatic variations have not been ruled out as the cause of the current global rise in temperature, and scientists are still assessing the influence of anthropogenic (human-made) pollutants. In 1988, the World Meteorological Organization (WMO) and the United Nations (UN) set up the Intergovernmental Panel on Climate Change (IPCC), a body of more than two thousand scientists, to investigate the causes of and issue predictions regarding climate change. In June 1996, the IPCC confirmed that global warming was taking place and that human activities were probably to blame.

Assessing the impact of humankind on the global climate is complicated by the natural variability on both geological and human time scales. The present episode of global warming has thus far still left England approximately 1°C/1.8°F cooler than during the peak of the so-called Medieval Warm Period from 1000 to 1400. The latter was part of a purely natural climatic fluctuation on a global scale. The interval between this period and the recent rise in temperatures was unusually cold throughout the world, relative to historical temperatures. Scientists predict that a doubling of carbon dioxide concentrations, expected before the end of the 21st century, will increase the average global temperature by 1.4-5.8°C/2.5-10.4°F.

In addition to a rise in average global temperature, global warming has caused seasonal variations to be more pronounced in recent decades. Examples are the most severe winter on record in the eastern USA 1976-77, and the record heat waves in the Netherlands and Denmark the following year. Mountain glaciers have shrunk, late summer Arctic sea-ice has thinned by 40%, and sea levels have risen by 10-20 cm/4-8 in. Scientists have predicted a greater number of extreme weather events, and sea levels are expected to rise by 9-88 cm/4-35 in by 2100. 1998 was the warmest year globally of the last millennium, according to US researchers who used tree rings and ice cores to determine temperatures over the past 1,000 years.

Global Warming and its Effects on Flora and Fauna

introduction

Like humans, most organisms prefer a stable environment. But whereas we can turn up the air conditioning or throw on a sweater, all that most other species can do is move around. This means that global warming will alter the distribution of species, and alter ecosystems. That much is clear. Exactly what the changes might be, though, is much harder to say. Part of the uncertainty stems from the range of predictions about the climate in the future. We know that global temperatures rose in the 20th century. Continuous records indicate that the average global temperature has risen by 0.5°C/0.9°F over the last hundred years. Most scientists accept that the increase in greenhouse gases, especially carbon dioxide, produced by human activity is part of the reason. These gases trap solar heat, which is absorbed and then re-emitted by the Earth's surface.

climate models and forecasts

Global climate models predict that, as the greenhouse effect grows stronger, temperatures will continue to rise. The forecasts are imprecise as they rely on estimates of many climatic effects that are poorly understood. A mid-range estimate is that the average world temperature will have risen by another 1.0°C/1.8°F by 2050. Some computerized world pictures put the rise as high as 3.0°C/5.4°F. That may not sound a lot, but it is blindingly fast by the standards of past changes in climate. So it will stretch the adaptability of long-lived organisms to the limit. Trees are likely to be especially vulnerable. Their growth may be increased if there is more carbon dioxide in the air, but many are also highly sensitive to temperature. The second problem of prediction is that climate models are coarse. They cannot say anything very useful about relatively small regions. No one knows, for example, whether northern Europe will go on getting warmer - with olive groves in some future southern England - or colder. The cold would also be sudden, brought about by catastrophic failure of the Atlantic ocean current which now keeps the temperature in these regions so comfortable. There could even be changes back and forth every few years, climatic chaos which would test the hardiest of species.

observed effects

So much for models. There are other, more reliable things to say about climatic effects on flora and fauna. Changes that have already been seen are both an indication of what we might see in future if temperatures go on shifting, and a sign of what to watch for. Small changes in temperature and timing can have big effects. In Britain the summers are getting longer - spring starts six days earlier than it did 30 years ago, and autumn comes a few days later. As well as causing obvious signs, such as leaves unfolding and buds and flowers appearing, this is already affecting many birds. Migrants such as swallows are arriving earlier, and native birds are laying their eggs earlier, feeding their hatchlings on the insects that the warmth and early plant growth encourages. The British Trust for Ornithology reports that 20 out of 65 species of birds are now laying their eggs an average of nine days earlier than in 1971. For most, this leads to increased numbers although it may also make them more vulnerable to stormy weather during the breeding season. Britain is likely to see new colonists as well - with birdwatchers hoping to see species such as the black kite, penduline tit, and fan-tailed warbler establishing themselves in new territory. But they may lose many more coastal species. Rising sea levels associated with global warming will inundate mudflats and salt marshes, home to many species that cannot live elsewhere. Mudflats, for instance, support worms and algae which provide food for water birds. More than half of Europe's wading birds now spend their winters around the British coastline, and 60% of redshank nest in salt marshes. If low-lying areas like East Anglia are threatened by the sea, many nature reserves will be lost. People will be forced to protect areas further inland with new sea defences, and the birds will have nowhere else to go. Other species are still more sensitive to climate. Butterflies, for instance, are only active when it is relatively warm, so they may benefit from a hotter, drier climate. But they may also need very specific vegetation, which is less likely to expand. The large blue butterfly, for example, lays its eggs on common thyme, which occurs in grazed short-turf sites. These sites are not particularly numerous, and are vulnerable to the droughts that could also accompany climate warming.

a complex picture

The overall picture will be extremely complex, with the response of each species depending on a whole set of factors - temperature, amount and timing of rainfall, abundance of food, and numbers of pests and predators. In other parts of the globe, forests will alter in composition, or shrink, and deserts will expand. A temperate country like the UK will probably see smaller changes than elsewhere (catastrophic freezing aside). But changes there will be. In the current state of knowledge, though, specifying the winners and losers is largely informed guesswork. Those guesses will be improved by intensive local observation of species abundance and reproductive behaviour over the coming years.

Global Warming: key dates

1967	US scientists Syukuvo Manabe and R T Wetherald warn that the increase in carbon dioxide in the atmosphere, produced by human activities, is causing a 'greenhouse effect', which will raise atmospheric temperatures and cause a rise in sea levels.
1980	A ten-year World Climate Research Programme is launched to study and predict climate changes and human influence on climate change.
1989	The warmest year on record worldwide; environmentalists suggest this is due to the 'greenhouse effect'.
3 June 1992	The United Nations Conference on Environment and Development is held in Rio de Janeiro, Brazil, attended by delegates from 178 countries, most of whom sign binding conventions to combat global warming.
1993	An ice core drilled in Greenland provides evidence of climate change over 250,000 years, suggesting that sudden fluctuations have been common and that the recent stable climate is unusual.
1995	The Prince Gustav Ice Shelf and the northern Larsen Ice Shelf in Antarctica begin to disintegrate as a result of global warming.
11 December 1997	Delegates at the Kyoto, Japan, conference on global warming agree to cut emissions of greenhouse gases by 5.2% from 1990 levels during the years 2008 and 2012.
17 April 1998	An iceberg 40 km/25 mi long and 4.8 km/3 mi wide breaks off from the Larson B Ice Shelf in Antarctica
November 1998	A summit held in Buenos Aires, attended by delegates from over 160 countries, discusses implementing the 1997 Kyoto Protocol to reduce global warming. Participants agree to devise strategies by 2000 for reducing emissions of greenhouse gases.
17 December 1998	The United Nations World Meteorological Organization (WMO) reports that 1998 is the warmest year on record, with a global average temperature of 14.4°C/58°F.
November 1999	Studies show that the Arctic icecap has shrunk by around 40% over the past 50 years, probably due to global warming. Reports show that polar bears in the region are in danger of starving to death because of their shortened hunting season.
16 December 1999	The WMO reports that the 1990s was the warmest decade and the 1900s the warmest century over the last 1,000 years.
16-27 July 2001	Representatives from more than 180 countries meet in Bonn, Germany, for a UN conference on global warming and US president George W Bush announces US withdrawal from the 1998 Kyoto Protocol.
December 2001	Scientists surveying the North Atlantic report increasing sea temperatures and an associated dramatic decline in the number of zooplankton, the staple diet of many marine creatures.
February 2002	Rising sea levels and cyclones force the government of Tuvalu, an island nation in the Pacific, to commence phased evacuation of its population under an agreement with New Zealand.
March 2002	In Antarctica the Larsen B iceshelf collapses with dramatic speed. It shatters into an estimated 500 billion tonnes of icebergs, which is more than all the icebergs of the previous 50 years combined.
September 2003	A UN study into climate change reports that the earth is warmer now than it has been at any time in the last 2,000 years.

February 2004	A study by NASA and Chile's Centro de Estudios Cientificos indicates that the Patagonian Ice-fields of Chile and Argentina, the largest non-Antarctic ice masses in the Southern Hemisphere, are melting faster than any other glaciers on Earth.
2005	The Lamont-Doherty Earth Observatory reports a measurable decline between 1950 and 1990 in the amount of sun reaching the Earth's surface due to global dimming, the reduction in sunlight reaching the surface of the planet, possibly due to aerosols. The conclusion may be that the effect of global dimming may have masked the extent of global warming.

What Hath Man Wrought

Go to site

Extensive account of the causes and consequences of global warming. It offers discussion of issues as diverse as greenhouse gases, ocean currents, flooded coasts, the fluctuations of the Earth's temperature as far back as 15,000 years ago, and the role of human economic activities in the temperature increase. The site has also incorporated links to a series of space institutes, climate centres, and environmental agencies which conduct related research.

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globefish

another name for the puffer fish.

Globe Theatre

17th-century London theatre, octagonal and open to the sky, near Bankside, Southwark, where many of Shakespeare's plays were performed by Richard Burbage and his company. It was burned down in 1613, rebuilt in 1614, and pulled down in 1644. The reconstructed Globe Theatre was opened to the public in August 1996, largely due to the campaigning efforts of actor Sam Wanamaker. Mark Rylance was appointed the first artistic director of the Globe in 1995.

The original theatre was built in 1599 by Cuthbert Burbage. It was burned down after a cannon, fired during a performance of *Henry VIII*, set light to the thatch. The site was rediscovered in October 1989 near the remains of the contemporaneous Rose Theatre. The new Globe Theatre opened to the public with a performance of Shakespeare's *The Two Gentlemen of Verona*, the first stage production to be held on the site of the Elizabethan theatre in more than 380 years.

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globular cluster

spherical or near-spherical star cluster containing from approximately 10,000 stars to many millions. About 200 known globular clusters are distributed in a spherical halo around our Galaxy. They consist of old stars, formed early in the Galaxy's history. Globular clusters are also found around other galaxies.

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glomerulus

in the kidney, the cluster of blood capillaries at the threshold of the renal tubule, or nephron, responsible for filtering out the fluid that passes down the tubules and ultimately becomes urine. In the human kidney there are approximately one million tubules, each possessing its own glomerulus.

The structure of the glomerulus allows a wide range of substances including amino acids and sugar, as well as a large volume of water, to pass out of the blood. As the fluid moves through the tubules, most of the water and all of the sugars are reabsorbed, so that only waste remains, dissolved in a relatively small amount of water. This fluid collects in the bladder as urine.

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glottis

in medicine, narrow opening at the upper end of the larynx that contains the vocal cords.

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glow-worm

wingless female of any of a large number of luminous beetles (fireflies). The luminous organs, situated under the abdomen, at the end of the body, give off a greenish glow at night and attract winged males for mating. There are about 2,000 species of glow-worms, distributed worldwide. (Family Lampyridae.)

glow-worm

The simplest way to tell the sex of a glow-worm is by measuring the rate at which its emits light pulses. A male flashes once every 5.8 seconds, a female every 2.1 seconds.

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glucagon

in biology, a hormone secreted by the pancreas, which increases the concentration of glucose in the blood by promoting the breakdown of glycogen in the liver. Secretion occurs in response to a lowering of blood glucose concentrations.

Glucagon injections can be issued to people living with patients with diabetes who are being treated with insulin. Hypoglycaemia may develop in such patients in the event of inadequate control of diabetes. An injection of glucagon can be used to reverse hypoglycaemia before serious symptoms, such as unconsciousness, develop.

glucose

or dextrose or grape sugar; $C_6H_{12}O_6$

simple sugar present in the blood and manufactured by green plants during photosynthesis. It belongs to the group of chemicals known as carbohydrates. The respiration reactions inside cells involves the oxidation of glucose to produce ATP, the 'energy molecule' used to drive many of the body's biochemical reactions.

As well as being used in respiration to release useful energy glucose may also be transported to specific parts of the body for other uses. The liver and muscles can turn it into glycogen, which acts as an energy store. It can also be turned into fat and stored in fatty tissue. In humans and other vertebrates optimum blood glucose levels are maintained by the hormone insulin. An inability to control glucose levels may be caused by the disease diabetes.

Green plants make glucose during photosynthesis. They can turn it into starch, which acts as an energy store and this starch may form an important part of the human diet.

Glucose is prepared in syrup form by the hydrolysis of cane sugar or starch, and may be purified to a white crystalline powder. Glucose is a monosaccharide sugar (made up of a single sugar unit), unlike the more familiar sucrose (cane or beet sugar), which is a disaccharide (made up of two sugar units: glucose and fructose).

glucose tolerance test

in medicine, a method of assessing the efficiency of the body to metabolize glucose, which is used in the diagnosis of diabetes. It involves the starvation of the subject for several hours before giving a standard amount of glucose by mouth. Concentrations of glucose are measured in the blood and the urine over several hours.

glue

type of adhesive.

glue-sniffing

or solvent misuse

inhalation of the fumes from organic solvents of the type found in paints, lighter fuel, and glue, for their hallucinatory effects. As well as being addictive, solvents are dangerous for their effects on the user's liver, heart, and lungs. It is believed that solvents produce hallucinations by disrupting the cell membrane of brain cells, thus altering the way the cells conduct electrical impulses.

gluon

in physics, a gauge boson that carries the strong nuclear force, responsible for binding quarks together to form the strongly interacting subatomic particles known as hadrons. There are eight kinds of gluon.

Gluons cannot exist in isolation; they are believed to exist in balls ('glueballs') that behave as single particles. The existence of glueballs has not yet been definitely confirmed.

gluten

protein found in cereal grains, especially wheat and rye. Gluten enables dough to expand during rising. Sensitivity to gliadin, a type of gluten, gives rise to coeliac disease.

glyceride

ester formed between one or more acids and glycerol (propan-1,2,3-triol). A glyceride is termed a mono-, di-, or triglyceride, depending on the number of hydroxyl groups from the glycerol that have reacted with the acids.

Glycerides, chiefly triglycerides, occur naturally as esters of fatty acids in plant oils and animal fats.

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glycerine

another name for glycerol.

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glycerol

or glycerine or propan-1,2,3-triol; $HOCH_2CH(OH)CH_2OH$

thick, colourless, odourless, sweetish liquid. It is obtained from vegetable and animal oils and fats (by treatment with acid, alkali, superheated steam, or an enzyme), or by fermentation of glucose, and is used in the manufacture of high explosives, in antifreeze solutions, to maintain moist conditions in fruits and tobacco, and in cosmetics.

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glycine

or aminoethanoic acid; $CH_2(NH_2)COOH$

simplest amino acid, and one of the main components of proteins. When purified, it is a sweet, colourless crystalline compound.

Glycine was found in space in 1994 in the star-forming region Sagittarius B2. The discovery is important because of its bearing on the origins of life on Earth. Glycine is the only biogenic amino acid that is not chiral.

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glycogen

polymer (a polysaccharide) of the sugar glucose made and retained in the liver as a carbohydrate store, for which reason it is sometimes called animal starch. It is a source of energy when needed by muscles, where it is converted back into glucose by the hormone insulin and metabolized.

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glycol

or ethylene glycol or ethane-1,2-diol; $HOCH_2CH_2OH$

thick, colourless, odourless, sweetish liquid. It is used in antifreeze solutions, in the preparation of ethers and esters (used for explosives), as a solvent, and as a substitute for glycerol.

GMT

abbreviation for **Greenwich Mean Time**.

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gnat

any of various small flies of the order Diptera, that sometimes suck blood. In Britain, mosquitoes are often called gnats.

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gneiss

coarse-grained metamorphic rock, formed under conditions of high temperature and pressure, and often occurring in association with schists and granites. It has a foliated, or layered, structure consisting of thin bands of micas and/or amphiboles dark in colour alternating with bands of granular quartz and feldspar that are light in colour. Gneisses are formed during regional metamorphism; **paragneisses** are derived from metamorphism of sedimentary rocks and **orthogneisses** from metamorphism of granite or similar igneous rocks.

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gnu

another name for wildebeest.

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goat

ruminant mammal (it chews the cud), closely related to sheep. Both male and female goats have horns and beards. They are sure-footed animals, and feed on shoots and leaves more than on grass. (Genus *Capra*, family Bovidae.)

Domestic varieties are descended from the **scimitar-horned wild goat** (*C. aegagrus*) and have been kept for over 9,000 years in southern Europe and Asia. They are kept for milk or for mohair (angora and cashmere goats). Wild species include the **ibex** (*C. ibex*) of the Alps and **markhor** (*C. falconeri*) of the Himalayas, 1 m/3 ft high and with long twisted horns. The **Rocky Mountain goat** (*Oreamnos americanus*) is a 'goat antelope' and is not closely related to true goats.

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goblet cell

in biology, cup-shaped cell present in the epithelium of the respiratory and gastrointestinal tracts. Goblet cells secrete mucin, the main constituent of mucous, which lubricates the mucous membranes of these tracts.

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goby

small marine bony fish. Nearly all gobies are found in the shallow coastal waters of the temperate and tropical oceans. Gobies can change sex in order to mate if a member of the opposite sex is not available. Females more readily change to males than males to females.

The first dorsal fin consists of a few flexible spines and the second dorsal fin is opposed to the anal fin. The caudal fin is generally rounded, with the pelvic fins united to form a cup-shaped sucker.

classification

Gobies are in the family Gobiidae, order Perciformes, class Osteichthyes.

Goddard, Robert Hutchings (1882-1945)

US rocket pioneer. He launched the first liquid-fuelled rocket at Auburn, Massachusetts, in 1926. By 1932 his rockets had gyroscopic control and could carry cameras to record instrument readings. Two years later a Goddard rocket achieved the world altitude record with an ascent of 3 km/1.9 mi.

Goddard developed the principle of combining liquid fuels in a rocket motor, the technique used subsequently in every practical space vehicle. He was the first to prove by actual test that a rocket will work in a vacuum and he was the first to fire a rocket faster than the speed of sound.

Goddard Space Flight Center

NASA field centre at Greenbelt, Maryland, responsible for the development and operation of uncrewed scientific satellites, including the Hubble Space Telescope and the Geostationary Operational Environmental Satellite (GOES). Goddard is also the home of the National Space Science Data Center, a repository of data collected by satellites. Established in 1959 as NASA's first space flight centre, the Goddard complex now consists of 50 buildings.

Goddard Space Flight Center

Go to site

Packed with news and information on space missions and science projects at Goddard, as well as a biography of US rocket pioneer Robert Goddard. Press releases dating back to 1995 and fact sheets are available in the Flight Center press room. The site features a good collection of recently acquired images of Earth from space, with captions and links.

Gödel, Kurt (1906-1978)

Austrian-born US mathematician and philosopher. He proved that a mathematical system always contains statements that can be neither proved nor disproved within the system; in other words, as a science, mathematics can never be totally consistent and totally complete. He worked on relativity, constructing a mathematical model of the universe that made travel back through time theoretically possible.

Gödel, Kurt

Go to site

Biography and photograph of the 20th-century mathematician famous for his work on set theory, which is also described on this St Andrews University-run Web site. Also provided are literature references for further reading on the life and works of Gödel.

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goiter

enlargement of the thyroid gland seen as a swelling on the neck. It is most pronounced in simple goiter, which is caused by iodine deficiency. Much more common is toxic goiter or thyrotoxicosis, caused by overactivity of the thyroid gland.

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gold

chemical symbol Au

shiny, yellow, ductile and very malleable, metallic element, atomic number 79, atomic weight 197. Its symbol comes from the Latin *aurum* meaning 'gold'. It occurs in nature frequently as a free metal (see native metal) and is highly resistant to acids, tarnishing, and corrosion. Pure gold is the most malleable of all metals and is used as gold leaf or powder, where small amounts cover vast surfaces, such as gilded domes and statues.

The elemental form is so soft that it is alloyed for strength with a number of other metals, such as silver, copper, and platinum. Its purity is then measured in karats on a scale of 24 (24K = pure gold). It is used mainly for decorative purposes (jewelry, gilding) but also for coinage, dentistry, and conductivity in electronic devices.

Although gold is 'noble' in that it shows very little chemical reactivity, it can be dissolved in aqua regia (a mixture of nitric and hydrochloric acid). From such solutions, certain gold compounds, such as the chloride $AuCl_3$, can be prepared.

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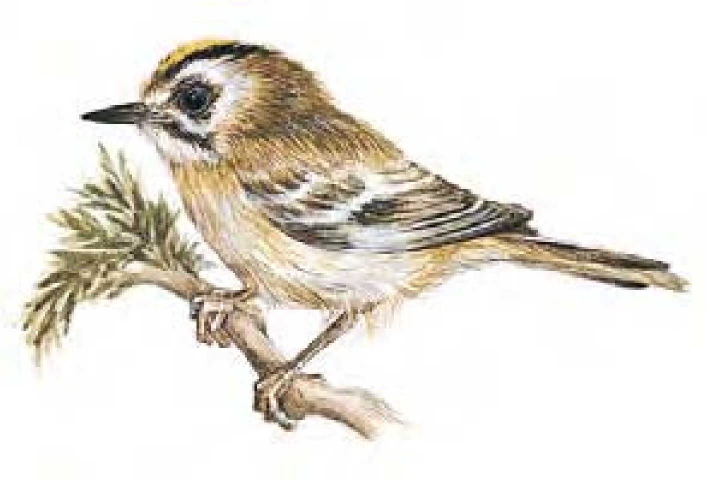
goldcrest

smallest European bird, about 9 cm/3.5 in long and weighing 5 g/0.011 lb; a warbler. It is olive green, with a bright orange-yellow streak running from the beak to the back of the head and a black border above the eye. The tail is brown, marked with black and white, and the cheeks, throat, and breast are a greyish white. (Species *Regulus regulus*, family Muscicapidae, order Passeriformes.)

The goldcrest builds its nest in conifers. It is found all over Europe, particularly frequenting fir woods. In winter it can be found feeding with tit flocks, moving through deciduous woodlands.

goldcrest



(Image © Research Machines plc)

The smallest European bird, the goldcrest, is widespread in Europe and Asia and builds its nest high up in trees.

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goldenrod

one of several tall and leafy North American perennial plants, belonging to the daisy family. Flower heads are mostly composed of many small yellow flowers, or florets. (Genus *Solidago*, family Compositae.)

Goldenrod

Go to site

Analysis of this North American plant. There is a detailed description of the plant and its habitat, as well as notes on its constituents. There is also an informative description of the possible medicinal uses of the plant and an introduction to species.

golden section

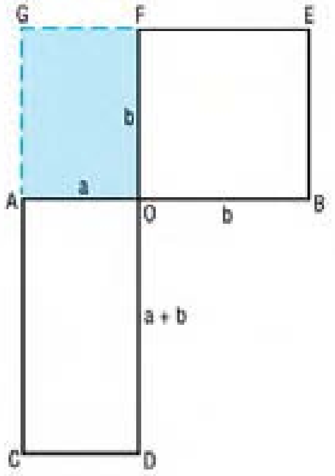
or golden mean

mathematical relationship between three points, A, B, C, in a straight line, in which the ratio AC:BC equals the ratio BC:AB (about 8:13 or 1:1.618). The area of a rectangle produced by the whole line and one of the segments is equal to the square drawn on the other segment. A **golden rectangle** has sides in the golden mean. Considered a visually satisfying ratio, it was first constructed by the Greek mathematician Euclid and used in art and architecture, where it was given almost mystical significance by some Renaissance theorists.

The golden section was used extensively by certain painters, above all Piero della Francesca, who had an architectural background. In Vincent van Gogh's picture *Mother and Child* the Madonna's face fits perfectly into a golden rectangle.

In mathematics, the ratio of consecutive Fibonacci numbers tends to the golden ratio.

golden section



(Image © Research Machines plc)

The golden section is the ratio a:b, equal to 8:13. A golden rectangle is one, like that shaded in the picture, that has its length and breadth in this ratio. These rectangles are said to be pleasant to look at and have been used instinctively by artists in their pictures.

Fibonacci Numbers and the Golden Section

Go to site

Fascinating facts and puzzles involving the Fibonacci series and the golden section. This site also includes biographical information about Fibonacci and some practical applications of his mathematical theories.

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goldfinch

songbird found in Eurasia, North Africa, and North America. (Species *Carduelis carduelis*, family Fringillidae, order Passeriformes.)

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goldfish

fish belonging to the carp family, found in East Asia. It is greenish-brown in its natural state, but has been bred by the Chinese for centuries, taking on highly coloured and sometimes freakishly shaped forms. Goldfish can occur in a greater range of colours than any other animal tested. (Species *Carassius auratus*, family Cyprinidae.)

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gold rush

large influx of gold prospectors to an area where gold deposits have recently been discovered. The result is a dramatic increase in population. Cities such as Johannesburg, Melbourne, and San Francisco either originated or were considerably enlarged by gold rushes. Melbourne's population trebled from 77,000 to some 200,000 between 1851 and 1853, while San Francisco boomed from a small coastal village of a few hundred people to the largest city in the western USA during the California gold rush of 1848–56.

Gold rushes

Year	Major event
1848	Sutter's Mill, California (the 'Fortyniners')

1851	New South Wales and Victoria, Australia
1880s	Rhodesia
1886	Fortymile Creek, Yukon, Canada; Johannesburg, Transvaal; Kimberley, West Australia
1890s	Klondike River, Yukon, Canada

California as I Saw It: First-Person Narratives of California's Early Years, 1849-1900

Go to site

Part of the American Memory presentation of the US Library of Congress, this site features the eyewitness accounts of pioneers living in California during the years between the Gold Rush and the turn of the 20th century. The collection includes text and illustrations, covering such topics as the encounters between pioneers and those already established in California; the effects of mining, ranching, agriculture, and urban development on the land; the arrival of statehood; and the myth and mystique of California. This site includes an historical introduction for context and a regional map. The collection can be browsed by keyword, subject, author, or title.

Gold Rush

Go to site

Companion to a US Public Broadcasting Service (PBS) television programme, this site embraces the adventure story that was the California Gold Rush. Here you will find detailed information on the first discovery of gold and the wild fever that followed. Some of the many subjects explored here include women of the Gold Rush, success stories, the effects of different cultures coming together, the rise of San Francisco, the terrible environmental destruction brought on by mechanized mining, and the creation of the enduring California myth that has come to define the American Dream. There are also classroom resources and a section of fun facts.

Golgi, Camillo (1843-1926)

Italian cell biologist who was awarded a Nobel Prize for Physiology or Medicine in 1906 with Santiago Ramón y Cajal for their discovery of the fine structure of the nervous system.

Golgi's use of silver salts in staining cells proved so effective in showing up the components and fine processes of nerve cells that even the synapses - tiny gaps between the cells - were visible. The **Golgi apparatus**, a series of flattened membranous cavities found in the cytoplasm of cells, was first described by him in 1898.

Golgi apparatus

or Golgi body

stack of flattened membranous sacs found in the cells of eukaryotes. Many molecules travel through the Golgi apparatus on their way to other organelles or to the endoplasmic reticulum. Some are modified or assembled inside the sacs. The Golgi apparatus is named after the Italian physician Camillo Golgi.

Goliath beetle

large beetle found only in tropical countries. The biggest Goliath beetle *Goliathus giganteus*, found in equatorial Africa, may be more than 150 mm/6 in long and is one of the largest insects.

They lay their eggs in the rotting wood of trees, and most adults feed on the tender floral parts or suck the sap exuded from trees. Its 'brushed velvet' wingcases are maroon and the pronotum (shield) is black with roughly longitudinal white stripes.

classification

Goliath beetles belong to the subfamily Cetoniinae of the family Scarabaeidae in order Coleoptera, class Insecta, phylum Arthropoda.

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gonad

the part of an animal's body that produces the sperm or egg cells (ova) required for sexual reproduction. The sperm-producing gonad is called a testis, and the egg-producing gonad is called an ovary.

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gonadotrophin

any hormone that supports and stimulates the function of the gonads (sex glands); some gonadotrophins are used as fertility drugs.

Gondwanaland

or Gondwana

southern landmass formed 200 million years ago by the splitting of the single world continent Pangaea. (The northern landmass was Laurasia.) It later fragmented into the continents of South America, Africa, Australia, and Antarctica, which then drifted slowly to their present positions. The baobab tree found in both Africa and Australia is a relic of this ancient land mass.

A database of the entire geology of Gondwanaland has been constructed by geologists in South Africa. The database, known as Gondwana Geoscientific Indexing Database (GO-GEOID), displays information as a map of Gondwana 155 million years ago, before the continents drifted apart.

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gonorrhea

common sexually transmitted disease arising from infection with the bacterium *Neisseria gonorrhoeae*, which causes inflammation of the genito-urinary tract. After an incubation period of two to ten days, infected men experience pain while urinating and a discharge from the penis; infected women often have no external symptoms.

Untreated gonorrhea carries the threat of sterility to both sexes; there is also the risk of blindness in a baby born to an infected mother. The condition is treated with antibiotics, though ever-increasing doses are becoming necessary to combat resistant strains.

Good King Henry

perennial plant belonging to the goosefoot family, growing to 50 cm/1.6 ft, with triangular leaves which are mealy when young. Spikes of tiny greenish-yellow flowers appear above the leaves in midsummer. (*Chenopodium bonus-henricus*, family Chenopodiaceae.)

Good King Henry

Go to site

Informative resource relating to the perennial plant Good King Henry. It contains a detailed description of the plant and its habitat. There are also notes on the cultivation of the plant, as well as details of other plants belonging to the goosefoot family, including white goosefoot and red goosefoot.

Goodyear, Charles (1800-1860)

US inventor who developed rubber coating in 1837 and vulcanized rubber in 1839, a method of curing raw rubber to make it strong and elastic.

Google

Internet search engine that ranks Web pages according to the number of links they have from other pages. It also uses sophisticated text-matching techniques to determine the importance and relevance of a site to a search.

As well as searching over 4 billion Web pages for text or images, Google can also search for stories posted to news sites as well as postings to Usenet newsgroups. Google was created in 1998 by Larry Page and Sergei Brin, doctoral students at Stanford University, California. The name is a play on the word 'googol', referring to the number represented by 1 followed by 100 zeroes.

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goose

any of several large aquatic birds belonging to the same family as ducks and swans. There are about 12 species, found in North America, Greenland, Europe, North Africa, and Asia north of the Himalayas. Both sexes are similar in appearance: they have short, webbed feet, placed nearer the front of the body than in other members of the family, and a slightly hooked beak. Geese feed entirely on grass and plants, build nests of grass and twigs on the ground, and lay 5-9 eggs, white or cream-coloured, according to the species. (Genera mainly *Anser* and *Branta*, family Anatidae, order Anseriformes.)

The **barnacle goose** (*B. leucopsis*) is about 60 cm/2 ft long and weighs about 2 kg/4.5 lb. It is black and white, marbled with blue and grey, and the beak is black. The **bean goose** (*A. fabalis*) is a grey species of European wild goose with an orange or yellow and black beak. It breeds in northern Europe and Siberia. The **Brent goose** (*B. bernicla*) is a small goose, black or brown, white, and grey in colour. The world population of Brent geese was 25,000 in 1996. The **greylag goose** (*A. anser*) is the ancestor of domesticated geese.

Other species include the **Canada goose** (*B. canadensis*) (common to North America and introduced into Europe in the 18th century), the **pink-footed goose** (*A. brachyrhynchus*), the **white-fronted goose** (*A. albifrons*), and the **ne-ne** or **Hawaiian goose** (*B. sandvicensis*).

gooseberry

several prickly shrubs of the genus *Ribes* in the saxifrage family, native to Eurasia and North America, and closely related to currants in the same genus. The fleshy, red, blackish or green fruits are edible. The pasture gooseberry *R. cyanosbati* is native to North America. The European gooseberry *R. grossalaria* is cultivated in gardens.

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goosefoot

any of a group of plants belonging to the goosefoot family, closely related to spinach and beets. The seeds of white goosefoot (*C. album*) were used as food in Europe from Neolithic times, and also from early times in the Americas. White goosefoot grows to 1 m/3 ft tall and has lance- or diamond-shaped leaves and packed heads of small inconspicuous flowers. The green part is eaten as a spinach substitute. (Genus *Chenopodium*, family Chenopodiaceae.)

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gopher

any of a group of burrowing rodents. Gophers are a kind of ground squirrel represented by some 20 species distributed across western North America, Europe, and Asia. Length ranges from 15 cm/6 in to 90 cm/16 in, excluding the furry tail; colouring ranges from plain yellowish to striped and spotted species. (Genus *Citellus*, family Sciuridae.)

The name **pocket gopher** is applied to the eight genera of the North American family Geomyidae.

gopher

Gophers distinguish between different alarm callers and decide on whether they should react or not. If the caller is in a territory that is not too close they may not react, presumably deciding that the danger is not near enough. As with people, some gophers are jumpier than others and give alarm calls more frequently; their calls may not always be responded to.

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gopher tortoise

land tortoise occurring in the southern USA. It has a domed shell and scaly legs. Its forelegs are flattened for digging the burrow where it lives. Gopher tortoises reach lengths of up to 37 cm/14.5 in.

classification

The gopher tortoise *Gopherus polyphemus* is in family Cheloniidae, order Testudinae, class Reptilia.

Gordon setter

breed of dog. See setter.

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gorge

narrow steep-sided valley or canyon that may or may not have a river at the bottom. A gorge may be formed as a waterfall retreats upstream, eroding away the rock at the base of a river valley; or it may be caused by rejuvenation, when a river begins to cut downwards into its channel for some reason – for example, in response to a fall in sea level. Gorges are common in limestone country (see karst), where they may be formed by the collapse of the roofs of underground caverns.

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gorilla

largest of the apes, found in the dense forests of West Africa and mountains of central Africa. The male stands about 1.8 m/6 ft high and weighs about 200 kg/450 lb. Females are about half this size. The body is covered with blackish hair, silvered on the back in older males. Gorillas live in family groups; they are vegetarian, highly intelligent, and will attack only in self-defence. They are dwindling in numbers, being shot for food by some local people, or by poachers taking young for zoos, but protective measures are having some effect. (Species *Gorilla gorilla*.)

Gorillas construct stoutly built nests in trees for overnight use. The breast-beating movement, once thought to indicate rage, actually signifies only nervous excitement. There are three races – western lowland, eastern lowland, and mountain gorillas – and US scientists suggested in 1994 that there may be two separate species of gorilla. In 1998 the Worldwide Fund for Nature estimated that there were 111,000 western lowland gorillas remaining, 10,000 eastern lowland, and 620 mountain gorillas.

Gorilla

Go to site

Illustrated guide to the gorilla including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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gorse

or furze or whin

any of a group of plants native to Europe and Asia, consisting of thorny shrubs with spine-shaped leaves growing thickly along the stems and bright-yellow coconut-scented flowers. (Genus *Ulex*, family Leguminosae.)

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goshawk

or northern goshawk

woodland hawk similar in appearance to the peregrine falcon, but with shorter wings and legs. It is native to most of Europe, Asia, and North America, and is used in falconry. The male is much smaller than the female. It is ash grey on the upper part of the body and whitish underneath with brown horizontal stripes; it has a dark head and cheeks with a white stripe above the eye. The tail has dark bands across it. (Species *Accipiter gentilis*, order Falconiformes.)

Goshawks lay up to five eggs in nests in mature woodland. The incubation period is 35-42 days. Males weigh around 700-750 g, whereas the larger females can weigh up to 2 kg.

Goshawks feed on a wide variety of prey - a 1998 British study identified more than 3,000 prey items - ranging from small chaffinches to larger prey, such as rabbits, squirrels, rooks, jays, woodpigeons, and even buzzards.

goshawk

The male goshawk mates up to 600 times with his partner for every clutch of eggs. This ensures that the sperm of any rival are completely swamped.

Gould, Stephen Jay (1941-2002)

US palaeontologist and writer. In 1972 he proposed the theory of punctuated equilibrium, suggesting that the evolution of species did not occur at a steady rate but could suddenly accelerate, with rapid change occurring over a few hundred thousand years. His books include *Ever Since Darwin* (1977), *The Panda's Thumb* (1980), *The Flamingo's Smile* (1985), *Wonderful Life* (1990), and *The Structure of Evolutionary Theory* (2002).

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gourd

names applied to various members of the family Cucurbitaceae, including melons, squashes, and pumpkins. In a narrower sense, the name is applied to an inedible, ornamental variety of pumpkin *Cucurbita pepa*.

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gout

hereditary form of arthritis, marked by an excess of uric acid crystals in the tissues, causing pain and inflammation in one or more joints (usually of the feet or hands). Acute attacks are treated with anti-inflammatories.

The disease, ten times more common in men, poses a long-term threat to the blood vessels and the kidneys, so ongoing treatment may be needed to minimize the levels of uric acid in the bloodstream. It is aggravated by heavy drinking.

gout: dinosaurs

Two *Tyrannosaurus rex* skeletons show scars characteristic of gout, presumably due to excessive consumption of red meat. Gout has also been seen in birds and reptiles.

gout: pigs

Pigs never suffer from gout. In humans, this painful disease is caused by a build-up of uric acid. Pigs have an enzyme that breaks uric acid into soluble components. Humans do not have this enzyme, so they suffer from gout and pigs do not.

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governor

in engineering, any device that controls the speed of a machine or engine, usually by regulating the intake of fuel or steam.

Scottish inventor James Watt invented the steam-engine governor in 1788. It works by means of heavy balls, which rotate on the end of linkages and move in or out because of centrifugal force according to the speed of rotation. The movement of the balls closes or opens the steam valve to the engine. When the engine speed increases too much, the balls fly out, and cause the steam valve to close, so the engine slows down. The opposite happens when the engine speed drops too much.

GP

in medicine, abbreviation for **general practitioner**.

GPS

abbreviation for global positioning system.

Graaf, Regnier de (1641-1673)

Dutch physician and anatomist who discovered the ovarian follicles, which were later named **Graafian follicles**. He named the ovaries and gave exact descriptions of the testicles. He was also the first to isolate and collect the secretions of the pancreas and gall bladder.

Graafian follicle

fluid-filled capsule that surrounds and protects the developing egg cell inside the ovary during the menstrual cycle. After the egg cell has been released, the follicle remains and is known as a corpus luteum.

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graft

in medicine, a piece of tissue that has been removed from one person and implanted either in another person or elsewhere on the same individual, to remedy a defect in that tissue. Skin grafts, for example, are used to treat patients with substantial burns. The skin is taken from an area of the body that has not been affected by the burn. An organ graft is often referred to as a transplant.

Vein grafts can be used to replace parts of arteries in the heart and the lower limbs that have become blocked. Bone marrow grafting involves the transfusion of bone marrow from an unaffected individual to treat a patient with a haematological malignancy. Advances in chemotherapy have allowed the development of autologous bone marrow transplantation.

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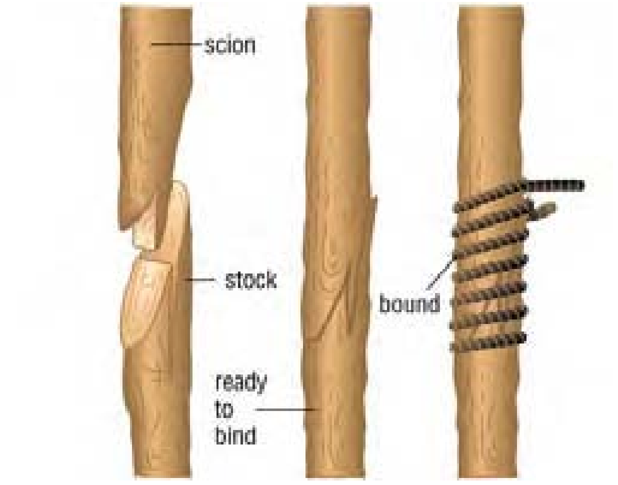
grafting

in medicine, the operation by which an organ or other living tissue is removed from one organism and transplanted into the same or a different organism.

In horticulture, it is a technique widely used for propagating plants, especially woody species. A bud or shoot on one plant, termed the **scion**, is inserted into another, the **stock**, so that they continue growing together, the tissues combining at the point of union. In this way some of the advantages of both plants are obtained.

Grafting is usually only successful between species that are closely related and is most commonly practised on roses and fruit trees. The grafting of nonwoody species is more difficult but it is sometimes used to propagate tomatoes and cacti. See also transplant.

grafting



(Image © Research Machines plc)

Grafting, a method of artificial propagation in plants, is commonly used in the propagation of roses and fruit trees. A relatively small part, the scion, of one plant is attached to another plant so that growth continues. The plant receiving the transplanted material is called the stock.

Graham, Thomas (1805-1869)

Scottish chemist who laid the foundations of physical chemistry (the branch of chemistry concerned with changes in energy during a chemical transformation) by his work on the diffusion of gases and liquids. **Graham's law** (1829) states that the diffusion rate of a gas is inversely proportional to the square root of its density.

His work on colloids (which have larger particles than true solutions) was equally fundamental; he discovered the principle of dialysis, that colloids can be separated from solutions containing smaller molecules by the differing rates at which they pass through a semipermeable membrane. The human kidney uses the same principle to extract nitrogenous waste.

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grain

the smallest unit of mass in the three English systems (avoirdupois, troy, and apothecaries' weights) used in the UK and USA, equal to 0.0648 g. It was reputedly the weight of a grain of wheat. One pound avoirdupois equals 7,000 grains; one pound troy or apothecaries' weight equals 5,760 grains.

---

gram

symbol g

metric unit of mass; one-thousandth of a kilogram.

---

grand unified theory

in physics, sought-for theory that would combine the theory of the strong nuclear force (called quantum chromodynamics) with the theory of the weak nuclear and electromagnetic forces (see forces, fundamental). The search for the grand unified theory is part of a larger programme seeking a unified field theory, or 'theory of everything', which would combine all the forces of nature (including gravity) within one framework.

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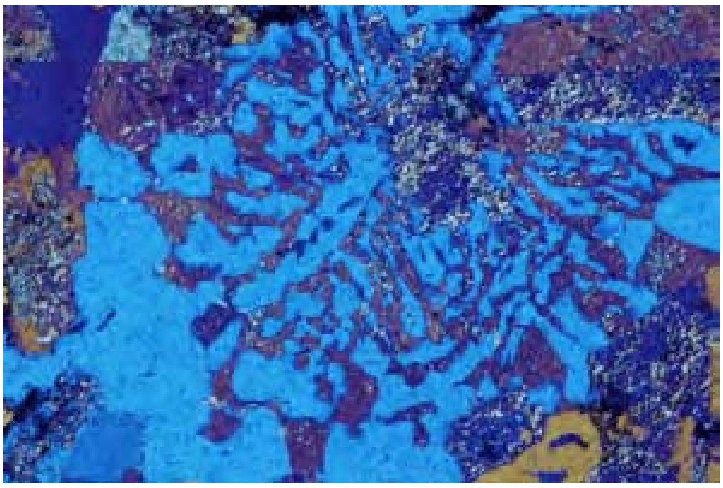
granite

coarse-grained intrusive igneous rock, typically consisting of the minerals quartz, feldspar, and biotite mica. It may be pink or grey, depending on the composition of the feldspar. Granites are chiefly used as building materials.

Granite is formed when magma (molten rock) is forced between other rocks in the Earth's crust. It cools and crystallizes deep underground. As it cools slowly large crystals are formed. Granites often form large intrusions in the core of mountain ranges, and they are usually surrounded by zones of metamorphic rock (rock that has been altered by heat or pressure). Granite areas have characteristic moorland scenery. In exposed areas the bedrock may be weathered along joints and cracks to produce a tor, consisting of rounded blocks that appear to have been stacked upon one another.

altered granite



(Image © Corel)

Altered granite through a polarized microscope. Granite is the most common type of intrusive rock.

granite

(Image © Research Machines plc)

Lichen-covered granite stones have been piled together to make a boundary wall in western Ireland. Fields in this part of the country are bare and rocky, and the stones must be lifted in order to cultivate the fertile soil.

granite

(Image © Research Machines plc)

Granite is an igneous rock, normally found deep in the earth's crust and made of crystals formed from the cooling of molten magma. It is sometimes exposed at the surface where the sedimentary rock, such as sandstone, has been eroded. Surface concentrations of Cornish granite can be found on the highlands of Land's End and Bodmin Moor.

---

grape

fruit of any grape vine, especially *V. vinifera*. (Genus *Vitis*, family Vitaceae.)

black grapes

(Image © Corel)

Black grapes on the vine at Chateauneuf-du-Papes, France. During the pressing process the yeast on the skin of the grape converts the sugar content of the grape juice into ethanol (ethyl alcohol).

---

grapefruit

round, yellow, juicy, sharp-tasting fruit of the evergreen grapefruit tree. The tree grows up to 10 m/more than 30 ft and has dark shiny leaves and large white flowers. The large fruits grow in grapelike clusters (hence the name). Grapefruits were first established in the West Indies and subsequently cultivated in Florida by the 1880s; they are now also grown in Israel and South Africa. Some varieties have pink flesh. (*Citrus paradisi*, family Rutaceae.)

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graph

pictorial representation of numerical data, such as statistical data, or a method of showing the mathematical relationship between two or more variables by drawing a diagram.

There are often two axes, or reference lines, at right angles intersecting at the origin - the zero point, from which values of the variables (for example, distance and time for a moving object) are assigned along the axes. (The axes may not always intersect at the origin; if the data run from, for example, 500 to 1000 on each axis, then the point of intersection could be at (500,500) and this should be clearly labelled.) Pairs of simultaneous values (for example, the distance moved after a particular time) are plotted as points in the area between the axes, and the points then joined by a smooth curve to produce a graph. The horizontal axis is usually referred to as the x-axis, and the vertical axis as the y-axis. The 'controllable/flowing' quantity is usually plotted on the x-axis; this is often time.

Cartesian coordinates

On a line graph values are plotted using coordinates, components used to define the position of a point by its perpendicular distance from a set of two or more axes, or reference lines. For a two-dimensional area defined by two axes at right angles, the coordinates of a point are given by its perpendicular distances from the y-axis and x-axis, written in the form (x,y). For example, a point P that lies three units from the y-axis and four units from the x-axis has Cartesian coordinates (3,4).

straight-line graph

This type of graph is produced by plotting the variables of a linear equation with the general form

$y = mx + c$

where m is the slope of the line represented by the equation and c is the y-intercept, or the value of y where the line crosses the y-axis in the Cartesian coordinate system.

histogram

Histograms are used in statistics, showing frequency of data, in which the horizontal axis details discrete units or class boundaries, and the vertical axis represents the frequency. Blocks are drawn such that their areas (rather than their height as in a bar chart) are proportional to the frequencies within a class or across several class boundaries. There are no spaces between blocks.

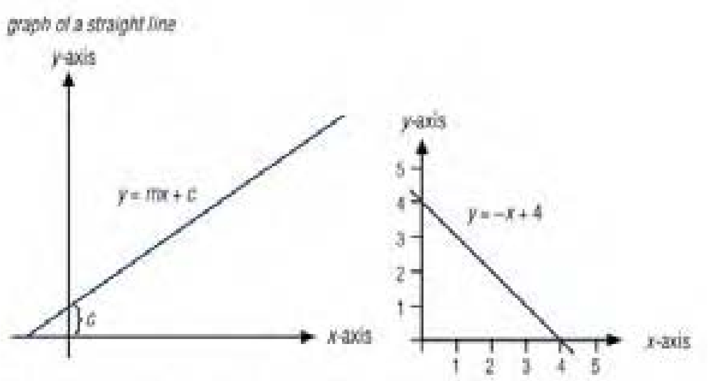
applications

Graphs have many practical applications in all disciplines, for example **distance-time graphs** are used to describe the motion of a body by illustrating the relationship between the distance that it travels and the time taken. Plotting distance (on the vertical axis) against time (on the horizontal axis) produces a graph the gradient of which is the body's speed. If the gradient is constant (the graph is a straight line), the body has uniform or constant speed; if the gradient varies (the graph is curved), then so does the speed and the body may be said to be accelerating or decelerating.

speed-time graphs are used to describe the motion of a body by illustrating how its speed or velocity changes with time. The gradient of the graph gives the object's acceleration: if the gradient is zero (the graph is horizontal) then the body is moving with constant speed or uniform velocity; if the gradient is constant, the body is moving with uniform acceleration. The area under the graph gives the total distance travelled by the body.

Conversion graphs are used for changing values from one unit to another, for example from Celsius to Fahrenheit, with the two axes representing the different units.

graph

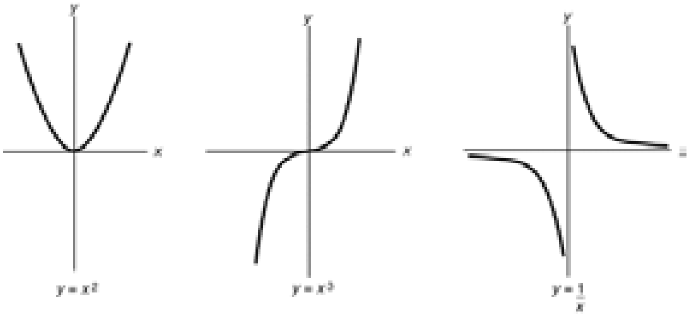


the equation of the straight-line graph takes the form $y = mx + c$, where m is the gradient (slope) of the line, and c is the y-intercept (the value of y where the line cuts the y-axis) for example, a graph of the equation $y = -x + 4$ will have a gradient of -1 and will cut the y-axis at $y = 4$

(Image © Research Machines plc)

A graph is pictorial illustration of numerical data. It is a useful tool for interpreting data and is often used to spot trends or approximate a solution.

graph



(Image © Research Machines plc)

When a quadratic expression is plotted on graph paper and the points are joined smoothly, the resulting shape is a U-shaped curve (a parabola). Where the x^2 expression is negative, as in $y = 3 - x^2$, the parabola is inverted. The graph of a cubic function can have between one and three bends in the curve. In a reciprocal function, as the value of x gets close to 0, y becomes infinite. As x gets very large, y gets very small but never reaches 0.

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graphical user interface

GUI

in computing, a type of user interface in which programs and files appear as icons (small pictures), user options are selected from pull-down menus, and data are displayed in windows (rectangular areas), which the operator can manipulate in various ways. The operator uses a pointing device, typically a mouse, to make selections and initiate actions. It is also known as **WIMP** (Windows, Icons, Menus, Pointing device).

The concept of the graphical user interface was developed by the Xerox Corporation in the 1970s, was popularized with the Apple Macintosh computers in the 1980s, and is now available on most types of computer - most notably as Windows, an operating system for IBM PC-compatible microcomputers developed by the software company Microsoft.

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graphic equalizer

control used in hi-fi systems that allows the distortions introduced in the sound output by unequal amplification of different frequencies to be corrected.

The frequency range of the signal is divided into separate bands, usually third-octave bands. The amplification applied to each band is adjusted by a sliding contact; the position of the contact indicates the strength of the amplification applied to each frequency range.

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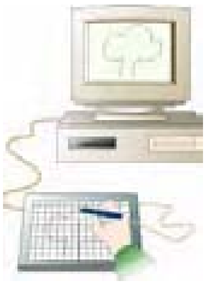
graphics tablet

or bit pad

in computing, an input device in which a stylus or cursor is moved, by hand, over a flat surface. The computer can keep track of the position of the stylus, so enabling the operator to input drawings or diagrams into the computer.

A graphics tablet is often used with a form overlaid for users to mark boxes in positions that relate to specific registers in the computer, although developments in handwriting recognition may increase its future versatility.

graphics tablet



(Image © Research Machines plc)

A graphics tablet enables images drawn freehand to be translated directly to the computer screen.

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graphite

blackish-grey, soft, flaky, crystalline form of carbon. It is used as a lubricant and as the active component of pencil lead.

Graphite, like diamond and fullerene, is an allotrope of carbon. The carbon atoms are strongly bonded together in sheets, but the bonds between the sheets are weak, allowing the layers to slide over one another. Graphite has a very high melting point (3,500°C/6,332°F), and is a good conductor of heat and electricity. It absorbs neutrons and is therefore used to moderate the chain reaction in nuclear reactors.

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graph plotter

alternative name for a plotter.

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grass

any of a very large family of plants, many of which are economically important because they provide grazing for animals and food for humans in the form of cereals. There are about 9,000 species distributed worldwide except in the Arctic regions. Most are perennial, with long, narrow leaves and jointed, hollow stems; flowers with both male and female reproductive organs are borne on spikelets; the fruits are grainlike. Included in the family are bluegrass, wheat, rye, maize, sugarcane, and bamboo. (Family Gramineae.)

British Lawnmower Museum

Go to site

Only in the British Isles can you find a museum that is dedicated to grass-cutting machines. This online museum has a section on the deranged sport of lawnmower racing, as well as 'Lawnmowers of the rich and famous', and many pictures of museum exhibits.

grasshopper

any of several insects with strongly developed hind legs, enabling them to leap into the air. The hind leg in the male usually has a row of protruding joints that produce the characteristic chirping sound when rubbed against the hard wing veins. Locusts, crickets, and katydids are related to grasshoppers. (Families Acrididae and Tettigoniidae, order Orthoptera.)

The **short-horned grasshoppers** constitute the family Acrididae, and include locusts. All members of the family feed voraciously on vegetation. Eggs are laid in a small hole in the ground, and the unwinged larvae become adult after about six moults.

grass-of-Parnassus

or eastern parnassia

plant (*Parnassia glauca*), unrelated to grasses, found growing in moist grasslands and thickets of North America. It is low-growing, with a rosette of heart-shaped, stalked leaves, and has five-petaled, white flowers with conspicuous green veins.

grass tree

Australian plant belonging to the lily family. The tall, thick stems have a grasslike tuft at the top above which rises a flower spike resembling a spear; this often appears after bushfires and in some species can grow to a height of 3 m/10 ft. (Genus *Xanthorrhoea*, family Liliaceae.)

gravel

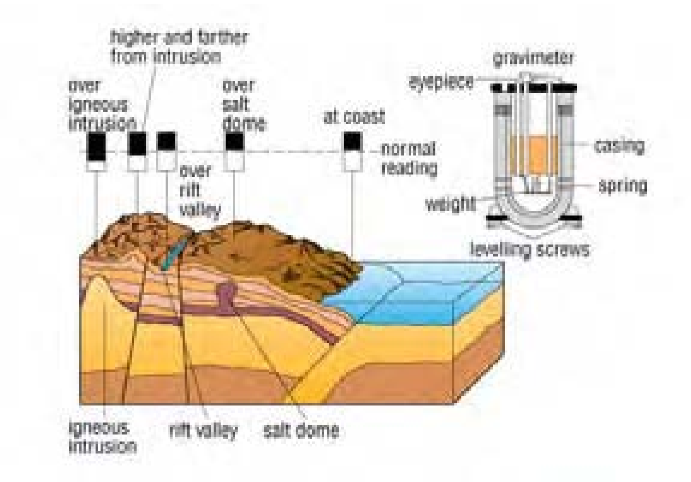
coarse sediment consisting of pebbles or small fragments of rock, originating in the beds of lakes and streams or on beaches. Gravel is quarried for use in road building, railway ballast, and for an aggregate in concrete. It is obtained from quarries known as gravel pits, where it is often found mixed with sand or clay.

Some gravel deposits also contain placer deposits of metal ores (chiefly tin) or free metals (such as gold and silver).

gravimetry

measurement of the Earth's gravitational field. Small variations in the gravitational field (gravimetric anomalies) can be caused by varying densities of rocks and structure beneath the surface. Such variations are measured by a device called a gravimeter (or gravity-meter), which consists of a weighted spring that is pulled further downwards where the gravity is stronger. Gravimetry is used by geologists to map the subsurface features of the Earth's crust, such as underground masses of dense rock such as iron ore, or light rock such as salt.

gravimetry



(Image © Research Machines plc)

The gravimeter is an instrument for measuring the force of gravity at a particular location. Variations in the force of gravity acting on a weight suspended by a spring cause the spring to stretch. The gravimeter is used in aerial surveys. Geological features such as intrusions and salt domes are revealed by the stretching of the spring.

gravitational field

region around a body in which other bodies experience a force due to its gravitational attraction. The gravitational field of a massive object such as the Earth is very strong and easily recognized as the force of gravity, whereas that of an object of much smaller mass is very weak and difficult to detect. Gravitational fields produce only attractive forces.

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gravitational field strength

symbol g

strength of the Earth's gravitational field at a particular point. It is defined as the gravitational force in newtons that acts on a mass of one kilogram. The value of *g* on the Earth's surface is taken to be 9.806 N kg^{-1}.

The symbol *g* is also used to represent the acceleration of a freely falling object in the Earth's gravitational field. Near the Earth's surface and in the absence of friction due to the air, all objects fall with an acceleration of 9.8 m s^{-2}/32 ft s^{-2}.

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gravitational force

or gravity

one of the four fundamental forces of nature, the other three being the electromagnetic force, the weak nuclear force, and the strong nuclear force. The gravitational force is the weakest of the four forces, but acts over great distances. The particle that is postulated as the carrier of the gravitational force is the graviton.

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gravitational lensing

bending of light by a gravitational field, predicted by German-born US physicist Albert Einstein's general theory of relativity. The effect was first detected in 1917, when the light from stars was found to bend as it passed the totally eclipsed Sun. More remarkable is the splitting of light from distant quasars into two or more images by intervening galaxies. In 1979 the first double image of a quasar produced by gravitational lensing was discovered and a quadruple image of another quasar was later found. Numerous multiple and/or distorted images of quasars and galaxies caused by gravitational lensing are now known.

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graviton

in physics, the gauge boson that is the postulated carrier of the gravitational force.

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gravity

force of attraction that arises between objects by virtue of their masses. The larger the mass of an object the more strongly it attracts other objects. On Earth, gravity causes objects to have weight; it accelerates objects (at 9.806 metres per second per second/32.174 ft per second per second) towards the centre of the Earth, the ground preventing them falling further.

The Earth's gravity also attracts the Moon towards the Earth, keeping the Moon in orbit around the Earth. The Moon's gravity is one-sixth that of Earth's, so objects on the Moon weigh less than on Earth. The Sun contains 99.8% of the mass of the Solar System, and the resulting large force of gravity keeps the planets of the Solar System in orbit around the Sun.

A spacecraft launched from Earth must overcome the force of gravity before entering space. This is achieved by using rocket boosters at various stages of the launch. The spacecraft needs an acceleration of three times that of gravity (3 g). The speed required to escape the Earth's gravitational field is 40,000 kph/25,000 mph.

gravity

The maximum speed with which a falling raindrop can hit you is about 29 kmph/18 mph. In a vacuum, the further an object falls, the more speed it gains, but in the real world, air resistance eventually balances out the accelerating effect of gravity.

Astro Weight

Go to site

Enter your weight and click on 'Calculate', and this site gives your weight on all nine planets of the Solar System plus the largest five moons of Jupiter. It also includes a link to a page where you can calculate your age in all nine planetary years.

From Apples to Orbits: The Gravity Story

Go to site

Find out all about the force that brought that legendary fruit down on top of Isaac Newton's head, and its importance to the development of space-age science. This nicely packaged site from the impressive ThinkQuest domain considers the history of gravity theory as well as small- and large-scale effects of the force, and includes sample experiments to test them out.

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gravure

one of the three main printing methods, in which printing is done from a plate etched with a pattern of recessed cells in which the ink is held. The greater the depth of a cell, the greater the strength of the printed ink. Gravure plates are expensive to make, but the process is economical for high-volume printing and reproduces illustrations well.

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gray

symbol Gy

SI unit of absorbed radiation dose. It replaces the rad (1 Gy equals 100 rad), and is defined as the dose absorbed when one kilogram of matter absorbs one joule of ionizing radiation. Different types of radiation cause different amounts of damage for the same absorbed dose; the SI unit of **dose equivalent** is the sievert.

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grayling

freshwater fish *Thymallus arcticus* of the family Salmonidae. It has a long, multirayed dorsal fin and exhibits a coloration shading from silver to purple. It is found in northern parts of North America, Europe, and Asia. It was once common in the Great Lakes.

Great Artesian Basin

largest area of artesian water in the world. It underlies much of Queensland, New South Wales, and South Australia, and in prehistoric times formed a sea. It has an area of 1,750,000 sq km/675,750 sq mi.

Great Bear

popular name for the constellation Ursa Major.

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great circle

circle drawn on a sphere such that the diameter of the circle is a diameter of the sphere. On the Earth, all meridians of longitude are half great circles; among the parallels of latitude, only the Equator is a great circle.

The shortest route between two points on the Earth's surface is along the arc of a great circle. These are used extensively as air routes although on maps, owing to the distortion brought about by projection, they do not appear as straight lines.

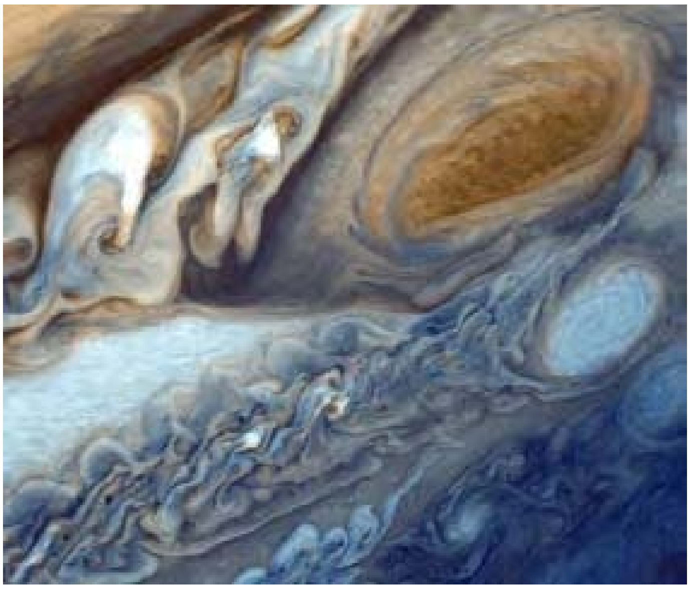
Great Dane

breed of large, short-haired dog, often fawn or brindle in colour, standing up to 76 cm/30 in tall, and weighing up to 70 kg/154 lb. It has a large head and muzzle, and small, erect ears. It was formerly used in Europe for hunting boar and stags.

Great Red Spot

prominent oval feature, 14,000 km/8,500 mi wide and some 30,000 km/20,000 mi long, in the atmosphere of the planet Jupiter, south of its equator. It was first observed in 1664. Space probes show it to be an anticlockwise vortex of cold clouds, coloured possibly by phosphorus.

Great Red Spot



(Image © NASA)

Enhanced view of Jupiter's Great Red Spot region. Below the Great Red Spot are two more cyclonic storms. The Voyager image was among the first to reveal the incredibly turbulent flow within Jupiter's zonal bands, which from afar look stable and placid.

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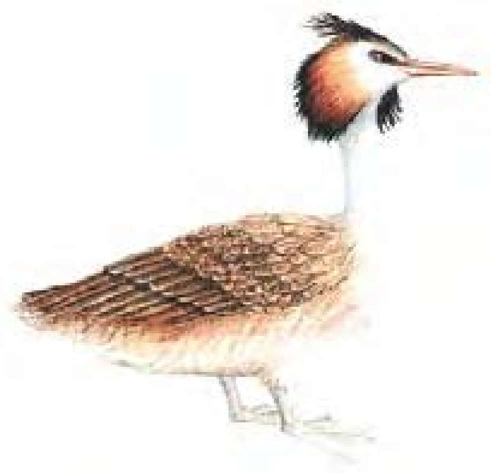
grebe

any of a group of 19 species of water birds. The **great crested grebe** (*Podiceps cristatus*) is the largest of the Old World grebes. It feeds on fish, and lives on ponds and marshes in Europe, Asia, Africa, and Australia. It grows to 50 cm/20 in long and has a white breast, with chestnut and black feathers on its back and head. Dark ear tufts and a prominent collar or crest of feathers around the base of the head appear during the breeding season; these are lost in winter. (Family Podicipedidae, order Podicipediformes.)

Grebes have broad, flat feet, and the toes are partially webbed, the legs being set extremely far back on the body. The wings are short and rounded, there is practically no tail, and flight is low. Both sexes are similar in appearance.

grebe



(Image © Research Machines plc)

The great crested grebe is easily recognized by its long slender neck and daggerlike bill. It has a wide range: Europe, Asia, Africa south of the Sahara, Australia, and New Zealand. Its diet consists largely of fish, caught by diving beneath the surface of the lakes, ponds, rivers, and coastal waters where it lives.

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green audit

inspection of a company to assess the total environmental impact of its activities or of a particular product or process.

For example, a green audit of a manufactured product looks at the impact of production (including energy use and the extraction of raw materials used in manufacture), use (which may cause pollution and other hazards), and disposal (potential for recycling, and whether waste causes pollution).

Such 'cradle-to-grave' surveys allow a widening of the traditional scope of economics by ascribing costs to variables that are usually ignored, such as despoliation of the countryside or air pollution.

greenbottle

type of blowfly.

greenfinch

olive-green songbird common in Europe and North Africa. It has bright-yellow markings on the outer tail feathers and wings; males are much brighter in colour than females. (Species *Carduelis chloris*, family Fringillidae, order Passeriformes.)

greenfly

plant-sucking insect, a type of aphid.

greenhouse effect

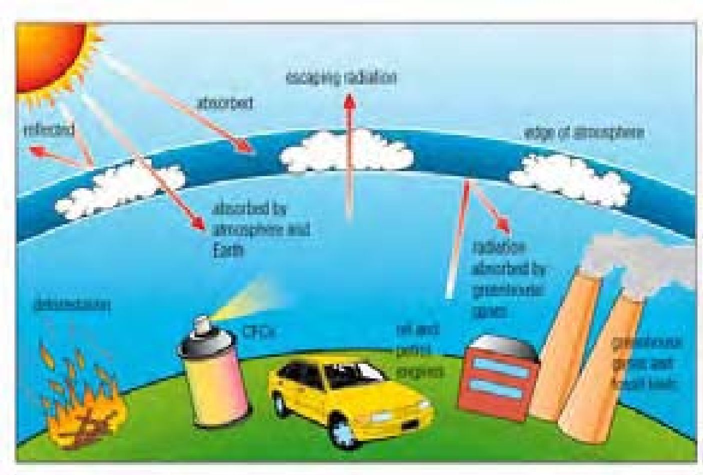
phenomenon of the Earth's atmosphere by which solar radiation, trapped by the Earth and re-emitted from the surface as long-wave infrared radiation, is prevented from escaping by various gases (the 'greenhouse gases') in the air. These gases trap heat because they readily absorb infrared radiation. As the energy cannot escape, it warms up the Earth, causing an increase in the Earth's temperature (global warming). The main greenhouse gases are carbon dioxide, methane, and chlorofluorocarbons (CFCs) as well as water vapour. Fossil-fuel consumption and forest fires are the principal causes of carbon dioxide build-up; methane is a by-product of agriculture (rice, cattle, sheep).

The United Nations Environment Programme estimates that by 2025, average world temperatures will have risen by 1.5°C/2.7°F with a consequent rise of 20 cm/7.9 in in sea level. Low-lying areas and entire countries would be threatened by flooding and crops would be affected by the change in climate. However, predictions about global warming and its possible climatic effects are tentative and often conflict with each other.

At the 1992 Earth Summit it was agreed that by 2000 countries would stabilize carbon dioxide emissions at 1990 levels, but to halt the acceleration of global warming, emissions would probably need to be cut by 60%. Any increases in carbon dioxide emissions are expected to come from transport. The Berlin Mandate, agreed unanimously at the climate conference in Berlin in 1995, committed industrial nations to the continuing reduction of greenhouse gas emissions after 2000, when the existing pact to stabilize emissions runs out. The stabilization of carbon dioxide emissions at 1990 levels by 2000 would not be achieved by a number of developed countries, including Spain, Australia, and the USA, according to 1997 estimates. Australia is in favour of different targets for different nations, and refused to sign a communiqué at the South Pacific Forum meeting in the Cook Islands in 1997 which insisted on legally-binding reductions in greenhouse gas emissions. The United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol in 1997, committing the world's industrialized countries to cutting their annual emissions of harmful gases. By July 2001 the Protocol had been signed by 84 parties and ratified by 37; the USA announced its refusal to ratify the Protocol in June 2001.

Dubbed the 'greenhouse effect' by Swedish scientist Svante Arrhenius, it was first predicted in 1827 by French mathematician Joseph Fourier.

greenhouse effect


escaping radiation
absorbed
reflected
edge of atmosphere
absorbed by atmosphere and Earth
radiation absorbed by greenhouse gases
deforestation
CFCs
oil and petrol engines
greenhouse gases and fossil fuels

(Image © Research Machines plc)

The warming effect of the Earth's atmosphere is called the greenhouse effect. Radiation from the Sun enters the atmosphere but is prevented from escaping back into space by gases such as carbon dioxide (produced for example, by the burning of fossil fuels), nitrogen oxides (from car exhausts), and CFCs (from aerosols and refrigerators). As these gases build up in the atmosphere, the Earth's average temperature is expected to rise.

The Greenhouse Effect: How the Earth Stays Warm

Go to site

Explanation of the greenhouse effect, the process by which atmospheric gases trap heat. This page links to a description of how this perfectly normal and essential process is being turned into something harmful by the pollutants humans put into the atmosphere. It also explains the related phenomenon, the hole in the ozone layer.

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green monkey disease

another name for Marburg disease, a virus originating in Central Africa.

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green movement

collective term for the individuals and organizations involved in efforts to protect the environment.
The movement includes political parties such as the Green Party and organizations like Friends of the Earth and Greenpeace. See also environmental issues.

Despite a rapid growth of public support, and membership of environmental organizations running into many millions worldwide, political green groups have failed to win significant levels of the vote in democratic societies.

Green Movement: key dates

1798	Thomas Malthus's *Essay on the Principle of Population* is published, setting out the idea that humans are also bound by ecological constraints.
1824	Society for the Prevention of Cruelty to Animals founded.
1835-39	Droughts and famine in India result in the first connections being made between environmental damage (deforestation) and climate change.
1864	George Marsh's 'Man and Nature' is the first comprehensive study of humans' impact on the environment.
1865	The Commons Preservation Society is founded, raising the issue of public access to the countryside, and is taken further by the mass trespasses of the 1930s.
1872	Yellowstone National Park is created in the USA; a full system of national parks is established 40 years later.
1893	The National Trust is founded in the UK to buy land in order to preserve places of natural beauty and cultural landmarks.
1930	Chlorofluorocarbons (CFCs) are invented; they are hailed as a boon for humanity as they are not only cheap and nonflammable but are also thought not to be harmful to the environment.
1934	Drought exacerbates soil erosion, causing the 'Dust Bowl Storm' in the USA, during which some 350 million tons of topsoil are blown away.
1948	The United Nations creates a special environmental agency, the International Union for the Conservation of Nature (IUCN).
1952	Air pollution causes massive smog in London, England, killing some 4,000 people and leading to clean-air legislation.
1960s	Public awareness of the damage to the environment caused by pollution increases, encouraged by such books as Rachel Carson's *Silent Spring* and Garret Hardin's essay 'The Tragedy of the Commons', which challenges individuals to recognize their personal responsibility for environmental degradation as a result of lifestyle choices.
1969	Friends of the Earth is launched in the USA as a breakaway group from the increasingly conservative Sierra Club; there is an upsurge of more radical active groups within the environmental movement over the following years.
1972	*Blueprint for Survival*, a detailed analysis of the human race's ecological predicament and proposed solutions, is published in the UK by Teddy Goldsmith and others from the *Ecologist* magazine.
1974	The first scientific warning of serious depletion of the protective ozone layer in upper atmosphere by CFCs is announced.
1980	US president Jimmy Carter commissions the report *Global 2000*, reflecting the entry of environmental concerns into mainstream politics.
1983	The German political party The Greens (Die Grünen) win 27 seats in the Bundestag (parliament).
1985	The Greenpeace ship *Rainbow Warrior* is sunk by French intelligence agents in a New Zealand harbour during a protest against French nuclear testing in the South Pacific. One crew member is killed.
1988	NASA scientist James Hansen warns the US Congress about global warming, announcing 'The greenhouse effect is here.'
1989	European elections put green issues firmly on political agenda as Green parties across Europe attract unprecedented support, especially in the UK, where the Greens receive some 15% of votes cast (though not of seats).
1989	*The Green Consumer Guide* is published in the UK, one of many such books worldwide advocating 'green consumerism'.
1991	The Gulf War has massive environmental consequences, primarily as a result of the huge quantity of oil discharged into the Gulf from Kuwait's oilfields.
1992	United Nations Earth Summit in Rio de Janeiro arouses great media interest but achieves little progress in tackling difficult global environmental issues because many nations fear possible effects on trade.

1994	Protests against road building in many parts of the UK; for example, in the 'Battle of Wanstonia', green activists occupy buildings and trees in East London in an attempt to halt construction of the M11 motorway.
1995	Animal-rights activists campaign against the export of live animals; activist Jill Phipps is killed on 1 February during a protest at Coventry airport. In May Greenpeace's London headquarters are raided by the Ministry of Defence and files and computer disks are confiscated.
1996	A new political force, Real World, is formed from a coalition of 32 campaigning charities and pressure groups.
1997	The second Earth Summit takes place in New York. Delegates report on progress since the 1992 Rio Summit, but fail to agree on a deal to address the world's escalating environmental crisis. Delegates at the Kyoto, Japan, conference on global warming agree to cut emission of greenhouse gases by 5.2% from 1990 levels during the years 2008-2012.
1999	Genetically modified (GM) crops are identified as a potential threat to the environment. In the UK legislation is introduced requiring all foodstuffs containing any GM ingredients to be clearly labelled. The number of demonstrations at GM crop test sites escalates. In the USA, GM crops are grown and eaten extensively, with little public protest.
2000	Despite being caught red-handed, a group of UK anti-GM protesters who vandalized a government-run experimental GM maize crop on private land are found not guilty by a sympathetic jury.
2001	US president George W Bush angers international opinion by rejecting the Kyoto treaty on climate change, on the grounds that he will not sign anything that will harm US economic interests.
2005	Thousands of participants at the Montreal climate summit discuss how to meet the targets in the Kyoto treaty, and what measures should follow when it expires in 2012.

Greenpeace

international environmental pressure group, founded in Vancouver, Canada, in 1971, with a policy of non-violent direct action backed by scientific research. During a protest against French atmospheric nuclear testing in the South Pacific in 1985, its ship *Rainbow Warrior* was sunk by French intelligence agents, killing a crew member. In 1995, it played a prominent role in opposing the disposal of waste from an oil rig in the North Sea, and again attempted to disrupt French nuclear tests in the Pacific. In 2004, Greenpeace (now headquartered in the Netherlands) had a global membership of 2.8 million in 41 countries.

Greenpeace

Go to site

Home page of Greenpeace, the environmental and ecological campaign group. The site includes detailed information on current campaigns and additional resources on issues such as the climate, nuclear power, oceans, genetic engineering, and forestry.

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green revolution

in agriculture, the change in methods of arable farming instigated in the 1940s and 1950s in countries of the developing world. The intent was to provide more and better food for their populations, albeit with a heavy reliance on chemicals and machinery. It was abandoned by some countries in the 1980s. Much of the food produced was exported as cash crops, so that local diet did not always improve.

The green revolution tended to benefit primarily those landowners who could afford the investment necessary for such intensive agriculture. Without a dosage of 70-90 kg/154-198 lb of expensive nitrogen fertilizers per hectare, the high-yield varieties will not grow properly. Hence, rich farmers tended to obtain bigger yields while smallholders were unable to benefit from the new methods.

In terms of production, the green revolution was initially successful in Southeast Asia; India doubled its wheat yield in 15 years, and the rice yield in the Philippines rose by 75%. However, yields have levelled off in many areas; some countries that cannot afford the dams, fertilizers, and machinery required, have adopted intermediate technologies.

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greenshank

greyish shorebird of the sandpiper group. It has long olive-green legs and a long, slightly upturned bill, with white underparts and rump and dark grey wings. It breeds in northern Europe and regularly migrates through the Aleutian Islands, southwest of Alaska. (Species *Tringa nebularia*, family Scolopacidae, order Charadriiformes.)

Greenwich Mean Time

GMT

local time on the zero line of longitude (the **Greenwich meridian**), which passes through the Old Royal Observatory at Greenwich, London. It was replaced in 1986 by coordinated universal time (UTC), but continued to be used to measure longitudes and the world's standard time zones.

See also time.

Greenwich Mean Time

(Image © Research Machines plc)

The meridian line at Greenwich in London, England. A meridian line is an imaginary line that runs from the North Pole to the South Pole. By international convention, the meridian line at Greenwich, which runs through the Royal Observatory telescope, marks 0° longitude and is the point from which all other lines of longitude are measured.

greyhound

ancient breed of dog, with a long narrow head, slight build, and long legs. It stands up to 75 cm/30 in tall. It is renowned for its swiftness, and can exceed 60 kph/40 mph. Greyhounds were bred to hunt by sight, their main quarry being hares. Hunting hares with greyhounds is the basis of the ancient sport of coursing. Track-based greyhound racing is a popular spectator sport.

The Italian greyhound is similar in build to the ordinary greyhound, but very much smaller, weighing only about 3.6 kg/8 lb.

grey matter

in biology, those parts of the brain and spinal cord that are made up of interconnected and tightly packed nerve cell nucleuses. The outer layers of the cerebellum contains most of the grey matter in the brain. It is the region of the brain that is responsible for advanced mental functions. Grey matter also constitutes the inner core of the spinal cord. This is in contrast to white matter, which is made of the axons of nerve cells.

grid

network by which electricity is generated and distributed over a region or country. It contains many power stations and switching centres and allows, for example, high demand in one area to be met by surplus power generated in another.

The term is also used for any grating system, as in a cattle grid for controlling the movement of livestock across roads, and a conductor in a storage battery or electron gun.

grid reference

numbering system used to specify a location on a map. The numbers representing grid lines at the bottom of the map (eastings) are given before those at the side (northings). Successive decimal digits refine the location within the grid system.

griffon

small breed of dog originating in Belgium. Red, black, or black and tan in colour and weighing up to 5 kg/11 lb, griffons are square-bodied and round-headed. There are rough- and smooth-coated varieties.

The name is also applied to several larger breeds of hunting dogs with rough coats, including two bred in northern France to pursue wild boar.

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griffon Bruxelloise

breed of terrierlike toy dog originally bred in Belgium. It weighs up to 4.5 kg/10 lb and has a harsh and wiry coat that is red or black in colour. The smooth-haired form of the breed is called the **petit Brabançon**.

The griffon Bruxelloise has a large rounded head with semi-erect ears; large black eyes with black eye-rims; and a short nose surrounded with black hair that converges upwards to meet the hair round the eyes. Its chest is wide and deep; legs are straight and of medium length; the tail is traditionally docked and carried upwards.

Grignard, (François Auguste) Victor (1871-1935)

French chemist. He was awarded the Nobel Prize for Chemistry in 1912 for his discovery in 1900 of a series of organic compounds, the **Grignard reagents**, that found applications as some of the most versatile reagents in organic synthesis. Members of the class contain a hydrocarbon radical, magnesium, and a halogen such as chlorine.

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grooming

in biology, the use by an animal of teeth, tongue, feet, or beak to clean fur or feathers. Grooming also helps to spread essential oils for waterproofing. In many social species, notably monkeys and apes, grooming of other individuals is used to reinforce social relationships.

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grosbeak

any of various thick-billed finches. The **pine grosbeak** (*Pinicola enucleator*) breeds in Arctic forests. Its plumage is similar to that of the pine crossbill. (Family Fringillidae, order Passeriformes.)

Gross, David Jonathon (1941-)

US physicist. With US physicists Hugh Politzer and Frank Wilczek, Gross shared the Nobel Prize for Physics in 2004 for his contribution to the theoretical explanation of how the strong nuclear force holds quark subatomic particles together.

Gross and his fellow Nobel laureates derived a theory to explain how the strong force, or the colour interaction, acts between quarks. Quarks are subatomic particles that make up protons and neutrons in the nucleus of an atom. Previously it was not understood how quarks could not be made to act as individual particles except at very high energies; the work by the laureates showed that the strong force acts to make the attraction between quarks increase with distance, so that the further apart they are, the stronger the force is that brings them back together, preventing individual quarks from leaving the nucleus. This work was detailed in two scientific publications published in 1971 and formed the basis of the theory of colour interaction known as quantum chromodynamics (QCD), that allowed the completion of the standard model of particle physics.

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ground

an electrical connection between an appliance and the ground, which becomes part of the circuit. In the event of a fault in an electrical appliance (for example, involving connection between the live part of the circuit and the outer casing) the current flows to ground, causing no harm to the user.

In most domestic installations, grounding is achieved by a connection to an underground metal water-supply pipe buried in the ground before it enters the premises.

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groundnut

another name for peanut.

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groundwater

water present underground in porous rock strata and soils; it emerges at the surface as springs and streams. The groundwater's upper level is called the water table. Rock strata that are filled with groundwater that can be extracted are called **aquifers**. Aquifers must be both porous (filled with holes) and permeable (full of holes that are interconnected so that the water is able to flow).

Most groundwater near the surface moves slowly through the ground while the water table stays in the same place. The depth of the water table reflects the balance between the rate of infiltration, called recharge, and the rate of discharge at springs or rivers or pumped water wells. The force of gravity makes underground water run 'downhill' underground, just as it does above the surface. The greater the slope and the permeability, the greater the speed. Velocities vary from 100 cm/40 in per day to 0.5 cm/0.2 in.

Groundwater Quality and the Use of Lawn and Garden Chemicals by Homeowners

Go to site

Extensive information about the problem of keeping groundwater free from garden chemicals. There is a description of groundwater, as well as detailed information on pesticides and their use. There are also notes on applying lawn and garden chemicals, and what should be done with the leftovers.

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group

in chemistry, a vertical column of elements in the periodic table. Elements in a group have similar physical and chemical properties; for example, the group I elements (the alkali metals: lithium, sodium, potassium, rubidium, caesium, and francium) are all highly reactive metals that form univalent ions. There is a gradation of properties down any group: in group I, melting and boiling points decrease, and density and reactivity increase.

Group 0 consists of the noble gases (rare gases) and group II consists of the alkaline-earth metals. Those elements placed between group II and III are the transition metals and group VII contains the halogens.

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group

in mathematics, a finite or infinite set of elements that can be combined by an operation; formally, a group must satisfy certain conditions. For example, the set of all integers (positive or negative whole numbers) forms a group with regard to addition because: (1) addition is associative, that is, the sum of two or more integers is the same regardless of the order in which the integers are added; (2) adding two integers gives another integer; (3) the set includes an identity element 0, which has no effect on any integer to which it is added (for example, 0 + 3 = 3); and (4) each integer has an inverse (for instance, 7 has the inverse -7), such that the sum of an integer and its inverse is 0.
Group theory is the study of the properties of groups.

Development of Group Theory

Go to site

History of the development of group theory in mathematics according to St Andrews University, Scotland. Biographical information on the mathematicians responsible and a description of the topic are also included on this site, along with links to many other sources on the history of mathematics.

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grouper

any of several species of large sea bass, especially the genera *Mycteroperca* and *Epinephelus*, found in warm waters.

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grouse

plump fowl-like game bird belonging to a subfamily of the pheasant family, which also includes the ptarmigan, capercaillie, and prairie chicken. Grouse are native to North America and northern Europe. They spend most of their time on the ground. During the mating season the males undertake elaborate courtship displays in small individual territories (leks). (Subfamily Tetraonidae, family Phasianidae, order Galliformes.)

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growth ring

another name for annual ring.

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groyne

wooden or concrete barrier built at right angles to a beach in order to block the movement of material along the beach by longshore drift. Groynes are usually successful in protecting individual beaches, but because they prevent beach material from passing along the coast they can mean that other beaches, starved of sand and shingle, are in danger of being eroded away by the waves. These areas are down-drift of the groyne. This happened, for example, at Barton-on-Sea in Hampshire, England, in the 1970s, following the construction of a large groyne at Bournemouth.

GRP

abbreviation for glass-reinforced plastic.

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grub

legless larval stages of Coleoptera (beetles) and Hymenoptera (bees, ants and wasps). See larvae.

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g-scale

scale for measuring force by comparing it with the force due to gravity (*g*), often called g-force.

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guanaco

hoofed ruminant (cud-chewing) mammal belonging to the camel family, found in South America on the pampas and mountain plateaux. It grows up to 1.2 m/4 ft at the shoulder, with the head and body measuring about 1.5 m/5 ft in length. It is sandy brown in colour, with a blackish face, and has fine wool. It lives in small herds and is the ancestor of the domestic llama and alpaca. It is also related to the other wild member of the camel family, the vicuna. (Species *Lama guanacoe*, family Camelidae.)

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guano

dried excrement of fish-eating birds that builds up under nesting sites. It is a rich source of nitrogen and phosphorous, and is widely collected for use as fertilizer. Some 80% comes from the sea cliffs of Peru.

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guarana

Brazilian woody climbing plant. A drink with a high caffeine content is made from its roasted seeds, and it is the source of the drug known as zoom in the USA. Starch, gum, and several oils are extracted from it for commercial use. (*Paullinia cupana*, family Sapindaceae.)

Guarana

Go to site

Informative resource relating to the Brazilian climbing plant guarana. It contains a detailed description of the plant and its habitat. There are also notes on the constituents of the plant, as well as information on the possible medicinal uses of guarana, which include acting as a stimulant and treating bowel complaints.

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guard cell

in plants, a specialized cell on the undersurface of leaves for controlling gas exchange and water loss. Guard cells occur in pairs and are shaped so that a pore, or stomata, exists between them. They can change shape with the result that the pore disappears. During warm weather, when a plant is in danger of losing excessive water, the guard cells close, cutting down evaporation from the interior of the leaf.

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guava

tropical American tree belonging to the myrtle family; the astringent yellow pear-shaped fruit is used to make guava jelly, or it can be stewed or canned. It has a high vitamin C content. (*Psidium guajava*, family Myrtaceae.)

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gudgeon

any of an Old World group of freshwater fishes of the carp family, especially the species *G. gobio* found in Europe and northern Asia on the gravel bottoms of streams. It is olive-brown, spotted with black, and up to 20 cm/8 in long, with a distinctive barbel (sensory bristle, or 'whisker') at each side of the mouth. (Genus *Gobio*, family Cyprinidae.)

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guelder rose

or snowball tree

cultivated shrub or small tree, native to Europe and North Africa, with round clusters of white flowers which are followed by shiny red berries. (*Viburnum opulus*, family Caprifoliaceae.)

Guelder Rose

Go to site

Informative resource relating to the guelder rose. It contains a detailed description of the plant and its habitat. There are also notes on the constituents of the plant, as well as information on the possible medicinal uses of the guelder rose, which include acting as an antispasmodic.

Guérin, Camille (1872-1961)

French bacteriologist who, with Albert Calmette, developed the BCG vaccine for tuberculosis in 1921.

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guillemot

any of several diving seabirds belonging to the auk family that breed on rocky North Atlantic and Pacific coasts. The **common guillemot** (*U. aalge*) has a long straight beak and short tail and wings; the feet are three-toed and webbed, the feathers are sooty brown and white. It breeds in large colonies on sea cliffs. The **black guillemot** (*C. grylle*) of northern coasts is much smaller and mostly black in summer, with orange legs when breeding. Guillemots build no nest, but lay one large, almost conical egg. (Genera *Uria* and *Cepphus*, family Alcidae, order Charadriiformes.)

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guinea fowl

any of a group of chickenlike African birds, including the **helmet guinea fowl** (*Numida meleagris*), which has a horny growth on the head, white-spotted feathers, and fleshy cheek wattles (loose folds of skin). It is the ancestor of the domestic guinea fowl. Guinea fowl are mostly gregarious ground-feeders, eating insects, leaves, and snails; at night they roost in trees. (Family Numididae, order Galliformes.)

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guinea pig

species of cavy, a type of rodent.

Guinea Pig Care

Go to site

From housing to health, this site contains lots of useful information for guinea-pig lovers, including a health chart to help you diagnose illnesses.

Guinea worm

parasitic, microscopic nematode worm found in India and Africa, affecting some 650,000 people in Nigeria alone. It enters the body via drinking water and migrates to break out through the skin. (Species *Dracunculus medinensis*.)

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guitarfish

sharklike ray that lives in the shallow waters of tropical seas. Unlike rays, which swim by flapping their pectoral fins, it swims like a shark by lashing its long, thick muscular tail. Guitarfish tend to be small, though one species can reach 2 m/6.6 ft in length.

Most species are ovoviparous (the fertilized egg develops inside the mother). Guitarfish have well developed dorsal and caudal fins. There are about 45 species of guitarfish: the shovelnose guitarfish *Rhinobatus productus* is an example.

classification

Guitarfish are in the family Rhinobatidae, order Rajiformes, subclass Elasmobranchii, class Chondrichthyes.

Gulf Stream

warm ocean current that flows north from the warm waters of the Gulf of Mexico along the east coast of America, from which it is separated by a channel of cold water originating in the southerly Labrador current. Off Newfoundland, part of the current is diverted east across the Atlantic, where it is known as the **North Atlantic Drift**, dividing to flow north and south, and warming what would otherwise be a colder climate in the British Isles and northwest Europe.

At its beginning the Gulf Stream is 80-150 km/50-93 mi wide and up to 850 m/2,788 ft deep, and moves with an average velocity of 130 km/80 mi a day. Its temperature is about 26°C. As it flows northwards, the current cools and becomes broader and less rapid.

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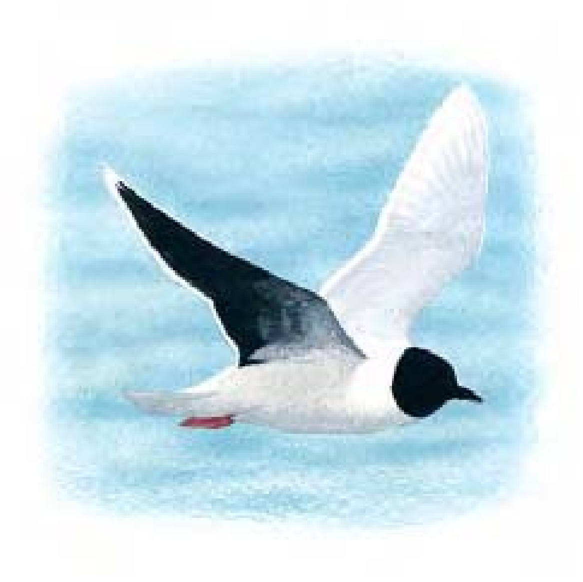
gull

any of a group of seabirds that are usually 25–75 cm/10–30 in long, white with grey or black on the back and wings, and have large beaks. Immature birds are normally a mottled brown colour. Gulls are sociable, noisy birds and they breed in colonies. (Genus principally *Larus*, subfamily Larinae, family Laridae, order Charadriiformes.)

The **common black-headed gull** (*L. ridibundus*), common on both sides of the Atlantic Ocean, is grey and white with (in summer) a dark-brown head and a red beak; it breeds in large colonies on wetlands, making a nest of dead rushes and laying, on average, three eggs. The **great black-headed gull** (*L. ichthyaetus*) is native to Asia. The **herring gull** (*L. argentatus*), common in the northern hemisphere, has white and pearl-grey plumage and a yellow beak. The **oceanic great black-backed gull** (*L. marinus*), found in the Atlantic, is over 75 cm/2.5 ft long.

The **kelp gull** or **Southern black-backed gull** (*L. dominicanus*) is common throughout the southern hemisphere. It feeds mainly on limpets, which are swallowed whole, with the shell later spat out and left in a heap around the nest area.

gull



(Image © Research Machines plc)

A common sight around the coasts of Europe, gulls nest in colonies, laying 2–3 eggs in a simple scrape on the ground.

gull

(Image © Research Machines plc)

The herring gull, *Larus argentatus*, is a common sight in English seaside towns. An infamous scavenger, it is now regarded as a nuisance in many coastal resorts. The herring gull can be distinguished from the common gull, which it closely resembles, by its larger size and slower, lazier wingbeats.

gull

(Image © Research Machines plc)

Herring gulls can often be sighted hanging in the wind above the sea, sometimes in loose, informal flocks. These omnivorous birds live on fish and offal, and on the eggs and young of other birds. But increasingly they are found in large numbers scavenging in rubbish tips, and are regarded as a potential carrier of disease.

gum

in mammals, the soft tissues surrounding the base of the teeth. Gums are liable to inflammation (gingivitis) or to infection by microbes from food deposits (periodontal disease).

gum

in botany, complex polysaccharides (carbohydrates) formed by many plants and trees, particularly by those from dry regions. They form four main groups: plant exudates (gum arabic); marine plant extracts (agar); seed extracts; and fruit and vegetable extracts. Some are made synthetically.

Gums are tasteless and odourless, insoluble in alcohol and ether but generally soluble in water. They are used for adhesives, fabric sizing, in confectionery, medicine, and calico printing.

gum arabic

substance obtained from certain species of acacia trees, especially *A. senegal*, with uses in medicine, confectionery, and adhesive manufacture.

gumtree

common name for the eucalyptus tree.

gun

any kind of firearm or any instrument consisting of a metal tube from which a projectile is discharged; see also pistol and small arms.

gun metal

type of bronze, an alloy high in copper (88%), also containing tin and zinc, so-called because it was once used to cast cannons. It is tough, hard-wearing, and resists corrosion.

gunpowder

or black powder

oldest known explosive, a mixture of 75% potassium nitrate (saltpetre), 15% charcoal, and 10% sulphur. Sulphur ignites at a low temperature, charcoal burns readily, and the potassium nitrate provides oxygen for the explosion. As gunpowder produces lots of smoke and burns quite slowly, it has progressively been replaced since the late 19th century by high explosives, although it is still widely used for quarry blasting, fuses, and fireworks. Gunpowder has high activation energy; a gun based on gunpowder alone requires igniting by a flint or a match.

It was probably first invented in China, where it was chiefly used for fireworks. It is possible that knowledge of it was transmitted from the Middle East to Europe. The writings of the English monk Roger Bacon show that he was experimenting with gunpowder in 1249. His mixture contained saltpetre, charcoal, and sulphur. The development of effective gunpowder was essential for the growing significance of cannons and handguns in the late medieval period. The Arabs produced the first known working gun, in 1304. Gunpowder was used in warfare from the 14th century but it was not generally adapted to civil purposes until the 17th century, when it began to be used in mining.

Gunter, Edmund (1581-1626)

English mathematician who became professor of astronomy at Gresham College, London in 1619. He is reputed to have invented a number of surveying instruments as well as the trigonometrical terms 'cosine' and 'cotangent'.

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gurnard

any of a group of coastal fish that creep along the sea bottom with the help of three fingerlike appendages detached from the pectoral fins. Gurnards are both tropical and temperate zone fish. (Genus *Trigla*, family Trigilidae.)

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gust

temporary increase in wind speed, lasting less than two minutes. Gusts are caused by rapidly moving air in higher layers of the atmosphere, mixing with slower air nearer the ground. Gusts are common in urban areas, where winds are funnelled between closely-spaced high buildings. Gusting winds do far more damage to buildings and crops than steady winds. The strongest gusts can exceed speeds of 100 m/328 ft per second.

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gut

or alimentary canal

in the digestive system, the part of an animal responsible for processing food and preparing it for entry into the blood.

The gut consists of a tube divided into segments specialized to perform different functions. The front end (the mouth) is adapted for food intake and for the first stages of digestion. The stomach is a storage area, although digestion of protein by the enzyme pepsin starts here; in many herbivorous mammals this is also the site of cellulose digestion. The small intestine follows the stomach and is specialized for digestion and for absorption. The large intestine, consisting of the colon, caecum, and rectum, has a variety of functions, including cellulose digestion, water absorption, and storage of faeces. From the gut nutrients are carried to the liver via the hepatic portal vein, ready for assimilation by the cells.

Gutenberg, Johannes (c. 1398-1468)

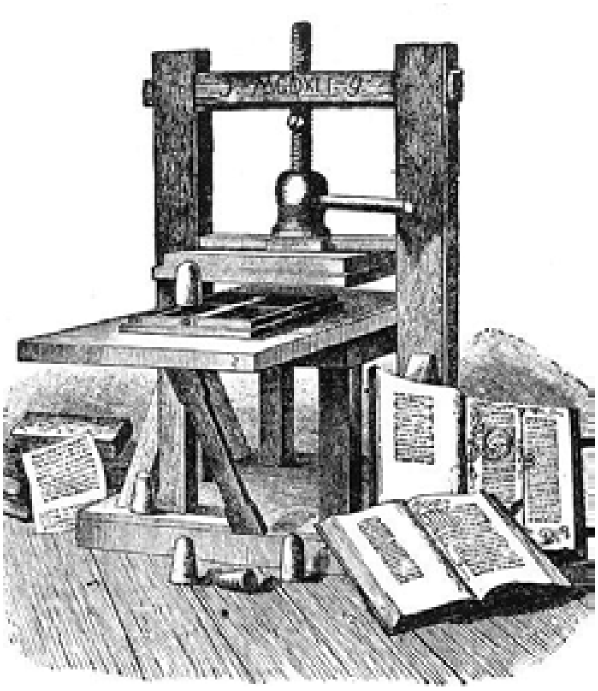
born Johann Gensfleisch zur Laden zum Gutenberg

German printer, the inventor of European printing from movable metal type (although Laurens Janszoon Coster has a rival claim).

Gutenberg began work on the process in the 1440s and in 1450 set up a printing business in Mainz. By 1456 he had produced the first printed Bible (known as the Gutenberg Bible). Much of the information available about Gutenberg is controversial and it is not known what other books he printed.

He punched and engraved a steel character (letter shape) into a piece of copper to form a mould which he filled with molten metal. The letters were in Gothic script and of equal height.

Gutenberg



(Image © Billie Love)

The printing press invented by the German printer Johannes Gutenberg (*c.*1400-1468). He invented the technique of printing from moveable type, and is regarded as the originator of the first printed bible, which has come to be known as the Gutenberg Bible (*c.* 1455).

Gutenberg, Johann

Go to site

Biography of the German goldsmith turned printer. Gutenberg's technical innovations and the lawsuits which dogged his career are set out. The rapid spread of Gutenberg's invention is also described.

gutta-percha

juice of various tropical trees of the sapodilla family (such as the Malaysian *Palaquium gutta*), which can be hardened to form a flexible, rubbery substance used for electrical insulation, dentistry, and golf balls; it has now been largely replaced by synthetic materials.

guttation

secretion of water on to the surface of leaves through specialized pores, or hydathodes. The process occurs most frequently during conditions of high humidity when the rate of transpiration is low. Drops of water found on grass in early morning are often the result of guttation, rather than dew. Sometimes the water contains minerals in solution, such as calcium, which leaves a white crust on the leaf surface as it dries.

Gy

symbol for gray, the SI unit of absorbed ionizing radiation dose, equal to an absorption of 1 joule per kilogram of irradiated matter.

gymnosperm

(Greek 'naked seed')

in botany, any plant whose seeds are exposed, as opposed to the structurally more advanced angiosperms, where they are inside an ovary. The group includes conifers and related plants such as cycads and ginkgos, whose seeds develop in cones. Fossil gymnosperms have been found in rocks about 350 million years old.

gynaecology

medical speciality concerned with disorders of the female reproductive system.

gynoecium

or gynaecium

collective term for the female reproductive organs of a flower, consisting of one or more carpels, either free or fused together.

gypsum

common sulphate mineral, composed of hydrous calcium sulphate, $CaSO_4.2H_2O$. It ranks 2 on the Mohs scale of hardness. Gypsum is used for making casts and moulds, and for blackboard chalk.

A fine-grained gypsum, called **alabaster**, is used for ornamental work. Roasted gypsum is known as **plaster of Paris**, because for a long time it was obtained from the gypsum quarries of the Montmartre district of Paris.

gyre

circular surface rotation of ocean water in each major sea (a type of current). Gyres are large and permanent, and occupy the northern and southern halves of the three major oceans. Their movements are dictated by the prevailing winds and the Coriolis effect. Gyres move clockwise in the northern hemisphere and anticlockwise in the southern hemisphere.

gyroscope

mechanical instrument, used as a stabilizing device and consisting, in its simplest form, of a heavy wheel mounted on an axis. The direction of the axis is stable; if it is displaced, the gyroscope tends to resist the change. Applications of the gyroscope principle include the gyrocompass, the autopilot for automatic control of an aircraft, and gyro-directed torpedoes.

H

symbol for henry, the SI unit of inductance, equal to the inductance of a closed circuit with a magnetic flux of 1 weber per ampere of current.

ha

symbol for hectare.

Haber, Fritz (1868-1934)

German chemist whose conversion of atmospheric nitrogen to ammonia opened the way for the synthetic fertilizer industry. His study of the combustion of hydrocarbons led to the commercial 'cracking' or fractional distillation of natural oil (petroleum) into its components (for example, diesel fuel, petrol, and paraffin). In electrochemistry, he was the first to demonstrate that oxidation and reduction take place at the electrodes; from this he developed a general electrochemical theory. He was awarded the Nobel Prize for Chemistry in 1918 for his work on the synthesis of ammonia from its elements.

At the outbreak of World War I in 1914, Haber was asked to devise a method of producing nitric acid for making high explosives. Later he became one of the principals in the German chemical warfare effort, devising weapons and gas masks, which led to protests against his Nobel Prize in 1918.

Haber, Fritz

The German chemist Fritz Haber developed chlorine gas for use by the Germans in World War I. Unable to live with this, his wife committed suicide in 1915.

Haber process

industrial process in which ammonia is manufactured by direct combination of its elements, nitrogen and hydrogen. The reaction is carried out at 752-932°F/400-500°C and at 200 atmospheric pressure. The two gases, in the proportions of 1:3 by volume, are passed over a catalyst of finely divided iron.

Around 10% of the reactants combine, and the unused gases are recycled. The ammonia is separated by either dissolving in water or cooling to liquid form.

$N_2 + 3H_2 \leftrightarrow 2NH_3$

---

habitat

in ecology, the localized environment in which an organism lives, and which provides for all (or almost all) of its needs. The diversity of habitats found within the Earth's ecosystem is enormous, and they are changing all the time. They may vary through the year or over many years. Many can be considered inorganic or physical; for example, the Arctic icecap, a cave, or a cliff face. Others are more complex; for instance, a woodland, or a forest floor. Some habitats are so precise that they are called **microhabitats**, such as the area under a stone where a particular type of insect lives. Most habitats provide a home for many species, which form a community.

Each species is specially adapted to life in its habitat. For example, an animal is adapted to eat other members of a food chain or food web found in the same habitat. Some species may be found in different habitats. They may be found to have different patterns of behaviour or structure in these different habitats. For example, a plant such as the blackberry may grow in an open habitat, such as a field, or in a shaded one, such as woodland. Its leaves differ in the two habitats.

Major Biomes of the World

Go to site

Site providing information on the distribution and nature of the world's major biomes. It looks at the structure, growth patterns, and taxonomy of the vegetation, in the context of soil types and climate variations. The site contains supporting materials for students including an online glossary and study hints.

---

hacking

unauthorized access to computer systems, either for fun or for malicious or fraudulent purposes. Hackers generally use computers and telephone lines to obtain access. In computing, the term is used in a wider sense to mean using software for enjoyment or self-education, not necessarily involving unauthorized access. The most destructive form of hacking is the introduction of a computer virus.

There is some dispute over the correct use of the term hacker. Some believe hacker should be used to describe someone who develops computer software, with the term cracker being used for a person who breaks into a computer system.

Some hackers call themselves ethical or white hat hackers. Ethical hackers probe Web sites for holes in the security system, either fixing the holes themselves or alerting the company in question. White hat hackers are computer experts employed by companies to hack into their networks to expose weaknesses in security.

Hacking Lexicon

Go to site

A to Z of hacking. This extensive list includes numerous terms 'used within the context of information security'. Entries are accompanied by 'key-point' remarks and examples.

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hadal zone

deepest level of the ocean, below the abyssal zone, at depths of greater than 6,000 m/19,500 ft. The ocean trenches are in the hadal zone. There is no light in this zone and pressure is over 600 times greater than atmospheric pressure.

Hadar

or Beta Centauri

second-brightest star in the constellation of Centaurus, and the 11th-brightest in the night sky. It is a blue-white giant star of magnitude 0.61, some 320 light years from the Sun. It is a binary star, comprising two stars of magnitudes 0.7 and 3.9.

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haddock

marine fish belonging to the cod family and found off the North Atlantic coastline. It is brown with silvery underparts and black markings above the pectoral fins. It can grow up to 1 m/3 ft in length. Haddock are important food fish; about 45 million kg/100 million lb are taken annually off the New England fishing banks alone. (Species *Melanogrammus aeglefinus*, family Gadidae.)

Hadrian's Wall

line of fortifications built by the Roman emperor Hadrian across northern Britain from the Cumbrian coast on the west to the North Sea on the east. The wall itself ran from Bowness-on-Windermere on the Solway Firth to Wallsend on the River Tyne, a distance of 110 km/68 mi. It was defended by 16 forts and smaller intermediate fortifications. It was breached by the Picts on several occasions and finally abandoned in about 383.

Referred to colloquially as the **Picts' Wall**, it was covered in some parts with a glistening, white coat of mortar. Numerous modifications were made to the original plan, usually owing to the need to conserve labour and resources for such an enormous project.

Hadrian's Wall

(Image © Research Machines plc)

Hadrian's Wall, seen from milecastle 41. Milecastles are the forts that the Romans erected at intervals along the wall. It was built by emperor Hadrian in 122 and was 80 Roman miles long (110 km/68 mi). Running from Wallsend-on-Tyne to Bowness-on-Windermere in the west, its purpose was to protect Roman England from the Scottish 'barbarians.'

Hadrian's Wall

(Image © Research Machines plc)

The multi-seater lavatory at Housesteads Fort (known to the Romans as Vercovicium) on Hadrian's Wall. Housesteads Fort in Cumbria was constructed along with the rest of the wall in around 122. The toilet is typical of Roman 'public' lavatories.

Hadrian's Wall

Go to site

This site provides historical information, photographs and diagrams of Hadrian's Wall, as well as descriptions of its features. You can also learn the latest 'news from the wall' and pick up tourist tips, including information on where to stay when visiting the wall.

---

hadron

in physics, a subatomic particle that experiences the strong nuclear force. Each is made up of two or three indivisible particles called quarks. The hadrons are grouped into the baryons (protons, neutrons, and hyperons), consisting of three quarks, and the mesons, consisting of two quarks.

Haeckel, Ernst Heinrich Philipp August (1834-1919)

German zoologist and philosopher. His theory of 'recapitulation', expressed as 'ontogeny repeats phylogeny' (or that embryonic stages represent past stages in the organism's evolution), has been superseded, but it stimulated research in embryology.

---

haematite

or hematite

principal ore of iron, consisting mainly of iron(III) oxide, Fe_2O_3. It occurs as **specular haematite** (dark, metallic lustre), **kidney ore** (reddish radiating fibres terminating in smooth, rounded surfaces), and a red earthy deposit.

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haematology

medical speciality concerned with disorders of the blood.

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haemoglobin

protein used by all vertebrates and some invertebrates for oxygen transport because the two substances combine reversibly. In vertebrates it occurs in red blood cells (erythrocytes), giving them their colour.

In the lungs or gills where the concentration of oxygen is high, oxygen attaches to haemoglobin to form **oxyhaemoglobin**. This process effectively increases the amount of oxygen that can be carried in the bloodstream. The oxygen is later released in the body tissues where it is at a low concentration, and the deoxygenated blood returned to the lungs or gills. Haemoglobin will combine also with carbon monoxide to form carboxyhaemoglobin, which has the effect of reducing the amount of oxygen that can be carried in the blood.

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haemolymph

circulatory fluid of those molluscs and insects that have an 'open' circulatory system. Haemolymph contains water, amino acids, sugars, salts, and white cells like those of blood. Circulated by a pulsating heart, its main functions are to transport digestive and excretory products around the body. In molluscs, it also transports oxygen and carbon dioxide.

---

haemolysis

destruction of red blood cells. Aged cells are constantly being lysed (broken down), but increased wastage of red cells is seen in some infections and blood disorders. It may result in jaundice (through the release of too much haemoglobin) and in anaemia.

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haemophilia

any of several inherited diseases in which normal blood clotting is impaired. The sufferer experiences prolonged bleeding from the slightest wound, as well as painful internal bleeding without apparent cause.

Haemophilias are nearly always sex-linked, transmitted through the female line only to male infants; they have afflicted a number of European royal households. Males affected by the most common form are unable to synthesize Factor VIII, a protein involved in the clotting of blood. Treatment is primarily with Factor VIII (now mass-produced by recombinant techniques), but the haemophiliac remains at risk from the slightest incident of bleeding. The disease is a painful one that causes deformities of joints.

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haemorrhage

loss of blood from the circulatory system. It is 'manifest' when the blood can be seen, as when it flows from a wound, and 'occult' when the bleeding is internal, as from an ulcer or internal injury.

Rapid, profuse haemorrhage causes shock and may prove fatal if the circulating volume cannot be replaced in time. Slow, sustained bleeding may lead to anaemia. Arterial bleeding is potentially more serious than blood lost from a vein. It may be stemmed by applying pressure directly to the wound.

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haemorrhoids

distended blood vessels (varicose veins) in the area of the anus, popularly called **piles**.

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haemostasis

natural or surgical stoppage of bleeding. In the natural mechanism, the damaged vessel contracts, restricting the flow, and blood platelets plug the opening, releasing chemicals essential to clotting.

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hafnium

chemical symbol Hf

(Latin Hafnia 'Copenhagen')

silvery, metallic element, atomic number 72, relative atomic mass 178.49. It occurs in nature in ores of zirconium, the properties of which it resembles. Hafnium absorbs neutrons better than most metals, so it is used in the control rods of nuclear reactors; it is also used for light-bulb filaments.

It was named in 1923 by Dutch physicist Dirk Coster (1889-1950) and Hungarian chemist Georg von Hevesy after the city of Copenhagen, where the element was discovered.

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hagfish

eel-like marine fish. Hagfish are virtually blind and jawless, with slit mouths surrounded by four pairs of tentacles. They attack other fish, usually those which are dead or dying, and rasp away all the flesh with their powerful, tooth-studded tongues, leaving only the skeleton of their prey. When not seeking food they burrow in mud at the bottom of the sea.

They occur in the temperate seas of both northern and southern hemispheres. The species of the genus *Heptatretus* inhabit the north Pacific and the seas off New Zealand, South Africa and Chile. Hagfish have 150 slime glands along their sides. If a hagfish is placed in a five-gallon/23-litre bucket of water and then subjected to stress, most of the water will be converted to slime within minutes.

classification

Hagfish are in the order Myxiniformes, class Myxini, superclass Agnatha.

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hail

precipitation in the form of pellets of ice (hailstones). Water droplets freeze as they are carried upwards. As the circulation continues, layers of ice are deposited around the droplets until they become too heavy to be supported by the air current and they fall as a hailstorm. It is caused by the circulation of moisture in strong convection currents, usually within cumulonimbus clouds.

hail

Hailstones can kill. In the Gopalganji region of Bangladesh in 1988, 92 people died after being hit by huge hailstones weighing up to 1 kg/2.2 lb.

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hair

fine filament growing from mammalian skin. Each hair grows from a pit-shaped follicle embedded in the second layer of the skin, the dermis. It consists of dead cells impregnated with the protein keratin.

The average number of hairs on a human head varies from 98,000 (red-heads) to 120,000 (blondes). Each grows at the rate of 5-10 mm/0.2-0.4 in per month, lengthening for about three years before being replaced by a new one. A coat of hair helps to insulate land mammals by trapping air next to the body. The thickness of this layer can be varied at will by raising or flattening the coat. In some mammals a really heavy coat may be so effective that it must be shed in summer and a thinner one grown. Hair also aids camouflage, as in the zebra and the white winter coats of Arctic animals; protection, as in the porcupine and hedgehog; bluffing enemies by apparently increasing the size, as in the cat; sexual display, as in humans and the male lion; and its colouring or erection may be used for communication.

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hairstreak

any of a group of small butterflies, related to blues and coppers. Hairstreaks live in both temperate and tropical regions. Most of them are brownish or greyish-blue with hairlike tips streaked with white at the end of their hind wings. (Genera *Callophrys* and other related genera, family Lycaenidae.)

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hake

any of various marine fishes belonging to the cod family, found in northern European, African, and American waters. They have silvery elongated bodies and grow up to 1 m/3 ft in length. They have two dorsal fins and one long anal fin. The silver hake (*M. bilinearis*) is an important food fish. (Genera *Merluccius* and *Urophycis*, family Gadidae.)

Haldane, J(ohn) B(urdon) S(anderson) (1892-1964)

Anglo-Indian physiologist, geneticist, and author of popular science books. In 1936 he showed the genetic link between haemophilia and colour blindness.

Hale, George Ellery (1868-1938)

US astronomer. He made pioneer studies of the Sun and founded three major observatories. In 1889 he invented the spectroheliograph, a device for photographing the Sun at particular wavelengths. In 1917 he established on Mount Wilson, California, a 2.5-m/100-in reflector, the world's largest telescope until superseded in 1948 by the 5-m/200-in reflector on Mount Palomar, which Hale had planned just before he died.

He, more than any other, was responsible for the development of observational astrophysics in the USA. He also founded the Yerkes Observatory in Williams Bay, Wisconsin, in 1897, with the largest refractor, 102 cm/40 in, ever built at that time.

Hale-Bopp

C/1995 01

large and exceptionally active comet, which in March 1997 made its closest fly-by to Earth since 2000 BC, coming within 190 million km/118 million mi. It has a nucleus of approximately 40 km/25 mi and an extensive gas coma (when close to the Sun Hale-Bopp released 10 tonnes of gas every second). Unusually, Hale-Bopp has three tails: one consisting of dust particles, one of charged particles, and a third of sodium particles.

Hale-Bopp was discovered independently in July 1995 by two US amateur astronomers, Alan Hale and Thomas Bopp.

Comet Hale-Bopp

Go to site

Nearly 5,000 images of the comet, which was visible to the naked eye when it came within 190 million km/118 million mi of the Earth in 1997. The site also includes information on its discovery and position, and details of current research findings.

Hales, Stephen (1677-1761)

English scientist who studied the role of water and air in the maintenance of life. He gave accurate accounts of water movement in plants. He demonstrated that plants absorb air, and that some part of that air is involved in their nutrition. His work laid emphasis on measurement and experimentation.

Hales's work on air revealed to him the dangers of breathing 'spent' air in enclosed places, and he invented a ventilator which improved survival rates when introduced on naval, merchant, and slave ships, in hospitals, and in prisons.

half-life

during radioactive decay, the time in which the activity of a radioactive source decays to half its original value (the time taken for half the atoms to decay). In theory, the decay process is never complete and there is always some residual radioactivity. For this reason, the half-life of a radioactive isotope is measured, rather than the total decay time. It may vary from millionths of a second to billions of years.

To determine a short half-life a Geiger-Muller tube can be used to count the number of particles emitted by a sample. To determine a longer half-life a mass spectrometer is used. Half-lives can be hours, months, or years. Some examples are: sodium-24, 15 hours; carbon-14, 5,730 years; plutonium-239, 24,000 years; and uranium-238, 4,500 million years.

halftone process

technique used in printing to reproduce the full range of tones in a photograph or other illustration. The intensity of the printed colour is varied from full strength to the lightest shades, even if one colour of ink is used. The picture to be reproduced is photographed through a screen ruled with a rectangular mesh of fine lines, which breaks up the tones of the original into areas of dots that vary in frequency according to the intensity of the tone. In the darker areas the dots run together; in the lighter areas they have more space between them.

halibut

any of a group of large flatfishes found in the Atlantic and Pacific oceans. The largest of the flatfishes, they may grow up to 2 m/6 ft in length and weigh 90-135 kg/200-300 lb. They are a very dark mottled brown or green above and pure white on the underside. The Atlantic halibut (*H. hippoglossus*) is caught offshore at depths from 180 m/600 ft to 730 m/2,400 ft. (Genus *Hippoglossus*, family Pleuronectidae.)

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halide

any compound produced by the combination of a halogen, such as chlorine or iodine, with a less electronegative element (see electronegativity). Halides may be formed by ionic bonds or by covalent bonds.

In organic chemistry, alkyl halides consist of a halogen and an alkyl group, such as methyl chloride (chloromethane).

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halite

mineral form of sodium chloride, NaCl. Common salt is the mineral halite. When pure it is colourless and transparent, but it is often pink, red, or yellow. It is soft and has a low density.

Halite occurs naturally in evaporite deposits that have precipitated on evaporation of bodies of salt water. As rock salt, it forms beds within a sedimentary sequence; it can also migrate upwards through surrounding rocks to form salt domes. It crystallizes in the cubic system.

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halitosis

bad breath. It may be caused by poor oral hygiene; disease of the mouth, throat, nose, or lungs; or disturbance of the digestion.

Hall effect

production of a voltage across a conductor or semiconductor carrying a current at a right angle to a surrounding magnetic field. It was discovered in 1897 by the US physicist Edwin Hall (1855-1938). It is used in the **Hall probe** for measuring the strengths of magnetic fields and in magnetic switches.

Haller, Albrecht von (1708-1777)

Swiss physician and scientist, founder of neurology. He studied the muscles and nerves, and concluded that nerves provide the stimulus that triggers muscle contraction. He also showed that it is the nerves, not muscle or skin, that receive sensation.

Halley, Edmond (1656-1742)

English astronomer. He not only identified the comet that was later to be known by his name, but also compiled a star catalogue, detected the proper motion of stars using historical records, and began a line of research that, after his death, resulted in a reasonably accurate calculation of the astronomical unit.

Halley calculated that the comet sightings reported in 1456, 1531, 1607, and 1682 all represented reappearances of the same comet. He reasoned that the comet would follow a parabolic path and announced in 1705 in his *Synopsis Astronomia Cometicae* that it would reappear in 1758. When it did, public acclaim for the astronomer was such that his name was irrevocably attached to it.

He made many other notable contributions to astronomy, including the discovery of the proper motions of the stars named Aldebaran, Arcturus, and Sirius, and working out a method of obtaining the solar parallax by observations made during a transit of Venus across the Sun. He was Astronomer Royal from 1720.

Halley, Edmond

Go to site

Detailed notes on the life of English astronomer Edmond Halley. The information here includes his life dates, family, and education. There are also descriptions of his religion, scientific disciplines, patronage, and his role in the development of technology.

Halley's Comet

comet that orbits the Sun roughly every 75 years, named after English astronomer Edmond Halley, who calculated its orbit. It is the brightest and most conspicuous of the periodic comets, and recorded sightings go back over 2,000 years. The comet travels around the Sun in the opposite direction to the planets.

Its orbit is inclined at almost 20° to the main plane of the Solar System and ranges between the orbits of Venus and Neptune. It will next reappear in 2061.

The comet was studied by space probes at its last appearance in 1986. The European probe Giotto showed that the nucleus of Halley's Comet is a tiny and irregularly shaped chunk of ice, measuring some 15 km/10 mi long by 8 km/5 mi wide, coated in a layer of very dark material, thought to be composed of carbon-rich compounds. This surface coating has a very low albedo, reflecting just 4% of the light it receives from the Sun. Although the comet is one of the darkest objects known, it has a glowing head and tail produced by jets of gas from fissures in the outer dust layer. These vents cover 10% of the total surface area and become active only when exposed to the Sun. The force of these jets affects the speed of the comet's travel in its orbit.

Halley's Comet

Go to site

Attractive site devoted to the comet, with facts and statistics, images, and information about the spacecraft that have monitored it.

hallmark

official mark stamped on British gold, silver, and (from 1913) platinum, instituted in 1327 (royal charter of London Goldsmiths) in order to prevent fraud. After 1363 personal marks of identification were added. Now tests of metal content are carried out at authorized assay offices in London, Birmingham, Sheffield, and Edinburgh; each assay office has its distinguishing mark, to which is added a maker's mark, date letter, and mark guaranteeing standard.

hallucinogen

any substance that acts on the central nervous system to produce changes in perception and mood and often hallucinations. Hallucinogens include LSD, peyote, and mescaline. Their effects are unpredictable and they are illegal in most countries.

In some circumstances hallucinogens may produce panic or even suicidal feelings, which can recur without warning several days or months after taking the drug. In rare cases they produce an irreversible psychotic state mimicking schizophrenia. Spiritual or religious experiences are common, hence the ritual use of hallucinogens in some cultures. They work by chemical interference with the normal action of neurotransmitters in the brain.

halogen

any of a group of five non-metallic elements with similar chemical bonding properties: fluorine, chlorine, bromine, iodine, and astatine. They form a linked group (Group 7) in the periodic table, descending from fluorine, the most reactive, to astatine, the least reactive. They all have coloured vapours and are poisonous. Melting points and boiling points increase going down the group. They combine directly with most metals to form salts, such as common salt (NaCl). Each halogen has seven electrons in its valence shell, which accounts for the chemical similarities displayed by the group.

Fluorine and chlorine are gases, bromine is a liquid, and astatine is a solid. The colour of the element darkens going down the group from fluorine, which is pale yellow, to astatine, which is black.

Halogens

Go to site

Definition and properties of halogens: fluorine, chlorine, bromine, iodine, and astatine. The history of their classification is also given and links are provided to related topics, such as the alkali metals.

halon

organic chemical compound containing one or two carbon atoms, together with bromine and other halogens. The most commonly used are halon 1211 (bromochlorodifluoromethane) and halon 1301 (bromotrifluoromethane). The halons are gases and are widely used in fire extinguishers. As destroyers of the ozone layer, they are up to ten times more effective than chlorofluorocarbons (CFCs), to which they are chemically related.

Levels in the atmosphere are rising by about 25% each year, mainly through the testing of fire-fighting equipment. The use of halons in fire extinguishers was banned in 1994.

halophyte

plant adapted to live where there is a high concentration of salt in the soil, for example in salt marshes and mud flats.

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hamadryad

or king cobra or giant cobra

large and poisonous cobra found from India to China and the Philippines, sometimes reaching a length of 5 m/16 ft. It is one of the longest and most venomous of snakes, and is yellow with black crossbands.

classification

The hamadryad *Ophiophagus hannah* is in family Elapidae, suborder Serpentes, order Squamata, class Reptilia.

---

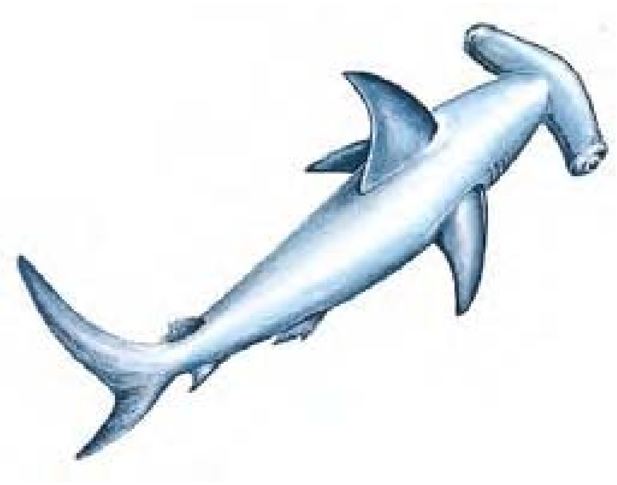
hammerhead

any of several species of shark found in tropical seas, characterized by having eyes at the ends of flattened hammerlike extensions of the skull. Hammerheads can grow to 4 m/13 ft in length. (Genus *Sphyrna*, family Sphyrnidae.)

hammerhead

Hammerheads can swim at speeds up to 70 kph/43 mph.

hammerhead



(Image © Research Machines plc)

The hammerhead shark's name derives from the flattened projections at the side of its head. The eyes are on the outer edges of the projections. The advantages of this head design are not known; it may be that the shark's vision is improved by the wide separation of the eyes, or the head may provide extra lift by acting as an aerofoil.

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hamster

any of a group of burrowing rodents with a thickset body, short tail, and cheek pouches to carry food. Several genera are found across Asia and in southeastern Europe. Hamsters are often kept as pets. (Genera include *Cricetus* and *Mesocricetus*, family Cricetidae.)

Species include the European and Asian **black-bellied** or **common hamster** (*C. cricetus*), about 25 cm/10 in long, which can be a crop pest and stores up to 90 kg/200 lb of seeds in its burrow. The **golden hamster** (*M. auratus*) lives in western Asia and southeastern Europe. All golden hamsters now kept as pets originated from one female and 12 young captured in Syria in 1930.

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hand

unit used in measuring the height of a horse from front hoof to shoulder (withers). One hand equals 10.2 cm/4 in.

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hanging valley

minor (tributary) valley that joins a larger glacial trough at a higher level than the trough floor. During glaciation the ice in the smaller valley was unable to erode as deeply as the ice in the trough, and so the valley was left perched high on the side of the trough when the ice retreated. A river or stream flowing along the hanging valley often forms a waterfall as it enters the trough. The Bridal Veil Falls in Yosemite National Park (USA) is an excellent example.

---

haploid

having a single set of chromosomes in each cell. Most higher organisms are diploid - that is, they have two sets - but their gametes (sex cells) are haploid. Some plants, such as mosses, liverworts, and many seaweeds, are haploid, and male honey bees are haploid because they develop from eggs that have not been fertilized. See also meiosis.

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hard disk

in computing, a storage device usually consisting of a rigid metal disk coated with a magnetic material. Data are read from and written to the disk by means of a disk drive. The hard disk may be permanently fixed into the drive or in the form of a disk pack that can be removed and exchanged with a different pack. Hard disks can have capacities as high as 500 gigabytes, with different versions intended for use with mainframe or personal computers.

Hard Disk Drives

Go to site

Chapter of the Internet PC Guide on hard disk drives. The pages look at the principles, configuration, and design of hard disk drives, and document their history and development.

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hardening of oils

transformation of liquid oils to solid products by hydrogenation.

Vegetable oils contain double covalent carbon-to-carbon bonds and are therefore examples of unsaturated compounds. When hydrogen is added to these double bonds, the oils become saturated. The more saturated oils are waxlike solids.

---

hardness

the resistance of a material to indentation by various means, such as scratching, abrasion, wear, and drilling. Methods of heat treatment can increase the hardness of metals. A scale of hardness was devised by German-Austrian mineralogist Friedrich Mohs in the 1800s, based upon the hardness of certain minerals from soft talc (Mohs hardness 1) to diamond (10), the hardest of all materials.

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hardware

mechanical, electrical, and electronic components of a computer system, as opposed to the various programs, which constitute software.

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hard water

water that does not lather easily with soap, and produces a deposit or scale (limescale) in kettles. It is caused by the presence of certain salts of calcium and magnesium.

Temporary hardness is caused by the presence of dissolved hydrogencarbonates (bicarbonates); when the water is boiled, they are converted to insoluble carbonates that precipitate as 'scale'.
Permanent hardness is caused by sulphates and silicates, which are not affected by boiling. Water can be softened by distillation, ion exchange (the principle underlying commercial water softeners), targeting with low frequency magnetic waves (this alters the crystal structure of calcium salts so that they remain in suspension), addition of sodium carbonate or of large amounts of soap, or boiling (to remove temporary hardness).

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hare

mammal closely related to the rabbit, similar in appearance but larger. Hares have very long black-tipped ears, long hind legs, and short upturned tails. (Genus *Lepus*, family Leporidae, order Lagomorpha.)

Throughout the long breeding season (June-August) there are chases and 'boxing matches' among males and females; the expression 'mad as a March hare' arises from this behaviour. The young ('leverets') are left by the mother immediately after birth. She stays about 200 m away where she is unlikely to draw attention to her litter and feeds them for just 10 minutes every 24 hours. Hares are largely nocturnal and avoid predators during the day by their stillness.

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harebell

perennial plant of the bellflower family, with bell-shaped blue flowers, found on dry grassland and heaths. It is known in Scotland as the bluebell. (*Campanula rotundifolia*, family Campanulaceae.)

harelip

congenital facial deformity, a cleft in the upper lip and jaw, which may extend back into the palate (cleft palate). It can be remedied by surgery.

Hargreaves, James (c. 1720-1778)

English inventor who co-invented a carding machine for cotton in 1760. In *c.* 1764 he invented his 'spinning jenny' (patented in 1770), which enabled a number of threads to be spun simultaneously by one person.

harmattan

in meteorology, a dry and dusty northeast wind that blows over West Africa.

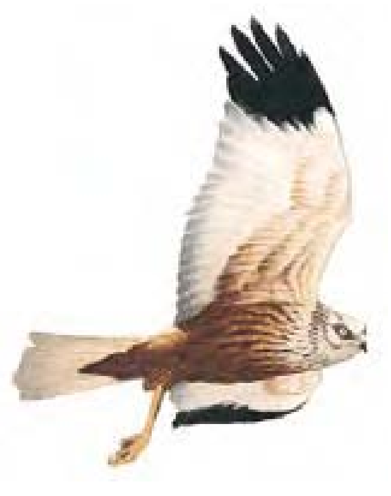
Harrier

the only truly successful vertical takeoff and landing fixed-wing aircraft, often called the **jump jet**. It was built in Britain and made its first flight in 1966. It has a single jet engine and a set of swivelling nozzles. These deflect the jet exhaust vertically downwards for takeoff and landing, and to the rear for normal flight. Designed to fly from confined spaces with minimal ground support, it refuels in midair.

harrier

any of a group of birds of prey, family Accipitridae, order Falconiformes. Harriers have long wings and legs, a small head with a short beak, an owl-like frill of thickset feathers around the face, and soft plumage. They eat frogs, birds, snakes, and small mammals, and are found mainly in marshy areas throughout the world.

marsh harrier



(Image © Research Machines plc)

The eight species of the marsh harrier, a long-winged hawk, are found among fens, swamps, marshes, and reed beds throughout Europe, North Africa, and the islands of the Indian Ocean and the Pacific. They feed on reptiles, amphibians, eggs, small mammals, and even carrion which they seek by quartering the ground in low flight and then dropping down.

harrier

breed of hound, similar to a foxhound but smaller, used in packs for hare-hunting.

Harrier Club of America

Go to site

Details of the origins of the breed, breed standards, and shows. There are a large number of photos, a full bibliography, and links to other harrier sites. Information on the dog is accessed by clicking on the harrier at the bottom of the home page.

harrow

agricultural implement used to break up the furrows left by the plough and reduce the soil to a fine consistency or tilth, and to cover the seeds after sowing. The traditional harrow consists of spikes set in a frame; modern harrows use sets of discs.

hartebeest

large African antelope with lyre-shaped horns set close on top of the head in both sexes. It can grow to 1.5 m/5 ft tall at the rather humped shoulders and up to 2 m/6 ft long. Although they are clumsy-looking runners, hartebeest can reach speeds of 65 kph/40 mph. (Species *Alcelaphus buselaphus*, family Bovidae.)

hart's-tongue

fern with straplike undivided fronds, up to 60 cm/24 in long, which have clearly visible brown spore-bearing organs on the undersides. The plant is native to Europe, Asia, and eastern North America, and is found on walls, in shady rocky places, and in woods. (*Phyllitis scolopendrium*, family Polypodiaceae.)

harvestman

small animal (an arachnid) related to spiders with very long, thin legs and a small body. Harvestmen are different from true spiders in that they do not have a waist or narrow part to the oval body. They feed on small insects and spiders, and lay their eggs in autumn, to hatch the following spring or early summer. They are found from the Arctic to the tropics. (Order Opiliones.)

harvest mite

another name for the chigger, a parasitic mite.

Harvey, William (1578-1657)

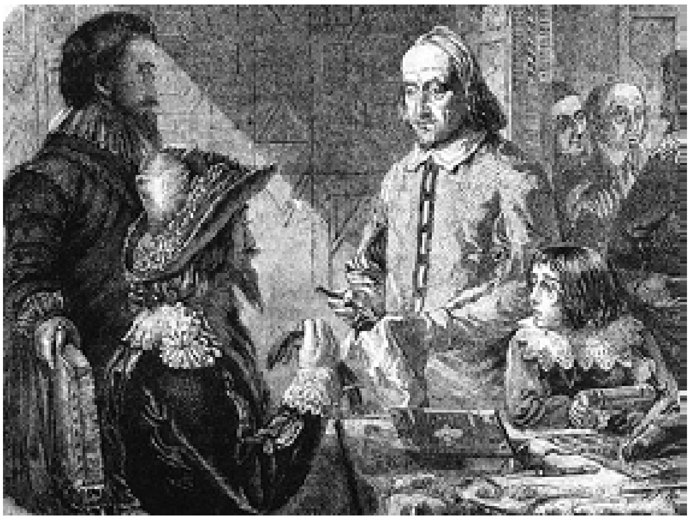
English physician who discovered the circulation of blood. In 1628 he published his book *De motu cordis/On the Motion of the Heart and the Blood in Animals*. He also explored the development of chick and deer embryos.

Harvey's discovery marked the beginning of the end of medicine as taught by Galen, which had been accepted for 1,400 years.

Harvey, William

A first edition of the book in which he outlined his discovery of the circulation of blood sold for $530,500 in 1998.

Harvey



(Image © Billie Love)

English doctor and anatomist William Harvey, demonstrating his theory of the circulation of the blood to the British king Charles I and other physicians. His discovery marked a new epoch in medical science, recognizing that the heart pumps blood in a continuous circulation. Appointed physician to St.

Bartholomew's Hospital, London, Harvey attended James I during his last illness and later became physician to his son Charles.

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hashish

drug made from the resin contained in the female flowering tops of hemp (cannabis).

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hash total

in computing, a validation check in which an otherwise meaningless control total is calculated by adding together numbers (such as payroll or account numbers) associated with a set of records. The hash total is checked each time data are input, in order to ensure that no entry errors have been made.

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hassium

chemical symbol Hs

synthesized, radioactive element of the transactinide series, atomic number 108, relative atomic mass 265. First synthesized in 1984 by the Laboratory for Heavy-Ion Research in Darmstadt, Germany, it was known by the temporary name unniloctium until 1997.

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haustorium

plural haustoria

specialized organ produced by a parasitic plant or fungus that penetrates the cells of its host to absorb nutrients. It may be either an outgrowth of hyphae (see hypha), as in the case of parasitic fungi, or of the stems of flowering parasitic plants, as in dodders (*Cuscuta*). The suckerlike haustoria of a dodder penetrate the vascular tissue of the host plant without killing the cells.

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hawfinch

European finch, about 18 cm/7 in long. It feeds on berries and seeds, and can crack cherry stones with its large, powerful beak. The male bird has brown plumage, a black throat and black wings with a bold white shoulder stripe, a short white-tipped tail, and a broad band of grey at the back of the neck. (Species *Coccothraustes coccothraustes*, family Fringillidae, order Passeriformes.)

Hawfinches spend most of their time in the treetops, where they eat the fruits of pine, hornbeam, plum, cherry, hawthorn, laurel, and holly trees. They build their nests of twigs and mosses in lichen-covered trees, 2-10 m/6.5-33 ft above the ground. They are abundant in southern Europe and are also found in the temperate parts of Asia.

---

hawk

any of a group of small to medium-sized birds of prey, belonging to the same family as eagles, kites, ospreys, and vultures. Hawks have short, rounded wings and a long tail compared with falcons, and keen eyesight; the sparrow hawk and goshawk are examples. (Especially genera *Accipiter* and *Buteo*, family Accipitridae.)

hawk

Some hawks have evolved a unique way of hanging on to their prey. The African harrier hawk and the Central and South American crane hawk can bend their legs both backwards and forwards from the middle joint. Their prey (mostly frogs, lizards, and baby birds) thus has great difficulty eluding them in even the trickiest crevices.

Hawking, Stephen (William) (1942-)

English physicist and cosmologist whose work in general relativity - particularly gravitational field theory - led to a search for a quantum theory of gravity to explain black holes and the Big Bang, singularities that classical relativity theory does not adequately explain. His book *A Brief History of Time* (1988) gives a popular account of cosmology and became an international best-seller. He later co-wrote (with Roger Penrose) *The Nature of Space and Time* (1996), and published *The Universe in a Nutshell* in 2002.

Hawking's objective of producing an overall synthesis of quantum mechanics and relativity theory began around the time of the publication in 1973 of his seminal book *The Large Scale Structure of Space-Time*, written with G F R Ellis. His most remarkable result, published in 1974, was that black holes could in fact emit particles in the form of thermal radiation - the so-called **Hawking radiation**.

Hawking, Stephen

Go to site

Stephen Hawking's own home page, with a brief biography, disability advice, and a selection of his lectures, including 'The beginning of time' and a series debating the nature of space and time.

Stephen Hawking's Universe

Go to site

Interesting site with original essays by some of today's leading figures in cosmology. The topics covered include 'Strange stuff explained' and 'Unsolved mysteries'.

---

hawk moth

or sphinx moth

any of a family, Sphingidae, of moths with thick bodies and narrow wings. Some 1,000 species are distributed throughout the world, but they are mainly tropical. The large hawk-moth larva usually has a 'horn' at the end of its body - for example, the bright-green tomato hornworm *Protoparcequinquemaculata*.

Haworth, (Walter) Norman (1883-1950)

English organic chemist who was awarded the Nobel Prize for Chemistry in 1937 for his work in synthesizing a vitamin (ascorbic acid, vitamin C) in 1933. He made significant advances in determining the structures of many carbohydrates, particularly sugars. He was knighted in 1947.

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hawthorn

any of a group of shrubs or trees belonging to the rose family, growing abundantly in eastern North America, and also in Europe and Asia. All have alternate, toothed leaves and bear clusters of showy white, pink, or red flowers. Their small applelike fruits can be red, orange, blue, or black. Hawthorns are popular as ornamentals. (Genus *Crataegus*, family Rosaceae.)

hawthorn

(Image © Research Machines plc)

A hawthorn tree, *Crataegus monogyna* in full blossom in May. The hawthorn, also known as the May- tree or whitethorn, is native to the British Isles. Its flowers are symbolic of spring and associated with lovers. Felling a hawthorn tree is traditionally thought to bring bad luck.

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hay

preserved grass used for winter livestock feed. The grass is cut and allowed to dry in the field before being removed for storage in a barn.

The optimum period for cutting is when the grass has just come into flower and contains most feed value. During the natural drying process, the moisture content is reduced from 70-80% down to a safe level of 20%. In normal weather conditions, this takes from two to five days, during which time the hay is turned by machine to ensure even drying. Hay is normally baled before removal from the field.

hay

(Image © Garret Nagle)

Baled hay in a field in Oxfordshire, England. Farming removes many nutrients from ecosystems. In a natural ecosystem nutrients are recycled during leaf-fall. In farming systems, however, nutrients are removed during harvest. Some are consumed directly by people, whereas others – such as the hay here – are consumed by animals, which are then in turn consumed by people. The more intensive the farming system, the more nutrients are taken from the land.

Hayashi track

in astronomy, path on the Hertzsprung-Russell diagram taken by protostars as they emerge from the clouds of dust and gas out of which they were born. A protostar appears on the right (cool) side of the Hertzsprung-Russell diagram and follows a Hayashi track until it arrives on the main sequence where hydrogen burning can start. It is named after the Japanese astrophysicist Chushiro Hayashi, who studied the theory of protostars in the 1960s.

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hay fever

allergic reaction to pollen, causing sneezing, with inflammation of the nasal membranes and conjunctiva of the eyes. Symptoms are due to the release of histamine. Treatment is by antihistamine drugs. An estimated 25% of Britons, 33% of Americans, and 40% of Australians suffer from hayfever.

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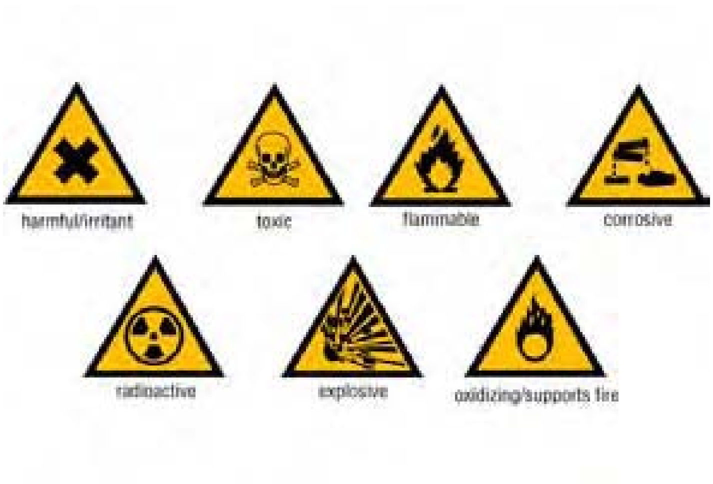
hazardous waste

waste substance, usually generated by industry, that represents a hazard to the environment or to people living or working nearby. Examples include radioactive wastes, acidic resins, arsenic residues, residual hardening salts, lead from car exhausts, mercury, non-ferrous sludges, organic solvents, asbestos, chlorinated solvents, and pesticides. The cumulative effects of toxic waste can take some time to become apparent (anything from a few hours to many years), and pose a serious threat to the ecological stability of the planet; its economic disposal or recycling is the subject of research.

hazard label



(Image © Research Machines plc)

The internationally recognized symbols, warning of the potential dangers of handling certain substances.

hazel

any of a group of shrubs or trees that includes the European common hazel or cob (*C. avellana*), of which the filbert is the cultivated variety. North American species include the American hazel (*C. americana*). (Genus *Corylus*, family Corylaceae.)

HDTV

abbreviation for high-definition television.

headache

pain felt within the skull. Most headaches are caused by stress or tension, but some may be symptoms of brain or systemic disease, including fever.

Chronic daily headache may be caused by painkiller misuse, according to the European Headache Foundation in 1996. People who take daily analgesics to treat chronic headaches may actually be causing the headaches by doing so. See also migraine.

headland

area of land running out into the sea. Headlands are often high points on the coastline, usually with steep cliffs, and may be made of more resistant rock than adjacent bays. Erosion is concentrated on the flanks of headlands due to wave refraction. Good examples include the chalk headland between Handfast Point and Ballard Point near Swanage, England, and the area between Tennyson Down and The Needles, Isle of Wight, England.

head louse

parasitic insect that lives in human hair (see louse).

headward erosion

the backwards erosion of material at the source (start) of a river or stream. Broken rock and soil at the source are carried away by the river, causing the source of the river to move backwards as erosion takes place in the opposite direction to the river's flow. The resulting lowering of the land behind the source may, over time, cause the river to cut backwards into a neighbouring valley to 'capture' another river.

health care

implementation of a satisfactory regimen to ensure long-lasting good health. Life expectancy is determined by the overall efficiency of the body's vital organs and the rate at which these organs deteriorate. Fundamental health care concerns include:

smoking

this is strongly linked to heart disease, stroke, bronchitis, lung cancer, and other serious diseases

exercise

regular physical exercise improves fitness, slows down the gradual decline in efficiency of the heart and lungs, and so helps to prolong life

diet

a healthy diet contains plenty of vegetable fibre, complex carbohydrates, vitamins, minerals, and enzymes, and polyunsaturated fats (which keep the level of blood cholesterol low), not saturated (animal) fats (which contribute to cholesterol storage in blood vessels)

weight

obesity (defined as generally being 20% or more above the desirable weight for age, sex, build, and height) is associated with many potentially dangerous conditions, such as coronary heart disease, diabetes, and stroke, as well as muscular and joint problems, and breathing difficulties

Animated Medical Graphics

Go to site

Uses animations to explain medical terms and topics to those without a medical background. Non-medical analogies are used in the explanations, to make the topics as accessible as possible.

HEBSWeb

Go to site

Neatly designed information service run by the Health Education Board of Scotland. The site is devoted to the promotion of public health issues and includes fact cards, posters, booklets, and statistics on smoking, mental and sexual health, dietary issues, accidents, and alcohol and drug misuse. The site also provides extensive accounts of campaigns, activities, support groups, leaflets, and other information especially geared for Scotland. There is also plenty of information for healthcare professionals.

Thrive Online

Go to site

General resource for every aspect of 'Healthy living'. The site has six main sections: 'Medical', 'Fitness', 'Sexuality', 'Nutrition', 'Serenity', and 'Weight'. Many smaller links deal with additional functionality, such as discussion boards about a range of topics. Tests can also be taken to see how healthy a person is.

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health screening

testing large numbers of apparently healthy people for disease (see screening).

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health, world

the health of people worldwide is monitored by the World Health Organization (WHO). Outside the industrialized world in particular, poverty and degraded environmental conditions mean that easily preventable diseases are widespread: WHO estimated in 1990 that 1 billion people, or 20% of the world's population, were diseased, in poor health, or malnourished. In North Africa and the Middle East, 25% of the population were ill.

vaccine-preventable diseases

Every year, 46 million infants are not fully immunized; 2.8 million children die and 3 million are disabled due to vaccine-preventable diseases (polio, tetanus, diphtheria, whooping cough, tuberculosis, and measles).

diarrhoea

Every year, there are 750 million cases in children, causing 4 million deaths. Oral rehydration therapy can correct dehydration and prevent 65% of deaths due to diarrhoeal disease. The basis of therapy is prepackaged sugar and salt. Treatment to cure the disease costs less than 20 cents, but fewer than one-third of children are treated in this way.

tuberculosis

1.6 billion people carry the bacteria, and there are 3 million deaths every year. Some 95% of all patients could be cured within six months using a specific antibiotic therapy which costs less than $30 per person.

prevention and cure

Increasing health spending in industrialized countries by only $2 per head would enable immunization of all children to be performed, polio to be eradicated, and drugs provided to cure all cases of diarrhoeal disease, acute respiratory infection, tuberculosis, malaria, schistosomiasis, and most sexually transmitted diseases.

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hearing aid

any device to improve the hearing of partially deaf people. Hearing aids usually consist of a battery-powered transistorized microphone/amplifier unit and earpiece. Some miniaturized aids are compact enough to fit in the ear or be concealed in the frame of eyeglasses.

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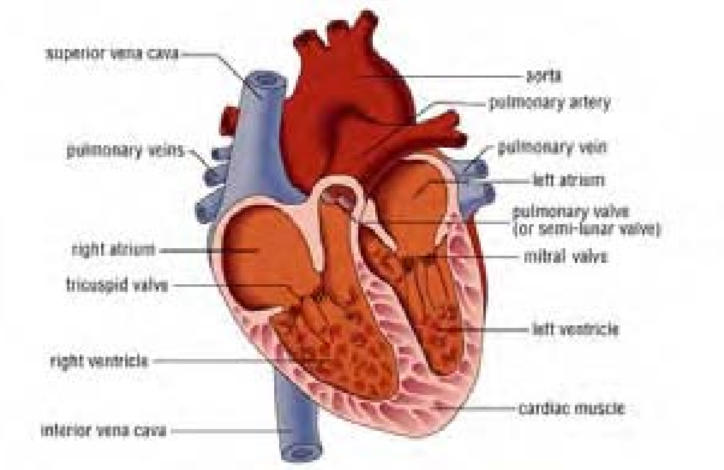
heart

muscular organ that rhythmically contracts to force blood around the body of an animal with a circulatory system. Annelid worms and some other invertebrates have simple hearts consisting of thickened sections of main blood vessels that pulse regularly. An earthworm has ten such hearts. Vertebrates have one heart. A fish heart has two chambers – the thin-walled atrium (once called the auricle) that expands to receive blood, and the thick-walled ventricle that pumps it out. Amphibians and most reptiles have two atria and one ventricle; birds and mammals have two atria and two ventricles. The beating of the heart is controlled by the autonomic nervous system and an internal control centre or pacemaker, the sinoatrial node.

The human heart is more or less conical in shape and is positioned within the chest, behind the breast bone, above the diaphragm, and between the two lungs. It has flattened back and front surfaces and is, in health, the size of a person's closed fist. However, it varies in size with the person's weight, age, sex, and state of health. Its capacity is about 20 cm^3 in the newborn, reaching 150-160 cm^3 in the mid-teens. The female heart has a smaller capacity and is lighter than the male. Mammals have a double circulatory system. In this kind of system the heart is divided into two halves, each half working as a separate pump. One side of the heart pumps blood to the lungs and back to the heart. The other side of the heart pumps blood to all other parts of the body and back to the heart.

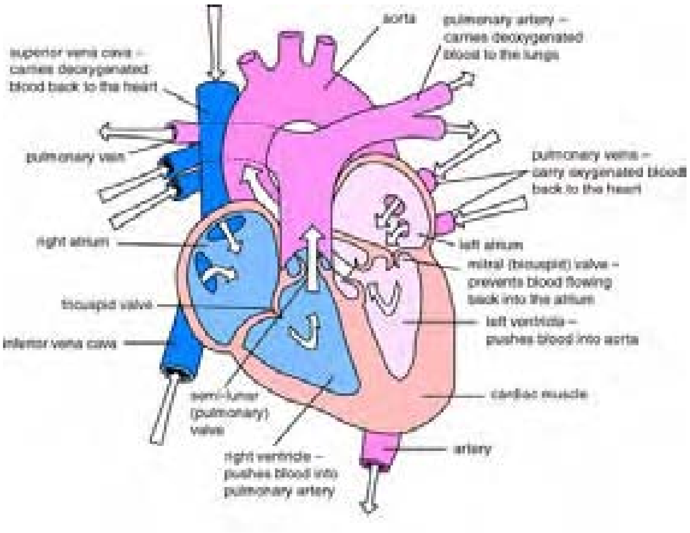
heart



(Image © Research Machines plc)

The structure of the human heart. During an average lifetime, the human heart beats more than 2,000 million times and pumps 500 million l/110 million gal of blood. The average pulse rate is 70–72 beats per minute at rest for adult males, and 78–82 beats per minute for adult females.

heart


aorta
pulmonary artery – carries deoxygenated blood to the lungs
superior vena cava – carries deoxygenated blood back to the heart
pulmonary vein
pulmonary veins – carry oxygenated blood back to the heart
right atrium
left atrium
mitral (bicuspid) valve – prevents blood flowing back into the atrium
tricuspid valve
left ventricle – pushes blood into aorta
inferior vena cava
cardiac muscle
semi-lunar (pulmonary) valve
artery
right ventricle – pushes blood into pulmonary artery

(Image © Research Machines plc)

The direction of blood flow through the heart.

Circulatory System: Online Learning

Go to site

Wide-ranging guide to the circulatory system. This attractive Web site contains pages on blood, arteries, veins, and capillaries, the heart, and diseases of the circulatory system. With accessible text and clear, attractive diagrams, this is an excellent resource.

Heart

Go to site

Graphic-intense Web site that allows you to follow blood flowing through the heart, using the animated interactive diagram. The names of the various chambers, blood vessels, and valves are all highlighted as the blood progresses. More facts are accessible through the site's links.

Heart: An Online Exploration

Go to site

Explore the heart: discover its complexities, development, and structure; follow the blood on its journey through the blood vessels; learn how to maintain a healthy heart; and look back on the history of cardiology. A picture gallery is also available to preview before the main section of the site.

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heart attack

or myocardial infarction

sudden onset of gripping central chest pain, often accompanied by sweating and vomiting, caused by death of a portion of the heart muscle following obstruction of a coronary artery by thrombosis (formation of a blood clot). Half of all heart attacks result in death within the first two hours, but in the remainder survival has improved following the widespread use of thrombolytic (clot-buster) drugs.

After a heart attack, most people remain in hospital for seven to ten days, and may make a gradual return to normal activity over the following months. How soon a patient is able to return to work depends on the physical and mental demands of their job.

Women are less likely to suffer heart attack than men. However, as heart disease in women tends to be given lower priority because of lower incidence, they tend to be more likely to die as a result. The best predictor of heart attacks among older people may be an echogram (sonogram) of carotid arteries.

American Heart Association

Go to site

Home page of the American Heart Association offers a risk assessment test, information about healthy living, including the effects of diet, and access to resources for both patients and carers.

Cut to the Heart

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page provides an interesting look at the history and pioneers of heart surgery. Read an article written by Robert Soufer, MD, which originally appeared in the *Yale University School of Medicine Heart Book*. This article provides an overview of the heart's function, the causes of heart failure, who is likely to develop heart failure, and what can be done to treat it. There is a section of photographs of troubled hearts with brief descriptions of what is ailing them. You can also view a map of the heart, which features a labelled diagram and an animated GIF of the path of blood flow through the heart with numbered descriptions. Below the diagram of the heart you will find a link to interesting facts about the human heart.

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heartbeat

regular contraction and relaxation of the heart, and the accompanying sounds. As blood passes through the heart a double beat is heard. The first is produced by the sudden closure of the valves between the atria and the ventricles. The second, slightly delayed sound, is caused by the closure of the valves found at the entrance to the major arteries leaving the heart. Diseased valves may make unusual sounds, known as heart murmurs.

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heartburn

burning sensation behind the breastbone (sternum). It results from irritation of the lower oesophagus (gullet) by excessively acid stomach contents, as sometimes happens during pregnancy and in cases of duodenal ulcer or obesity. It is often due to a weak valve at the entrance to the stomach that allows its contents to well up into the oesophagus.

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heart disease

disorder affecting the heart; for example, ischaemic heart disease, in which the blood supply through the coronary arteries is reduced by atherosclerosis; valvular heart disease, in which a heart valve is damaged; and cardiomyophathy, where the heart muscle itself is diseased. See also coronary artery disease.

heart disease

Deposits of calcium in diseased heart valves are sometimes actually bone tissue, possibly caused when heart cells follow a new developmental pathway as a result of inflammation.

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heart-lung machine

apparatus used during heart surgery to take over the functions of the heart and the lungs temporarily. It has a pump to circulate the blood around the body and is able to add oxygen to the blood and remove carbon dioxide from it. A heart-lung machine was first used for open-heart surgery in the USA in 1953.

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heat

form of energy possessed by a substance by virtue of the vibrational movement (kinetic energy) of its molecules or atoms. Heat energy is transferred by conduction, convection, and radiation. It always flows from a region of higher temperature (heat intensity) to one of lower temperature. Its effect on a substance may be simply to raise its temperature, or to cause it to expand, melt (if a solid), vaporize (if a liquid), or increase its pressure (if a confined gas).

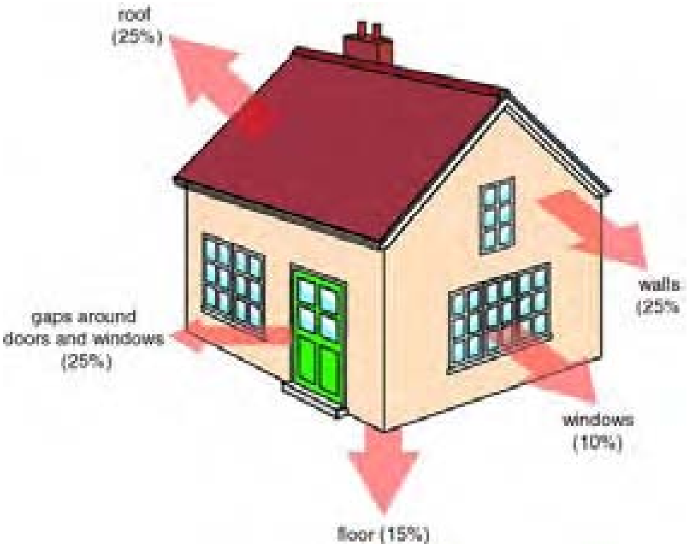
measurement

Quantities of heat are usually measured in units of energy, such as joules (J) or calories (cal). The specific heat of a substance is the amount of heat that is needed to raise the temperature of 1 kg of the substance by 1 K (°C).

conduction, convection, and radiation

Conduction is the passing of heat along a medium to neighbouring parts with no visible motion accompanying the transfer of heat; for example, when the whole length of a metal rod is heated when one end is held in a fire. Convection is the transmission of heat through a fluid (liquid or gas) in currents; for example, when the air in a room is warmed by a fire or radiator. Radiation is heat transfer by infrared rays. It can pass through a vacuum, travels at the same speed as light, and can be reflected and refracted; for example, heat reaches the Earth from the Sun by radiation. For the transformation of heat, see thermodynamics.

heat



(Image © Research Machines plc)

The ways in which heat energy is lost from an ordinary house. Insulation methods, such as fitting double glazing and draught excluders, can help to reduce heat losses.

heat capacity

in physics, the quantity of heat required to raise the temperature of an object by one degree. The **specific heat capacity** of a substance is the heat capacity per unit of mass, measured in joules per kilogram per kelvin ($J\ kg^{-1}\ K^{-1}$).

heat death

in cosmology, possible fate of the universe in which it continues expanding indefinitely while all the stars burn out and no new ones are formed. See critical density.

heath

in botany, any of a group of woody, mostly evergreen shrubs, including heather, many of which have bell-shaped pendant flowers. They are native to Europe, Africa, and North America. (Common Old World genera *Erica* and *Calluna*, family Ericaceae.)

heather

low-growing evergreen shrub of the heath family, common on sandy or acid soil. The common heather (*Calluna vulgaris*) is a carpet-forming shrub, growing up to 60 cm/24 in high and bearing pale pink-purple flowers. It is found over much of Europe and has been introduced to North America.

heather

(Image © Research Machines plc)

Heathland on Chynalls Point, on the south Cornwall coast. The word 'heath' is derived from the plant, heather, that thrives best in the poor, acidic soil of land that has been cleared of trees, then grazed by animals to prevent the trees growing back. The area of heathland covering mainland Britain today is about 2,000,000 acres/8,094 sq km, or roughly a fifth of what existed at the end of the 17th century. Heather is frequently found growing together with spring-flowering yellow gorse.

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heat of reaction

alternative term for energy of reaction.

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heat pump

machine, run by electricity or another power source, that cools the interior of a building by removing heat from interior air and pumping it out or, conversely, heats the inside by extracting energy from the atmosphere or from a hot-water source and pumping it in.

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heat shield

any heat-protecting coating or system, such as an ablation shield, which protects spacecraft from the heat of re-entry, when temperatures can reach 1,500°C/2,700°F.

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heat storage

any means of storing heat for release later. It is usually achieved by using materials that undergo phase changes, for example, Glauber's salt and sodium pyrophosphate, which melts at 70°C/158°F. The latter is used to store off-peak heat in the home: the salt is liquefied by cheap heat during the night and then freezes to give off heat during the day.

Other developments include the use of plastic crystals, which change their structure rather than melting when they are heated. They could be incorporated in curtains or clothing.

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heatstroke

or sunstroke

rise in body temperature caused by excessive exposure to heat. Mild heatstroke is experienced as feverish lassitude, sometimes with simple fainting; recovery is prompt following rest and replenishment of salt lost in sweat. Severe heatstroke causes collapse akin to that seen in acute shock, and is potentially lethal without prompt treatment, including cooling the body carefully and giving fluids to relieve dehydration. Death rates increase by 50% during heatwaves; heat stress is responsible for more deaths than any meteorological cause, including cyclones and floods.

heat treatment

in industry, the subjection of metals and alloys to controlled heating and cooling after fabrication to relieve internal stresses and improve their physical properties. Methods include annealing, quenching, and tempering.

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heavy water

or deuterium oxide; D_2O

water containing the isotope deuterium instead of hydrogen (relative molecular mass 20 as opposed to 18 for ordinary water).

Its chemical properties are identical with those of ordinary water, but its physical properties differ slightly. It occurs in ordinary water in the ratio of about one part by mass of deuterium to 5,000 parts by mass of hydrogen, and can be concentrated by electrolysis, the ordinary water being more readily decomposed by this means than the heavy water. It has been used in the nuclear industry because it can slow down fast neutrons, thereby controlling the chain reaction.

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hectare

symbol ha

metric unit of area equal to 10,000 square meters (2.47 acres).

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hedge

or hedgerow

row of closely planted shrubs or low trees, generally acting as a land division and windbreak. Hedges also serve as a source of food and as a refuge for wildlife, and provide a habitat not unlike the understorey of a natural forest.

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hedgehog

insectivorous mammal native to Europe, Asia, and Africa. The body, including the tail, is 30 cm/1 ft long. It is greyish brown in colour, has a piglike snout, and its back and sides are covered with sharp spines. When threatened it rolls itself into a ball bristling with spines. Hedgehogs feed on insects, slugs, mice, frogs, young birds, and carrion. Long-eared hedgehogs and desert hedgehogs are placed in different genera. (Genus *Erinaceus*, family Erinaceidae, order Insectivora.)

Hedgehogs normally shelter by day and go out at night. They find food more by smell and sound than by sight. The young are born in the late spring or early summer, and are blind, helpless, and covered with soft spines. For about a month they feed on their mother's milk, after which she teaches them to find their own food. In the autumn, hedgehogs make a nest of leaves and moss in the roots of a tree or in a hole in the ground and hibernate until spring.

Heisenberg, Werner (Karl) (1901-1976)

German physicist who developed quantum theory and formulated the uncertainty principle, which places absolute limits on the achievable accuracy of measurement. He was awarded the Nobel Prize for Physics in 1932 for his creation of quantum mechanics, work he carried out when only 24.

Heisenberg was concerned not to try to picture what happens inside the atom but to find a mathematical system that explained it. His starting point was the spectral lines given by hydrogen, the simplest atom. Assisted by Max Born, Heisenberg presented his ideas in 1925 as a system called **matrix mechanics**. He obtained the frequencies of the lines in the hydrogen spectrum by mathematical treatment of values within matrices or arrays. His work was the first precise mathematical description of the workings of the atom and with it Heisenberg is regarded as founding quantum mechanics, which seeks to explain atomic structure in mathematical terms. Heisenberg also was able to predict from studies of the hydrogen spectrum that hydrogen exists in two allotropes - ortho-hydrogen and para-hydrogen - in which the two nuclei of the atoms in a hydrogen molecule spin in the same or opposite directions respectively. The allotropes were discovered in 1929. In 1927 Heisenberg made the discovery of the **uncertainty principle**, for which he is best known. The uncertainty principle states that there is a theoretical limit to the precision with which a particle's position and momentum can be measured. In other words, it is impossible to specify precisely both the position and the simultaneous momentum (mass multiplied by velocity) of a particle. There is always a degree of uncertainty in either, and as one is determined with greater precision, the other can only be found less exactly. Multiplying together the uncertainties of the position and momentum yields a value approximately equal to Planck's constant. The idea that the result of an action can be expressed only in terms of the probability of a certain effect was revolutionary, and it discomforted even Albert Einstein, but is generally accepted today. In 1927 Heisenberg used the Pauli exclusion principle, which states that no two electrons can have identical sets of quantum numbers the same, to show that ferromagnetism (the ability of some materials to acquire magnetism in the presence of an external magnetic field) is caused by electrostatic interaction between the electrons.

Heisenberg, Werner Karl

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of physicist Werner Heisenberg. In addition to biographical information, you will find a list of references about Heisenberg and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Heisenberg. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

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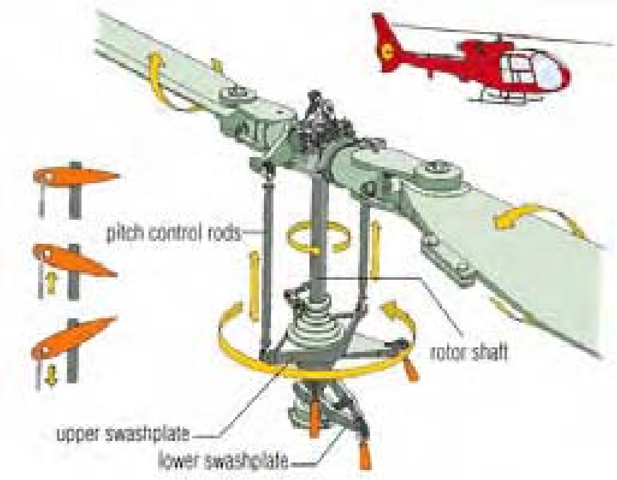
helicopter

powered aircraft that achieves both lift and propulsion by means of a rotary wing, or rotor, on top of the fuselage. It can take off and land vertically, move in any direction, or remain stationary in the air. It can be powered by piston or jet engine. The autogiro was a precursor.

The rotor of a helicopter has two or more blades of aerofoil cross-section like an aeroplane's wings. Lift and propulsion are achieved by angling the blades as they rotate. Experiments using the concept of helicopter flight date from the early 1900s, with the first successful lift-off and short flight in 1907. Ukrainian-US engineer Igor Sikorsky built the first practical single-rotor craft in the USA in 1939.

A single-rotor helicopter must also have a small tail rotor to counter the torque, or tendency of the body to spin in the opposite direction to the main rotor. Twin-rotor helicopters, like the Boeing Chinook, have their rotors turning in opposite directions to prevent the body from spinning. Helicopters are now widely used in passenger service, rescue missions on land and sea, police pursuits and traffic control, fire-fighting, and agriculture. In war they carry troops and equipment into difficult terrain, make aerial reconnaissance and attacks, and carry the wounded to aid stations. A fire-fighting helicopter was tested in Japan in 1996, designed to reach skyscrapers beyond the reach of fire-engine ladders.

helicopter



(Image © Research Machines plc)

The helicopter is controlled by varying the rotor pitch (the angle of the rotor blade as it moves through the air). For backwards flight, the blades in front of the machine have greater pitch than those behind the craft. This means that the front blades produce more lift and a backwards thrust. For forwards flight, the situation is reversed. In level flight, the blades have unchanging pitch.

helicopter

20
ROYAL NAVY
RESCUE

(Image © Research Machines plc)

For more than thirty years the Sea King, manufactured in the UK by GKN Westland, has been one of the most versatile helicopters in the world. It is a twin-engined, all-weather helicopter, which is able to detect and destroy submarines, as well as performing search-and-rescue functions, and providing logistical support.

helicopter

(Image © Research Machines plc)

Initially developed as an anti-submarine helicopter, the Royal Air Force also use Sea Kings for air-sea rescue. Search-and-rescue helicopters, like this one at RNAS Culdrose, Cornwall, are equipped with hydraulic hoists capable of lifting up to 272 kg/600 lb. The cabin can carry up to 22 survivors, or 9 stretchers and 2 medical officers.

helioseismology

study of the Sun's structure by analysing vibrations and monitoring effects on the Sun's surface. Compare with seismology.

heliosphere

region of space through which the solar wind flows outwards from the Sun. The **heliopause** is the boundary of this region, believed to lie about 100 astronomical units from the Sun, where the flow of the solar wind merges with the interstellar gas.

heliotrope

decorative plant belonging to the borage family, with distinctive spikes of blue, lilac, or white flowers, including the Peruvian or cherry pie heliotrope (*H. peruvianum*). (Genus *Heliotropium*, family Boraginaceae.)

helium

chemical symbol He

(Greek helios 'Sun')

colourless, odourless, gaseous, non-metallic element, atomic number 2, relative atomic mass 4.0026. It is grouped with the noble gases (rare gases) in Group 0 of the periodic table. Helium is nonreactive because of its full outer shell of electrons and forms no compounds. It is the second most abundant element (after hydrogen) in the universe, and has the lowest boiling (-268.9°C/-452°F) and melting points (-272.2°C/-458°F) of all the elements. It is present in small quantities in the Earth's atmosphere from gases issuing from radioactive elements (from alpha decay) in the Earth's crust; after hydrogen it is the second-lightest element.

Helium is a component of most stars, including the Sun, where the nuclear-fusion process converts hydrogen into helium with the production of heat and light. It is obtained by the compression and fractionation of naturally occurring gases. It is used for inflating balloons and as a dilutant for oxygen in deep-sea breathing systems. Liquid helium is used extensively in low-temperature physics (cryogenics).

Helium was originally discovered in 1868 in the spectrum of the Sun. It was found on Earth in 1895.

Helium: Discovery

it came from outer space

What is the second most abundant chemical element in the universe? A clue: nearly all of it was created only a few minutes after the Big Bang. This element was identified only 100 years ago, and, uniquely among the elements, was first discovered in the Sun. The answer, of course, is helium.

Chemists somewhat dryly characterize helium as an inert gas. Indeed it is one of the most unreactive gases known, as well as being one of the lightest. It was these properties that spurred its first commercial production, when, in 1914, it was found that incendiary bullets fired into a Zeppelin airship filled with helium did not cause the airship to catch fire or explode.

discovery in the Sun's spectrum

The story of helium begins with an eclipse of the Sun. For the 1868 eclipse, no fewer than four scientific expeditions set out to examine the solar prominences. These enormous eruptions of luminous gas flare hundreds of kilometres out into space and are clearly visible during an eclipse. Using the new method of spectrum analysis, invented by Robert Kirchhoff and Robert Bunsen in Germany, the scientists examined the spectrum of the Sun through telescopes and prisms. Different elements produce patterns of lines in the spectrum. Most of the lines they saw in the Sun's spectrum they attributed to hydrogen and possibly sodium.

But it seemed to Pierre Janssen, a French astronomer on one of the expeditions, that the light of the solar flares was so bright that it could be examined in daylight and when there was no eclipse. The same idea occurred to two English astronomers who were not on the expedition, William Huggins and Norman Lockyer. Lockyer and Janssen published their idea on the same day in 1868.

The new method enabled Lockyer to prove that the yellow line, which was thought to be sodium, was due to a different element altogether, and one not known on Earth. Professor Edward Frankland of Imperial College, London, suggested the name 'helium' from the Greek *helios* 'the Sun'.

Lockyer, who was ridiculed at first for predicting an unknown, extraterrestrial element, went on to found London's Science Museum and the science journal *Nature*, which he edited for 50 years.

supposed extraterrestrial found on Earth

In 1895, William Ramsay, a Scottish chemist, showed that helium existed in Earth. He heated the mineral cleveite, a variety of pitchblende, with dilute sulphuric acid. Although he mostly got nitrogen gas (about 20%), there was small amount of helium, which he identified by its spectrum: it showed the same lines first seen during the 1868 eclipse expeditions.

Pitchblende is one of the main constituents of uranium ore, containing the elements uranium, lead, radium, polonium, and actinium. Pierre and Marie Curie discovered radium and polonium in pitchblende 1898.

sources of helium

Helium is now known to be present in the Earth's atmosphere (0.0005%) and comes from gases issued by radioactive elements in the Earth's crust. Helium and other inert gases are evolved from hot springs that have their sources at great depths in the Earth. But the most important source of helium is in the natural gas from some petroleum springs in Texas, Utah, and Colorado in the USA and Medicine Hat in Canada.

For most of this century, helium has escaped from natural gas wells into the atmosphere. Then in 1958, after warnings from John Bardeen (one of the inventors of the transistor), the US government began to stockpile helium in empty gas wells.

ultimate cool

Helium may be an inert gas – it has no known compounds – but its alternative family name, noble gas, is altogether more fitting, for its properties make it uniquely useful in the modern world.

Helium is the only substance that never solidifies, however much it is cooled. It is the ultimate refrigerant. It boils at 4.2 K or -269°C, only a few degrees above absolute zero or -273.15°C. This is why it can be used to cool superconducting magnets and astronomical detectors that work best at very low temperatures. Currently, superconductors (conductors that offer no resistance to electricity) work only at cryogenic temperatures. Cooled to 2.18 K, helium becomes a superfluid, flowing uphill and through the tiniest holes. In medicine, liquid helium cools the superconducting magnets of magnetic resonance-imaging body scanners.

other uses

As a gas, helium is used in arc-welding equipment, in the manufacture of semiconductors, in powerful gas lasers, and to cool nuclear reactors. Deep-sea divers breathe it mixed with oxygen. Helium fills giant fragile balloons that carry scientific instruments to the edge of the Earth's atmosphere 35–40 km/20–25 mi high.

The *Apollo* space programme depended critically on liquid helium. The liquid hydrogen and oxygen fuels needed by the powerful rockets were cooled by helium: the astronauts could stay on the Moon only as long as the helium lasted.

Today, annual consumption of helium is about 100 million cu m/3,500 million cu ft and rising by about 5% per year. There may be 20 years' accessible supply left.

The most abundant element in the universe? It is hydrogen, which is also the lightest.

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helix

in mathematics, a three-dimensional curve resembling a spring, corkscrew, or screw thread. It is generated by a line that encircles a cylinder or cone at a constant angle.

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hellebore

poisonous European herbaceous plant belonging to the buttercup family. The stinking hellebore (*H. foetidus*) has greenish flowers early in the spring. (Genus *Helleborus*, family Ranunculaceae.)

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helleborine

one of several temperate Old World orchids, including the marsh helleborine (*E. palustris*) and the hellebore orchid (*E. helleborine*) introduced to North America. (Genera *Epipactis* and *Cephalanthera*, family Orchidaceae.)

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helminth

in medicine, collective name used to describe parasitic worms. There are several classes of helminth that can cause infections in humans, including ascarids (ascariasis), tapeworms, and threadworms.

Helmont, Jan Baptist van (1579-1644)

Flemish chemist and physician. Helmont was the first to realize that there are gases other than air, and established the present scientific sense of the word 'gas' (from Greek *cháos*). He also investigated the chemical properties of the fluids of the human body. His chief work, *Ortus medicinae*, was published by his son in 1648.

discoveries

Helmont identified four gases: carbon dioxide, carbon monoxide, nitrous oxide, and methane. He was the first to take the melting point of ice and the boiling point of water as standards for temperature and the first to use the term 'saturation' to signify the combination of an acid and a base. In medicine, Helmont used remedies that specifically considered the type of disease, the organ affected, and the causative agent. He demonstrated acid as the digestive agent in the stomach.

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hemisphere

half a sphere, produced when a sphere is sliced along a great circle.

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hemlock

plant belonging to the carrot family, native to Europe, western Asia, and North Africa. It grows up to 2 m/6 ft high and produces delicate clusters of small white flowers. The whole plant, especially the root and fruit, is poisonous, causing paralysis of the nervous system. The name 'hemlock' is also given to some North American and Asiatic conifers (genus *Tsuga*) belonging to the pine family. (*Conium maculatum*, family Umbelliferae.)

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hemp

annual plant originally from Asia, now cultivated in most temperate countries for the fibres produced in the outer layer of the stem, which are used in ropes, twines, and, occasionally, in a type of linen or lace. The drug cannabis is obtained from certain varieties of hemp. (*Cannabis sativa*, family Cannabaceae.)

The name 'hemp' is also given to other similar types of fibre: **sisal hemp** and **henequen** obtained from the leaves of *Agave* species native to Yucatán and cultivated in many tropical countries, and **manila hemp** obtained from *Musa textilis*, a plant native to the Philippines and the Maluku Islands, Indonesia.

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henbane

poisonous plant belonging to the nightshade family, found on waste ground throughout most of Europe and western Asia. It is a branching plant, up to 80 cm/31 in high, with hairy leaves and a sickening smell. The yellow flowers are bell-shaped. Henbane is used in medicine as a source of the drugs hyoscyamine and scopolamine. (*Hyoscyamus niger*, family Solanaceae.)

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henna

small shrub belonging to the loosestrife family, found in Iran, India, Egypt, and North Africa. The leaves and young twigs are ground to a powder, mixed to a paste with hot water, and applied to the fingernails and hair to give an orange-red hue. The colour may then be changed to black by applying a preparation of indigo. (*Lawsonia inermis*, family Lythraceae.)

Henna can also be used to dye both natural and synthetic textiles.

henry

symbol H

SI unit of inductance (the reaction of an electric current against the magnetic field that surrounds it). One henry is the inductance of a circuit that produces an opposing voltage of one volt when the current changes at one ampere per second.

It is named after the US physicist Joseph Henry.

Henry, Joseph (1797-1878)

US physicist, inventor of the electromagnetic motor in 1829 and of a telegraphic apparatus. He also discovered the principle of electromagnetic induction, roughly at the same time as Michael Faraday, and the phenomenon of self-induction. The unit of inductance, the henry, is named after him.

Henry, William (1774-1836)

English chemist and physician. In 1803 he formulated Henry's law, which states that when a gas is dissolved in a liquid at a given temperature, the mass that dissolves is in direct proportion to the pressure of the gas.

heparin

anticoagulant substance produced by cells of the liver, lungs, and intestines. It normally inhibits the clotting of blood by interfering with the production of thrombin, which is necessary for clot formation. Heparin obtained from animals is administered after surgery to limit the risk of thrombosis, or following pulmonary embolism to ensure that no further clots form, and during haemodialysis (using a kidney machine).

hepatic

of or pertaining to the liver.

hepatitis

any inflammatory disease of the liver, usually caused by a virus. Other causes include alcohol, drugs, gallstones, lupus erythematous, and amoebic dysentery. Symptoms include weakness, nausea, and jaundice.

Five different hepatitis viruses have been identified; A, B, C, D, and E. The hepatitis A virus (HAV) is the commonest cause of viral hepatitis, responsible for up to 40% of cases worldwide. It is spread by contaminated food. Hepatitis B, or serum hepatitis, is a highly contagious disease spread by blood products or in body fluids. It often culminates in liver failure, and is also associated with liver cancer, although only 5% of those infected suffer chronic liver damage. During 1995, 1.1 million people died of hepatitis B. Around 300 million people are carriers. Vaccines are available against hepatitis A and B.

Hepatitis C is mostly seen in people needing frequent transfusions. In 1999 there were an estimated 150 million people worldwide infected with hepatitis C and 75% of these will go on to develop chronic liver infections. Hepatitis D, which only occurs in association with hepatitis B, is common in the Mediterranean region. Hepatitis E is endemic in India and South America.

In 1998, the World Health Organization (WHO) estimated that some 350 million people were infected with hepatitis B.

herb

any plant (usually a flowering plant) tasting sweet, bitter, aromatic, or pungent, used in cooking, medicine, or perfumery; technically, a herb is any plant in which the aerial parts do not remain above ground at the end of the growing season.

herb

The herb catnip (*Nepeta cataria*) has a remarkable effect on cats. Members of the cat family roll over, extend their claws and twist in excitement when they smell the pungent odour of catnip. This reaction is believed to be caused by a chemical called trans-neptalacone, which is similar to a substance found in the female cat's urine.

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herbaceous plant

plant with very little or no wood, dying back at the end of every summer. The herbaceous perennials survive winters as underground storage organs such as bulbs and tubers.

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herbalism

in alternative medicine, the prescription and use of plants and their derivatives for medication. Herbal products are favoured by alternative practitioners as 'natural medicine', as opposed to modern synthesized medicines and drugs, which are regarded with suspicion because of the dangers of side effects and dependence.

Many herbal remedies are of proven efficacy both in preventing and curing illness. Medical herbalists claim to be able to prescribe for virtually any condition, except those so advanced that surgery is the only option.

Grey Wings Herbal

Go to site

Soothing music plays while waiting the loading of a home page filled with information about herbal medicine. Instructions are provided on preparing a great range of herbal medicines and using herbs in food. The site is part of the herb and herbal products Web ring. There is also a plain-English guide to the large number of horticultural and medical terms used by herbal medicine practitioners.

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herbarium

collection of dried, pressed plants used as an aid to identification of unknown plants and by taxonomists in the classification of plants. The plant specimens are accompanied by information, such as the date and place of collection, by whom collected, details of habitat, flower colour, and local names.

Herbaria range from small collections containing plants of a limited region, to the large university and national herbaria (some at botanical gardens) containing millions of specimens from all parts of the world.

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herbicide

any chemical used to destroy plants or check their growth (see weedkiller).

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herbivore

animal that feeds on green plants (or photosynthetic single-celled organisms) or their products, including seeds, fruit, and nectar. The most numerous type of herbivore is thought to be the zooplankton, tiny invertebrates in the surface waters of the oceans that feed on small photosynthetic algae. Herbivores are more numerous than other animals because their food is the most abundant. They form a vital link in the food chain between plants and carnivores.

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herb Robert

wild geranium found throughout Europe and central Asia and naturalized in North America. About 30 cm/12 in high, it has hairy leaves and small pinkish to purplish flowers. (*Geranium robertianum*, family Geraniaceae.)

Herculaneum

ancient city of Italy between Naples and Pompeii. Along with Pompeii, it was buried when Vesuvius erupted in AD 79. It was excavated from the 18th century onwards.

Hercules

fifth-largest constellation, lying in the northern hemisphere. Despite its size it contains no prominent stars. Its most important feature is the best example in the northern hemisphere of a globular cluster of stars 22,500 light years from the Sun, which lies between Eta and Zeta Herculis.

Hercules beetle

largest beetle in the world: males measure up to 17 cm/6.6 in in length; females are smaller. Hercules beetles are found mainly in the tropical and subtropical regions.

They are black, nocturnal, and exhibit extreme forms of sexual dimorphism (marked visual differences between males and females). Males have a dark-coloured, slender, curved horn of up to 10 mm/3.9 in long, on their heads.

classification

Hercules beetles *Dynastes hercules* belong to the subfamily Dynastinae, family Scarabaeidae, order Coleoptera, class Insecta, phylum Arthropoda.

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heredity

in biology, the transmission of traits from parent to offspring. See also genetics.

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hermaphrodite

organism that has both male and female sex organs. Hermaphroditism is the norm in such species as earthworms and snails, and is common in flowering plants. Cross-fertilization is common among hermaphrodites, with the parents functioning as male and female simultaneously, or as one or the other sex at different stages in their development. Human hermaphrodites are extremely rare.

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hermit crab

type of crab.

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hernia

or rupture

protrusion of part of an internal organ through a weakness in the surrounding muscular wall, usually in the groin. The appearance is that of a rounded soft lump or swelling.

Welcome to the Home Page for Hernia Information

Go to site

Easy to understand information about the various kinds of hernia. The causes of hernia are described together with different repair techniques and advice to sufferers.

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heroin

or diamorphine

powerful opiate analgesic, an acetyl derivative of morphine. It is more addictive than morphine but causes less nausea. Methadone can be used to help wean addicts off heroin however it too is addictive.

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heron

large to medium-sized wading bird belonging to the same family as bitterns, egrets, night herons, and boatbills. Herons have sharp bills, broad wings, long legs, slender bodies, and soft plumage. They are found mostly in tropical and subtropical regions, but also in temperate zones, on lakes, fens, and mudflats, where they wade searching for prey. (Genera include *Ardea*, *Butorides*, and *Nycticorax*; family Ardeidae, order Ciconiiformes.)

They capture small animals, such as fish, molluscs, and worms, by spearing them with their long bills. Herons nest in trees or bushes, on ivy-covered rocks, or in reedbeds, making a loose fabric of sticks lined with grass or leaves; they lay greenish or drab-coloured eggs, varying in number from two to seven according to the different species.

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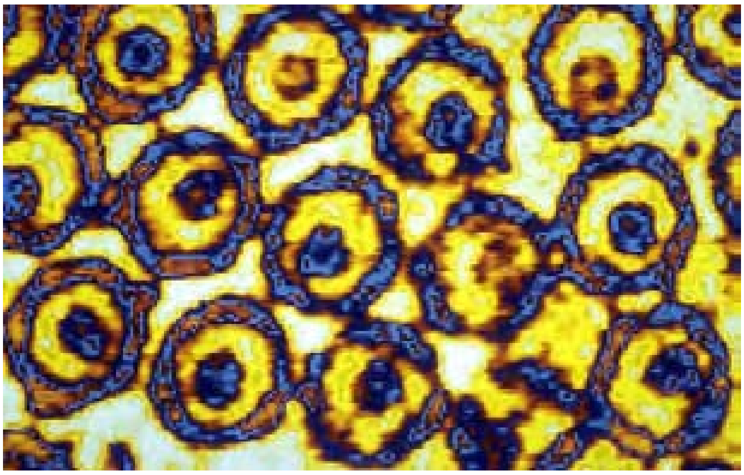
herpes

any of several infectious diseases caused by viruses of the herpes group.
Herpes simplex I is the causative agent of a common inflammation, the cold sore.
Herpes simplex II is responsible for genital herpes, a highly contagious, sexually transmitted disease characterized by painful blisters in the genital area. It can be transmitted in the birth canal from mother to newborn.
Herpes zoster causes shingles; another herpes virus causes chickenpox.

A number of antivirals treat these infections, which are particularly troublesome in patients whose immune systems have been suppressed medically; for example, after a transplant operation. The drug acyclovir, originally introduced for the treatment of genital herpes, has now been shown to modify the course of chickenpox and the related condition shingles, by reducing the duration of the illness.

A vaccine for shingles was tested by US researchers in 1999.

herpes



(Image © SmithKline Beecham Plc)

A false-colour micrograph of the *Herpes simplex* or cold sore virus. Herpes is the name given to any of several infectious diseases – including cold sores, genital herpes, shingles, chickenpox, and glandular fever – caused by the viruses in the herpes group.

Childhood Infections – Herpes

Go to site

Useful information about herpes. There is a detailed, illustrated description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

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herpes genitalis

or genital herpes

in medicine, an infection of the genital organs caused by the *Herpes simplex* virus. It is transmitted by sexual intercourse. Infection is marked by the formation of blisters on the genitals and pain. Treatment is with antiviral drugs, such as aciclovir, used orally or as creams. It can be passed from mother to child during birth, causing life-threatening illnesses and blindness.

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herring

any of various marine fishes belonging to the herring family, but especially the important food fish *Clupea harengus*. A silvered greenish blue, it swims close to the surface, and may be 25-40 cm/10-16 in long. Herring travel in schools several kilometres long and wide. They are found in large quantities off the east coast of North America, and the shores of northeastern Europe. Overfishing and pollution have reduced their numbers. (Family Clupeidae.)

herring

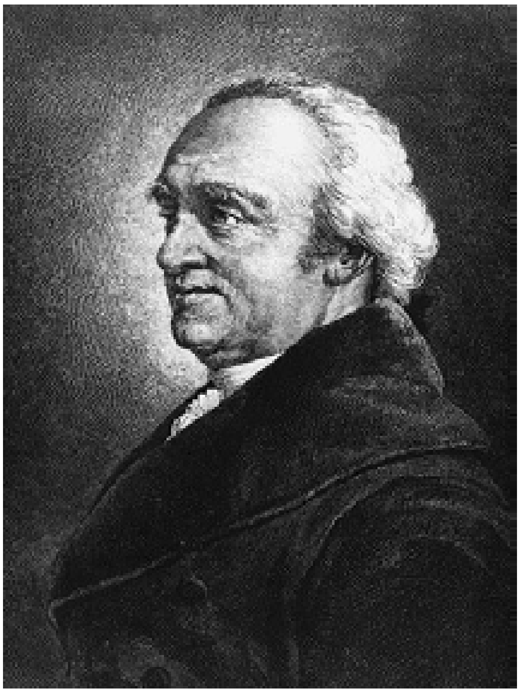
The wolf herring *Chirocentrus dorab* is the largest fish in the herring order. It grows up to 3.7 m/12 ft long.

Herschel, (Frederick) William (1738-1822)

German-born English astronomer. He was a skilled telescopemaker, and pioneered the study of binary stars and nebulae. He discovered the planet Uranus in 1781 and infrared solar rays in 1801. He catalogued over 800 double stars, and found over 2,500 nebulae, catalogued by his sister Caroline Herschel; this work was continued by his son John Herschel. By studying the distribution of stars, William established the basic form of our Galaxy, the Milky Way. He was knighted in 1816.

Herschel discovered the motion of binary stars around one another, and recorded it in his *Motion of the Solar System in Space* (1783). In 1789 he built, in Slough, a 1.2-m/4-ft telescope of 12 m/40 ft focal length (the largest in the world at the time), but he made most use of a more satisfactory 46-cm/18-in instrument. He discovered two satellites of Uranus and two of Saturn.

Herschel



(Image © Billie Love)

German-born astronomer William Herschel in 1781, the year in which he made his reputation by the discovery of Uranus, the first new planet to be identified for centuries. Herschel made his own telescopes and his early studies in astronomy drew him to the attention of George III, king of Great Britain and Ireland, who employed Herschel as his private astronomer.

Herschel, Caroline (Lucretia) (1750-1848)

German-born English astronomer, sister of William Herschel, and from 1772 his assistant in Bath, England. She discovered eight comets and worked on her brother's catalogue of star clusters and nebulae.

Herschel, Caroline

Go to site

Profile of the German-born astronomer. It traces her triumph over physical affliction, her interest in music, and her achievements in astronomy. Her role in the discovery of Neptune and comets is also described.

Herschel, John Frederick William (1792-1871)

English scientist, astronomer, and photographer who discovered thousands of close double stars, clusters, and nebulae. He coined the terms 'photography', 'negative', and 'positive', discovered sodium thiosulphite as a fixer of silver halides, and invented the cyanotype process; his inventions also include astronomical instruments.

From 1821 to 1823, with James South, he systematically remeasured the double stars discovered by his father William Herschel. He went on to revise his father's survey of the northern heavens and from 1834 to 1838 mapped the southern skies from the Cape of Good Hope Observatory in South Africa. His *General Catalogue of Nebulae and Clusters*, in which he coordinated into one catalogue the results of his father's, his own, and other astronomers' surveys, is still the standard reference catalogue; he had personally discovered 525 nebulae and clusters.

Hershko, Avram (1937-)

Hungarian-born Israeli scientist. With Israeli scientist Aaron Ciechanover and US scientist Irwin Rose shared the Nobel Prize for Chemistry in 2004 for his contributions to the understanding of the process of cell protein degradation.

Hershko was awarded his share of the Nobel Prize for his work concerning the mechanisms of protein degradation in the human cell. Although much was known about how a cell manufactured the 100,000 proteins that it used to function in various forms, such as hormones and enzymes, it was not known how damaged or unwanted proteins were removed, the process of protein degradation. Hershko and his fellow researchers discovered that a protein, later identified as ubiquitin, formed a stable covalent bond with unwanted proteins, effectively labelling them for disposal. Subsequent work showed that proteins labelled in this way were then moved to a structure in the cell called a proteasome, where they were degraded. It later became known that errors in the cell degradation process can cause diseases such as cystic fibrosis, cancer, and Alzheimer's disease to occur.

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hertz

symbol Hz

SI unit of frequency (the number of repetitions of a regular occurrence in one second). A wave source has a frequency of 1 Hz if it produces one wave each second. Human beings have an audible range from approximately 20 Hz to 20,000 Hz. Radio waves are often measured in megahertz (MHz), millions of hertz, and the clock rate of a computer is usually measured in megahertz. The unit is named after German physicist Heinrich Hertz.

Hertz, Heinrich Rudolf (1857-1894)

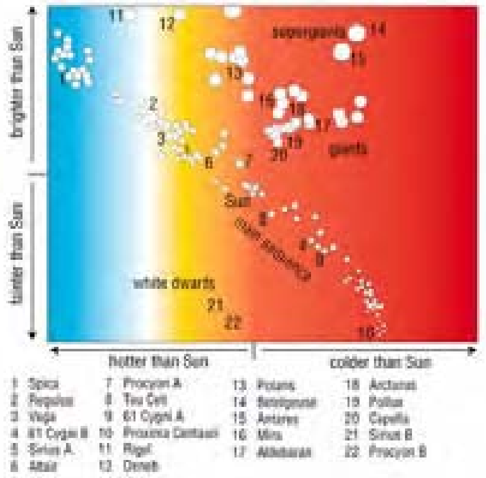
German physicist who studied electromagnetic waves, showing that their behaviour resembles that of light and heat waves.

Hertz confirmed James Clerk Maxwell's theory of electromagnetic waves. In 1888, he realized that electric waves could be produced and would travel through air, and he confirmed this experimentally. He went on to determine the velocity of these waves (which were later called radio waves) and, on showing that it was the same as that of light, devised experiments to show that the waves could be reflected, refracted, and diffracted.

Hertzsprung-Russell diagram

in astronomy, graph on which the surface temperatures of stars are plotted against their luminosities. Most stars, including the Sun, fall into a narrow band called the main sequence. When a star grows old it moves from the main sequence to the upper right part of the graph, into the area of the giants and supergiants. At the end of its life, as the star shrinks to become a white dwarf, it moves again, to the bottom left area. It is named after the Danish astronomer Ejnar Hertzsprung and the US astronomer Henry Russell, who independently devised it in the years 1911-13.

Hertzsprung-Russell diagram



(Image © Research Machines plc)

The Hertzsprung-Russell diagram relates the brightness (or luminosity) of a star to its temperature. Most stars fall within a narrow diagonal band called the main sequence. A star moves off the main sequence when it grows old.

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heterogeneous reaction

in chemistry, a reaction where there is an interface between the different components or reactants. Examples of heterogeneous reactions are those between a gas and a solid, a gas and a liquid, two immiscible liquids, or two different solids.

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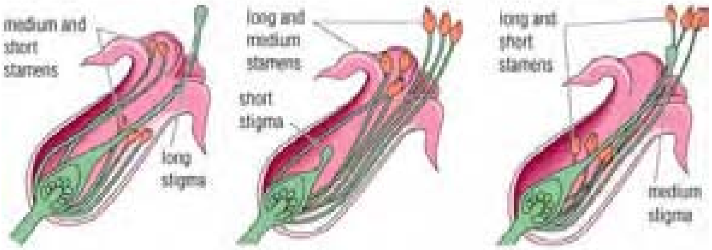
heterostyly

in botany, having styles of different lengths. Certain flowers, such as primroses (*Primula vulgaris*), have different-sized anthers and styles to ensure cross-fertilization (through pollination) by visiting insects.

heterostyly



(Image © Research Machines plc)

Heterostyly, in which lengths of the stamens and stigma differ in flowers of different plants of the same species. This is a device to avoid self-pollination and ensure cross-pollination by visiting insects.

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heterotroph

any living organism that obtains its energy from organic substances produced by other organisms. All animals and fungi are heterotrophs, and they include herbivores, carnivores, and saprotrophs (those that feed on dead animal and plant material).

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heterozygous

in a living organism, having two different alleles for a given trait. In homozygous organisms, by contrast, both chromosomes carry the same allele. In an outbreeding population an individual organism will generally be heterozygous for some genes but homozygous for others.

For example, in humans, alleles for both blue- and brown-pigmented eyes exist, but the 'blue' allele is recessive to the dominant 'brown' allele.

Only individuals with blue eyes are predictably homozygous for this trait; brown-eyed people can be either homozygous or heterozygous.

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heuristics

in computing, a process by which a program attempts to improve its performance by learning from its own experience.

Hevesy, Georg Karl von (1885-1966)

Hungarian-born Swedish chemist, discoverer of the element hafnium. He was awarded the Nobel Prize for Chemistry in 1943 for his use of a radioactive isotope (see radioactivity) to follow the steps of a biological process.

Hewish, Antony (1924-)

English radio astronomer who, with Martin Ryle, was awarded the Nobel Prize for Physics in 1974 for his work on the development of radioastronomy, particularly the aperture-synthesis technique, and the discovery of pulsars, rapidly rotating neutron stars that emit pulses of energy.

The discovery by Jocelyn Bell Burnell of a regularly fluctuating signal, which turned out to be the first pulsar, began a period of intensive research. Hewish discovered another three straight away, and more than 170 pulsars have been found since 1967.

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hexachlorophene

$(C_6HCl_3OH)_2CH_2$

white odourless bactericide, used in minute quantities in soaps and surgical disinfectants.

Trichlorophenol is used in its preparation, and, without precise temperature control, the highly toxic TCDD (tetrachlorodibenzodioxin; see dioxin) may form as a by-product.

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hexadecimal number system

or hex

number system to the base 16, used in computing. In hex the decimal numbers 0–15 are represented by the characters 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F. Hexadecimal numbers are easy to convert to the computer's internal binary code and are more compact than binary numbers.

Each place in a number increases in value by a power of 16 going from right to left; for instance, 8F is equal to 15 + (8 × 16) = 143 in decimal. Hexadecimal numbers are often preferred by programmers writing in low-level languages because they are more easily converted to the computer's internal binary (base-two) code than are decimal numbers, and because they are more compact than binary numbers and therefore more easily keyed, checked, and memorized. (See also ASCII.)

HF

in physics, abbreviation for high frequency. HF radio waves have frequencies in the range 3–30 MHz.

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hiatus hernia

in medicine, condition in which a portion of the stomach is displaced through the opening in the diaphragm, through which the oesophagus passes from the chest to the abdominal cavity.

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hibernation

state of dormancy in which certain animals spend the winter. It is associated with a dramatic reduction in all metabolic processes, including body temperature, breathing, and heart rate.

The body temperature of the Arctic ground squirrel falls to below 0°C/32°F during hibernation. Hibernating bats may breathe only once every 45 minutes, and can go for up to two hours without taking a breath.

A species of lemur, *cheirogaleus medius*, was the first primate found to hibernate through winter. Unlike other species that hibernate, dormant lemurs do not regulate their body temperature, which instead closely follows the ambient temperatures of their tree-hole homes.

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hibiscus

any of a group of plants belonging to the mallow family. Hibiscuses range from large herbaceous plants to trees. Popular as ornamental plants because of their brilliantly coloured, red to white, bell-shaped flowers, they include *H. syriacus* and *H. rosa-sinensis* of Asia and the rose mallow (*H. palustris*) of North America. (Genus *Hibiscus*, family Malvaceae.)

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hiccup

sharp noise caused by a sudden spasm of the diaphragm with closing of the windpipe, commonly caused by digestive disorder. On rare occasions, hiccups may become continuous, when they are very debilitating; treatment with a muscle-relaxant drug may be effective.

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hickory

tree belonging to the walnut family, native to North America and Asia. It provides a valuable timber, and all species produce nuts, though some are inedible. The pecan (*C. illinoensis*) is widely cultivated in the southern USA, and the shagbark (*C. ovata*) in the northern USA. (Genus *Carya*, family Juglandaceae.)

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hi-fi

abbreviation for high fidelity

faithful reproduction of sound.

Advances in mechanical equipment and electronics, such as digital recording techniques and compact discs, have made it possible to eliminate many distortions in sound-reproduction processes.

Higgs, Peter Ware (1929-)

English theoretical physicist who is best known for his prediction of an as yet undiscovered fundamental particle known as the **Higgs boson**. The Higgs boson, if discovered, will lead to our understanding of the origin of mass.

Higgs boson

or Higgs particle

postulated elementary particle whose existence would explain why particles have mass. The current theory of elementary particles, called the standard model, cannot explain how mass arises. To overcome this difficulty, Peter Higgs of the University of Edinburgh, Scotland, and Thomas Kibble of Imperial College, London, England, proposed in 1964 a new particle that binds to other particles and gives them their mass.

One of the major tasks of the Large Hadron Collider (LHC) at CERN when it begins operation in 2007 will be to search for the Higgs boson.

high-definition television

HDTV

type of digital television system offering a significantly greater number of scanning lines, and therefore a clearer picture, than that provided by conventional systems. Typically, HDTV has about twice the horizontal and vertical resolution of current 525-line (such as the American standard, NTSC) or 625-line standards (such as the British standard, PAL); a frame rate of at least 24 Hz; and a picture aspect ratio of 9:16 instead of the current 3:4. HDTV systems are rapidly being introduced in many countries.

high-level language

in computing, a programming language designed to suit the requirements of the programmer; it is independent of the internal machine code of any particular computer. High-level languages are used to solve problems and are often described as **problem-oriented languages**; for example, BASIC was designed to be easily learnt by first-time programmers; COBOL is used to write programs solving business problems; and FORTRAN is used for programs solving scientific and mathematical problems.

With the increasing popularity of windows-based systems, the next generation of programming languages was designed to facilitate the development of GUI interfaces; for example, Visual Basic wraps the BASIC language in a graphical programming environment. Support for object-oriented programming has also become more common, for example in C++ and Java. In contrast, **low-level languages**, such as assembly languages, closely reflect the machine codes of specific computers, and are therefore described as **machine-oriented languages**.

high-yield variety

crop that has been specially bred or selected to produce more than the natural varieties of the same species. During the 1950s and 1960s, new strains of wheat and maize were developed to reduce the food shortages in poor countries (the Green Revolution). Later, IR8, a new variety of rice that increased yields by up to six times, was developed in the Philippines. Strains of crops resistant to drought and disease were also developed. High-yield varieties require large amounts of expensive artificial fertilizers and sometimes pesticides for best results.

HII region

in astronomy, region of extremely hot ionized hydrogen, surrounding one or more hot stars, visible as a bright patch or emission nebula in the sky. The gas is ionized by the intense ultraviolet radiation from the stars within it. HII regions are often associated with interstellar clouds in which new stars are being born. An example is the Orion nebula. The HII region takes its name from a spectroscopic notation in which HI represents neutral hydrogen (H) and HII represents ionized hydrogen (H^+).

Hilbert, David (1862-1943)

German mathematician, philosopher, and physicist whose work was fundamental to 20th-century mathematics. He founded the formalist school with *Grundlagen der Geometrie/Foundations of Geometry* (1899), which was based on his idea of postulates.

Hilbert attempted to put mathematics on a logical foundation through defining it in terms of a number of basic principles, which Kurt Gödel later showed to be impossible. In 1900 Hilbert proposed a set of 23 problems for future mathematicians to solve, and gave 20 axioms to provide a logical basis for Euclidean geometry.

Hilbert, David

Go to site

Extensive biography of the German physicist, philosopher, and mathematician. The site contains a description of his contributions to physics and mathematics, and in particular describes the fact that he is considered to have had the greatest influence in geometry after Euclid. Several references for further reading are also listed, and the Web site also features a photograph of Hilbert.

Hill, David Octavius

Scottish landscape painter and photographer. He collaborated with fellow Scottish photographer Robert Adamson. See Hill and Adamson.

Hill and Adamson

David Octavius Hill (1802-1870) and Robert R Adamson (1821-1848)

Scottish photographers who worked together 1843–48. They made extensive use of the calotype process in their portraits of leading members of the Free Church of Scotland and their views of Edinburgh and the Scottish fishing village of Newhaven. They produced some 2,500 calotypes. Their work was rediscovered around 1900.

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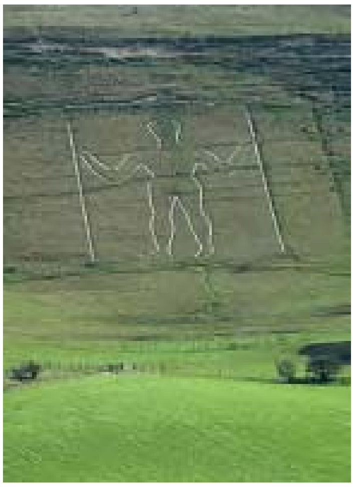
hill figure

in Britain, any of a number of figures, usually of animals, cut from the turf to reveal the underlying chalk. Their origins are variously attributed to Celts, Romans, Saxons, Druids, or Benedictine monks, although most are of modern rather than ancient construction. Examples include 17 White Horses, and giants such as the Cerne Abbas Giant, near Dorchester, Dorset, associated with a prehistoric fertility cult.

Nearly 50 hill figures are known in Britain, of which all but four are on the southern chalk downs of England. Some are landmarks or memorials; others have a religious or ritual purpose. It is possible that the current figures are on the site of, or reinforce, previous ones. There may have been large numbers of figures dotted on the landscape in the Iron Age, which were not maintained. The White Horse at Uffington, on the Berkshire Downs, used to be annually 'scoured' in a folk ceremony.

Other hill-figure designs include the Long Man of Wilmington on Windover Hill, East Sussex; crosses, such as the Bledlow and Whiteleaf crosses on the Chiltern Hills; a collection of military badges made at Fovant Down, Wiltshire (1916); an aeroplane, and a crown. A stag at Mormond Hill, Aberdeenshire, Scotland, is cut into white quartz.

Long Man of Wilmington



(Image © Corel)

The Long Man of Wilmington, on Windover Hill, East Sussex, England.

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hill fort

European Iron Age site with massive banks and ditches for defence, used as both a military camp and a permanent settlement. Examples found across Europe, in particular France, central Germany, and the British Isles, include Heuneberg near Sigmaringen, Germany, Spinans Hill in County Wicklow, Ireland, and Maiden Castle, Dorset, England.

Iron Age Germanic peoples spread the tradition of forts with massive defences, timberwork reinforcements, and sometimes elaborately defended gateways with guardrooms, the whole being overlooked from a rampart walk, as at Maiden Castle. The ramparts usually follow the natural line of a hilltop and are laid out to avoid areas of dead ground.

Hine, Lewis Wickes (1874-1940)

US sociologist and photographer. His dramatic photographs of child labour conditions in US factories at the beginning of the 20th century led to changes in state and local labour laws.

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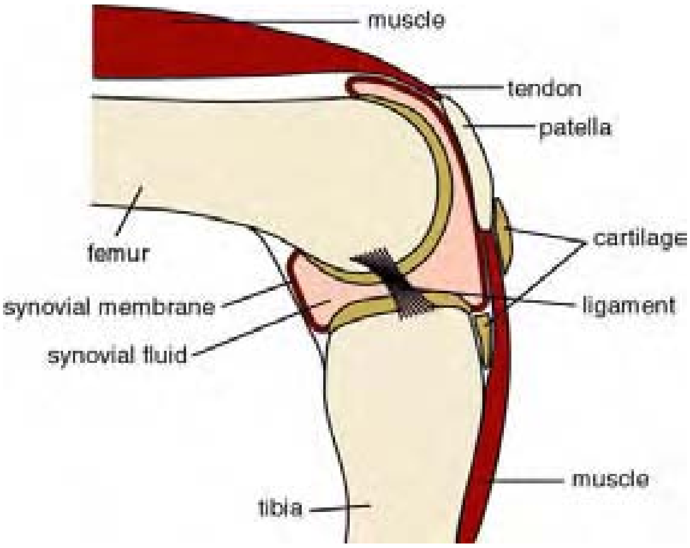
hinge joint

in vertebrates, a joint where movement occurs in one plane only. Examples are the elbow and knee, which are controlled by pairs of muscles, the flexors and extensors.

hinge joint



(Image © Research Machines plc)

The knee is an example of a hinge joint.

Hipparchus (c. 190-c. 120 BC)

Greek astronomer and mathematician. He invented trigonometry and calculated the lengths of the solar year and the lunar month, discovered the precession of the equinoxes, made a catalogue of 850 fixed stars, and advanced Eratosthenes' method of determining the situation of places on the Earth's surface by lines of latitude and longitude.

Hipparcos

contraction of high-precision parallax collecting satellite

satellite launched by the European Space Agency to orbit the Earth from 1989 to 1993. Named after the Greek astronomer Hipparchus, it was the world's first astrometry satellite, mapping the precise positions, distances, colours, brightnesses, and apparent motions of stars. This resulted in a catalogue of more than 2.5 million stars, published in 2000.

Hippocrates (c. 460-c. 377 BC)

Greek physician, often called the founder of medicine. Important Hippocratic ideas include cleanliness (for patients and physicians), moderation in eating and drinking, letting nature take its course, and living where the air is good. He believed that health was the result of the 'humours' of the body being in balance; imbalance caused disease. These ideas were later adopted by Galen.

He was born and practised on the island of Kos, where he founded a medical school. He travelled throughout Greece and Asia Minor, and died in Larisa, Thessaly. He is known to have discovered aspirin in willow bark. The *Corpus Hippocraticum/Hippocratic Collection*, a group of some 70 works, is attributed to him but was probably not written by him, although the works outline his approach to medicine. They include *Aphorisms* and the **Hippocratic Oath**, which embodies the essence of medical ethics.

Works by Hippocrates

Go to site

Translations of the works of Hippocrates by Francis Adams in downloadable form. Seventeen works by the father of medicine are to be found here, ranging from *On Ancient Medicine* (this was written in 400 BC!) to *On The Surgery*. The site also includes the philosopher's best known work *The Oath*. The text files are very large (with some exceptions, notably *The Oath*), but the server is very fast so don't be too put off downloading.

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hippopotamus

(Greek 'river horse')

large herbivorous, short-legged, even-toed hoofed mammal. The **common hippopotamus** (*Hippopotamus amphibius*) is found in Africa. It weighs up to 3,200 kg/7,040 lb, stands about 1.6 m/5.25 ft tall, and has a brown or slate-grey skin. It is an endangered species. (Family Hippopotamidae.)

Hippos are social animals and live in groups. Because they dehydrate rapidly (at least twice as quickly as humans), they must stay close to water. When underwater, adults need to breath every 2-5 minutes and calves every 30 seconds. When out of water, their skin exudes an oily red fluid that protects them against the Sun's ultraviolet rays. The hippopotamus spends the day wallowing in rivers or waterholes, only emerging at night to graze. It can eat up to 25-40 kg/55-88 lb of grass each night. The **pygmy hippopotamus** (*Choeropsis liberiensis*) lives in West Africa.

There are about 157,000 hippos in Africa (1993 estimate), but they are under threat from hunters because of the value of their meat, hides, and large canine teeth (up to 0.5 m/1.6 ft long), which are used as a substitute for ivory.

hippopotamus: death

When a hippopotamus dies, other hippos surround the corpse and lick it. They may remain like this for a whole day, driving away any hungry crocodiles. They only abandon the corpse when the crocodiles become too numerous to deter.

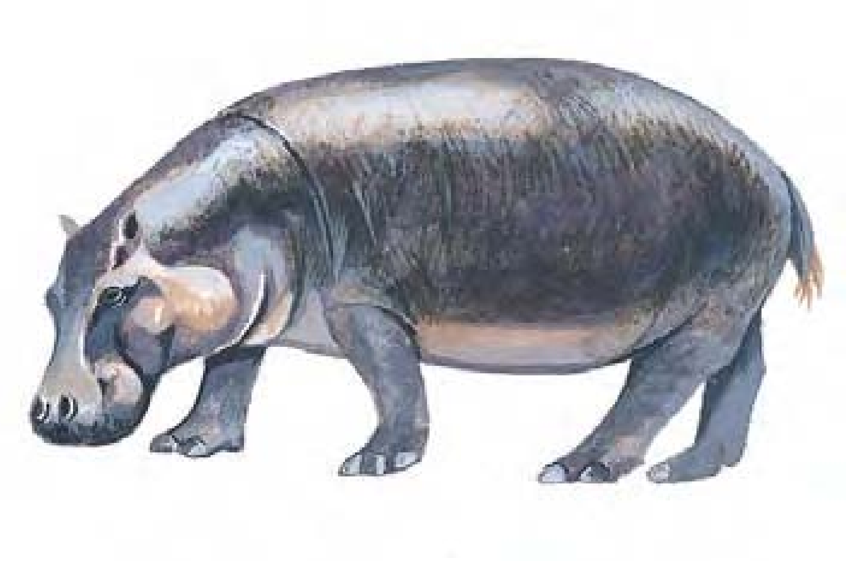
hippopotamus: feeding

During a nightly grazing session, a hippo can eat up to 40 kg/88 lb of grass and dead leaves. This is the equivalent of about 12 full sacks of food.

hippopotamus: jaws

A hippopotamus can open its jaws to an angle of 150° - almost a straight line (180°).

hippopotamus



(Image © Research Machines plc)

The common hippopotamus is adapted to life in the water, where it spends most of the day. It often lies submerged with only its eyes and nostrils above the surface. Its nostrils can be closed, and it has glands that give out an oily substance to protect its almost hairless skin.

hippopotamus

(Image © Corel)

The hippopotamus dehydrates quickly and has to spend much of the day in rivers or waterholes, emerging at night to graze. These individuals were photographed in the Mara River, Kenya.

Hippopotamus

Go to site

Illustrated guide to the hippopotamus including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

histamine

inflammatory substance normally released in damaged tissues, which also accounts for many of the symptoms of allergy. It is an amine, $C_5H_9N_3$. Substances that neutralize its activity are known as antihistamines.

Histamine was first described in 1911 by British physiologist Henry Dale (1875–1968).

histogram

in statistics, a graph showing frequency of data, in which the horizontal axis details discrete units or class boundaries, and the vertical axis represents the frequency. Blocks are drawn such that their areas (rather than their height as in a bar chart) are proportional to the frequencies within a class or across several class boundaries. There are no spaces between blocks.

If all the columns have the same width, then the element that appears most frequently (the mode) is represented by the tallest column. If the columns are of different widths the areas must be compared. Total frequency can be calculated by adding together the areas of all the columns.

histology

study of plant and animal tissue by visual examination, usually with a microscope.

Stains are often used to highlight structural characteristics such as the presence of starch or distribution of fats.

histology

in medicine, the laboratory study of cells and tissues.

historical archaeology

the archaeological study of historically documented cultures, especially in America and Australia, where it is directed at colonial and post-colonial settlements. The European equivalent is medieval and post-medieval archaeology.

HIV

abbreviation for human immunodeficiency virus

infectious agent identified as the cause of AIDS. It was first discovered in 1983 by Luc Montagnier of the

Pasteur Institute in Paris, who called it lymphocyte-associated virus (LAV). Independently, US scientist Robert Gallo of the National Cancer Institute in Bethesda, Maryland, claimed its discovery in 1984 and named it human T-lymphocytotrophic virus 3 (HTLV-III).

transmission

Worldwide, heterosexual activity accounts for three-quarters of all HIV infections. In Europe and the USA, high-risk groups are homosexual and bisexual men, prostitutes, intravenous drug users sharing needles, and haemophiliacs and other patients treated with contaminated blood products. The different distribution of risk in developed and developing countries occurs because different types of the virus are more common in different regions. The virus has a short life outside the body, which makes transmission of the infection by methods other than sexual contact, blood transfusion, and shared syringes extremely unlikely. Pregnant women infected with HIV are unlikely to pass it on to the fetus while in the uterus, but are quite likely to do so via vaginal fluids during birth or after breast-feeding the child. More than 90% of children born to an HIV-positive mother will contract the disease unless their parent has been treated with antiretroviral drugs.

To prevent the spread of HIV, evidence indicates a need to take early action and to invest in publicity and education campaigns. The second key element is to test pregnant women for HIV and give them antiviral drugs if they are HIV-positive, to prevent the transmission of the virus to the baby during childbirth.

AIDS: key dates

1977	Two homosexual men in New York are diagnosed as having the rare cancer Kaposi's sarcoma. They are thought to be the first victims of AIDS.
1979	The Center for Disease Control in Atlanta, Georgia, reports the first cases of the disease later known as AIDS.
1981	The Center for Disease Control in Atlanta, Georgia, first conclusively identifies AIDS; doctors realize they have previously seen similar cases among drug users and homosexuals.
1983	US medical researcher Robert Gallo at the US National Cancer Institute, Maryland, and French medical researcher Luc Montagnier at the Pasteur Institute in Paris, isolate the virus thought to cause AIDS; it becomes known as HIV (human immunodeficiency virus).
20 March 1987	The AIDS treatment drug AZT is given approval by the US Food and Drug Administration. Treatment costs US$10,000 per year per patient. The treatment does not cure the disease but it does relieve some symptoms and extend victims' lives.
31 December 1994	The number of AIDS cases worldwide exceeds 1 million for the first time, when the World Health Organization (WHO) announces that there are 1,025,073 officially reported AIDS cases.
1995	US researchers estimate that HIV reproduces at a rate of a billion viruses a day, even in otherwise healthy individuals, but is held at bay by the immune system producing enough white blood cells to destroy them. Gradually the virus mutates so much that the immune system is overwhelmed and the victim develops AIDS.
9 May 1996	Scientists discover a protein, 'fusin', which allows the HIV virus to fuse with a human immune system cell's outer membrane and inject genetic material. Its presence is necessary for the AIDS virus to enter the cell.
September 1996	The first three protease inhibitors are approved by the US Food and Drug Administration (FDA). Protease inhibitors are a new type of antiretroviral (a drug that stops the reproduction of HIV in the body).
January 1997	WHO estimates that 22.6 million men, women, and children have to date been infected by HIV, the virus responsible for causing AIDS. Approximately 42% of adult sufferers are female, with the proportion of women infected steadily increasing.
February 1997	The Centers for Disease Control and Prevention in Atlanta, Georgia, report that deaths among people with AIDS declined 13% during the first six months of 1996 over the same period the year before.
8 May 1997	US AIDS researcher David Ho and colleagues show how aggressive treatment of HIV-1 infection with a cocktail of three antiviral drugs can drive the virus to below the limits of conventional clinical detection within eight weeks.
9 February 1998	David Ho reports the discovery of the AIDS virus in a 1959 blood sample and suggests that a transfer of the virus from ape to human occurred in the late 1940s or early 1950s.
March 1998	According to a new study, a protein found in the urine of pregnant women could stop the reproduction of HIV, the virus that causes AIDS. The protein is known as human chorionic gonadotropin, or hcg. It also boosts the immune system and, because it is produced by the human body, is nontoxic and has very few side effects.
30 June 1998	Doctors report for the first time the ominous spread of a strain of the AIDS virus that is resistant to protease inhibitors, the medicines that have revolutionized care of the disease.
October 1998	Children born today in 29 sub-Saharan African nations face a life expectancy of just 47 years because of the toll the AIDS pandemic is taking on the region, according to a UN population report.
December 1998	Researchers report they have identified an inherited gene variation that in some patients causes an HIV infection to accelerate rapidly to AIDS. The identification of all the gene variations involved in both the rapid acceleration of HIV and in the slow progress of the disease would help in the design and testing of vaccines.
January 1999	WHO estimates that 33.4 million adults and children are living with AIDS at the end of 1998. Deaths due to HIV/AIDS in 1998 totalled 2.5 million, while the cumulative number of deaths reached 13.9 million.
January 1999	Researchers say they have conclusive evidence that the HIV virus has spread on at least three separate occasions from chimpanzees to humans in Africa. Chimps, which probably carried the virus for hundreds of thousands of years, apparently do not become ill from it. Understanding why, say AIDS experts, could help in a search for a cure and in the development of a vaccine.
February 1999	Thailand gives permission to the US company VaxGen Inc. to begin advance testing of an AIDS vaccine on about 2,500 people. The California-based company has already done preliminary trials of AIDSVAX vaccine on up to 90 Thai drug users. About 30 possible AIDS vaccines are in development, but AIDSVAX is the first to undergo massive testing to determine if it prevents AIDS infection.
February 1999	The first trial of an AIDS vaccine in Africa begins in a group of Ugandans considered at low risk of contracting the disease.
16 March 1999	US scientists report they have isolated an enzyme present in tears, which they believe has a powerful anti-HIV effect.
19 April 1999	The AIDS epidemic in South Africa reaches alarming new levels, with 10% of the population now infected with HIV. A national survey confirmed that the country has one of the highest rates of infection in the world.

21 April 1999	Hundreds of demonstrators rally in Washington, DC, to protest at policies which they say protect drug companies but make AIDS drugs too expensive for people in Africa.
April 1999	Scientists at Yerkes Regional Primate Center in Georgia, USA, announce that a 'safe' HIV vaccine has been successfully tested on monkeys. The vaccine, that uses harmless parts of HIV, protected monkeys from extremely virulent strains of the virus for at least 62 weeks.
12 May 1999	AIDS is now the leading cause of death in Africa, overtaking malaria as the continent's main killer disease, according to the UN.
1 June 1999	A new easier-to-take AIDS drug - Efavirenz - which has been hailed as 'a major advance in the treatment of HIV infection', is granted a licence for sale in the EU. It was approved in the USA the previous summer.
16 July 1999	Researchers in the USA and Uganda say they have identified a cheap and effective drug - called Nevirapine - which could control the spread of AIDS. The drug could prevent up to 400,000 children each year being born with the disease.
23 September 1999	Drug-resistant strains of HIV are on the increase, with as many as 3.8% of newly infected Americans failing to respond to a variety of different treatments, according to a study carried out by the AIDS Research Center at Rockerfeller University in New York.
November 1999	More than 50 million people are now infected with the HIV virus, according to UN and WHO estimates. More than 16 million have died from AIDS-related illnesses.
7 March 2000	Virologists at Thomas Jefferson University in Philadelphia say they have developed an HIV vaccine using a weakened rabies virus to carry a piece of the HIV virus safely into the cells of laboratory mice. The cells respond by creating immune system antibodies to attack the fragment, thus increasing their long-term capacity to fight off the HIV virus.
March 2000	A combination of drugs introduced in 1997 to treat HIV is shown to have dramatically increased the lifespan of patients, according to a comprehensive study carried out in Europe. The study shows that the drug combination known as Haart (highly-active antiretroviral therapy) is responsible for an overall decline of 64% in the risk of dying from AIDS within 10 years of developing the virus.
April 2000	The US government formally designates AIDS as a threat to international security and orders a major reassessment of its efforts against the disease. The Clinton administration acts after intelligence reports warn that the AIDS epidemic could trigger wars and genocide and undermine democratic governments, particularly in Africa.
May 2000	More than four out of every five deaths in Rwanda are now AIDS-related, according to government officials.
9 July 2000	The world's 13th conference on AIDS commences in South Africa. Botswanan President Festus Mogae warns that AIDS is causing a national crisis. Over a third of Botswanan adults is infected with HIV.
April 2001	A group of 38 multinational pharmaceutical firms abandon their legal challenge to a South African law that seeks to provide access to cheaper AIDS treatment by permitting the manufacture of generic drugs.
2005	Nigeria agrees to provide retro-viral drugs free of charge to fight HIV/AIDS.
2005	40.3 million people are estimated to be living with HIV/AIDS. 25 million have died since 1981.
May 2006	The origin of HIV is dicovered to have been in wild chimpanzees in Southern Cameroon.

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hoard

valuables or prized possessions that have been deliberately buried, often in times of conflict or war, and never reclaimed. Coins, objects in precious metals, and scrap metal are the most common objects found in hoards. In July 1991 the largest hoard found in Britain was discovered, consisting of 7,000 15th-century coins; it was declared a treasure trove.

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hobby

small falcon found across Europe and northern Asia. It is about 30 cm/1 ft long, with a grey-blue back, streaked front, and chestnut thighs. It is found in open woods and heaths, and feeds on insects and small birds. (Species *Falco subbuteo*.)

Hodgkin, Dorothy Mary Crowfoot (1910-1994)

English biochemist who analysed the structure of penicillin, insulin, and vitamin B_{12}. Hodgkin was the first to use a computer to analyse the molecular structure of complex chemicals, and this enabled her to produce three-dimensional models. She was awarded the Nobel Prize for Chemistry in 1964 for her work in the crystallographic determination of the structures of biochemical compounds, notably penicillin and cyanocobalamin (vitamin B_{12}).

Hodgkin studied the structures of calciferol (vitamin D_2), lumisterol, and cholesterol iodide, the first complex organic molecule to be determined completely by the pioneering technique of X-ray crystallography, a physical analysis technique devised by Lawrence Bragg (1890-1971), and at the time used only to confirm formulas predicted by organic chemical techniques. She also used this technique to determine the structure of penicillin, insulin, and vitamin B_{12}.

Hodgkin's disease

or lymphadenoma

rare form of cancer mainly affecting the lymph nodes and spleen. It undermines the immune system, leaving the sufferer susceptible to infection.

However, it responds well to radiotherapy and cytotoxic drugs, and long-term survival is usual.

Hodgkin's Disease Information

Go to site

Comprehensive information on lymphadenoma from the American Cancer Society. Written in easily understandable language, this guide explains the normal functions of the lymphatic system before describing the disease. There is information on risk factors, causes, diagnosis, and treatment of Hodgkin's disease, and latest research news. Further sources of information are also indicated.

Hoffman's voltameter

in chemistry, an apparatus for collecting gases produced by the electrolysis of a liquid.

It consists of a vertical E-shaped glass tube with taps at the upper ends of the outer limbs and a reservoir at the top of the central limb. Platinum electrodes fused into the lower ends of the outer limbs are connected to a source of direct current. At the beginning of an experiment, the outer limbs are completely filled with electrolyte by opening the taps. The taps are then closed and the current switched on. Gases evolved at the electrodes bubble up the outer limbs and collect at the top, where they can be measured.

Hofmeister, Wilhelm Friedrich Benedikt (1824-1877)

German botanist. He studied plant development and determined how a plant embryo, lying within a seed, is itself formed out of a single fertilized egg (ovule).

Hofmeister also discovered that mosses and ferns display an alternation of generations, in which the plant has two forms, spore-forming and gamete-forming.

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hog

any member of the pig family. The **river hog** (*Potamochoerus porcus*) lives in Africa, south of the Sahara. Reddish or black, up to 1.3 m/4.2 ft long plus tail, and 90 cm/3 ft at the shoulder, this gregarious animal roots for food in many types of habitat. The **giant forest hog** (*Hylochoerus meinerzthageni*) lives in thick forests of central Africa and grows up to 1.9 m/6 ft long. The **wart hog** is another African wild pig. The **pygmy hog** (*Sus salvanus*), the smallest of the pig family, is about 65 cm long (25 cm at the shoulder) and weighs 8-9 kg.

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hogback

geological formation consisting of a ridge with a sharp crest and abruptly sloping sides, the outline of which resembles the back of a hog. Hogbacks are the result of differential erosion on steeply dipping rock strata composed of alternating resistant and soft beds. Exposed, almost vertical resistant beds provide the sharp crests.

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hognose

North American colubrine, nonvenomous snake with a flattened head and a projecting snout for burrowing. (Genus *Heterodon*, family Elapidae, suborder Serpentes, order Squamata, class Reptilia.)

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hogweed

any of various coarse weeds, such as ragweed *Ambrosia* and sow thistle *Sonchus*.

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holism

in philosophy, the concept that the whole is greater than the sum of its parts.

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holistic medicine

umbrella term for an approach that virtually all alternative therapies profess, which considers the overall health and lifestyle profile of a patient, and treats specific ailments not primarily as conditions to be alleviated but rather as symptoms of more fundamental disease.

Hollerith, Herman (1860-1929)

US inventor of a mechanical tabulating machine, the first device for high-volume data processing. Hollerith's tabulator was widely publicized after being successfully used in the 1890 census. The firm he established, the Tabulating Machine Company, was later one of the founding companies of IBM.

Hollerith, Herman

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of inventor Herman Hollerith. In addition to biographical information, you will find a list of references about Hollerith and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Hollerith. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

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holly

tree or shrub of the genus *Ilex*, family Aquifoliaceae, generally with glossy, sharp-pointed leaves and red berries. American holly *I. opaca* of the eastern USA is used for Christmas decorations. Leaves of the Brazilian holly *I. paraguayensis* are used to make the tea yerba maté.

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hollyhock

tall flowering plant belonging to the mallow family. *A. rosea*, originally a native of Asia, produces spikes of large white, yellow, pink, or red flowers, 3 m/10 ft high when cultivated as a biennial; it is a popular cottage garden plant. (Genus *Althaea*, family Malvaceae.)

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holmium

chemical symbol Ho

(Latin Holmia 'Stockholm')

silvery, metallic element of the lanthanide series, atomic number 67, relative atomic mass 164.93. It occurs in combination with other rare-earth metals and in various minerals such as gadolinite. Its compounds are highly magnetic.

The element was discovered in 1878, spectroscopically, by the Swiss chemists Jacques-Louis Soret and Marc Delafontaine, and independently in 1879 by Swedish chemist Per Cleve (1840–1905), who named it after Stockholm, near which it was found.

Holocene epoch

period of geological time that began 10,000 years ago, and continues into the present. During this epoch the climate became warmer, the glaciers retreated, and human civilizations developed significantly.

It is the second and current epoch of the Quaternary period.

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holography

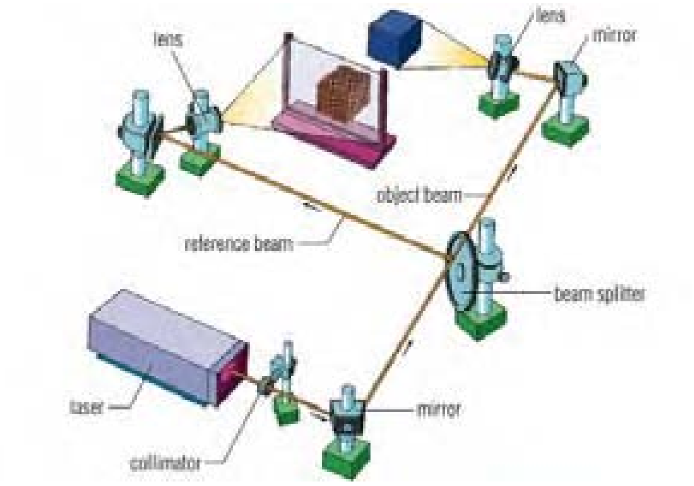
method of producing three-dimensional (3-D) images, called holograms, by means of laser light. Holography uses a photographic technique (involving the splitting of a laser beam into two beams) to produce a picture, or hologram, that contains 3-D information about the object photographed. Some holograms show meaningless patterns in ordinary light and produce a 3-D image only when laser light is projected through them, but reflection holograms produce images when ordinary light is reflected from them (as found on credit cards).

Although the possibility of holography was suggested as early as 1947 (by Hungarian-born British physicist Dennis Gabor), it could not be demonstrated until a pure, coherent light source, the laser, became available in 1963. The first laser-recorded holograms were created by Emmett Leith and Juris Upatnieks at the University of Michigan, USA, and Yuri Denisyuk in the Soviet Union.

The technique of holography is also applicable to sound, and bats may navigate by ultrasonic holography. Holographic techniques also have applications in storing dental records, detecting stresses and strains in construction and in retail goods, detecting forged paintings and documents, and producing three-dimensional body scans. The technique of detecting strains is of widespread application. It involves making two different holograms of an object on one plate, the object being stressed between exposures. If the object has distorted during stressing, the hologram will be greatly changed, and the distortion readily apparent.

Using holography, digital data can be recorded page by page in a crystal. As many as 10,000 pages (100 megabytes) of digital data can be stored in an iron-doped lithium niobate crystal of 1 cubic cm/0.06 cubic in.

holography



(Image © Research Machines plc)

Recording a transmission hologram. Light from a laser is divided into two beams. One beam goes directly to the photographic plate. The other beam reflects off the object before hitting the photographic plate. The two beams combine to produce a pattern on the plate which contains information about the 3-D shape of the object. If the exposed and developed plate is illuminated by laser light, the pattern can be seen as a 3-D picture of the object.

Amateur Holography

Go to site

Features an introduction to the field of holography, as well as a guide to creating your own holograms on a limited budget. There are also numerous links to related Web sites.

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homeopathy

or homoeopathy

system of alternative medicine based on the belief that symptoms of disease are part of the body's self-healing processes, and on the practice of administering extremely diluted doses of natural substances found to produce in a healthy person the symptoms manifest in the illness being treated. Developed by the German physician Samuel Hahnemann (1755-1843), the system is widely practised today as an alternative to allopathic (orthodox) medicine. However, its principles are incompatible with modern science and despite its popularity it seems to rely almost entirely on the placebo effect for any successful treatment.

Homeopathy Home Page

Go to site

Jumping-off point for a huge range of information on homeopathy. This well-arranged site accesses information on the homeopathic treatment of a variety of ailments and results of research into its efficacy. The online edition (and back issues) of *Homeopathy Online* have interesting articles on the application of homeopathy.

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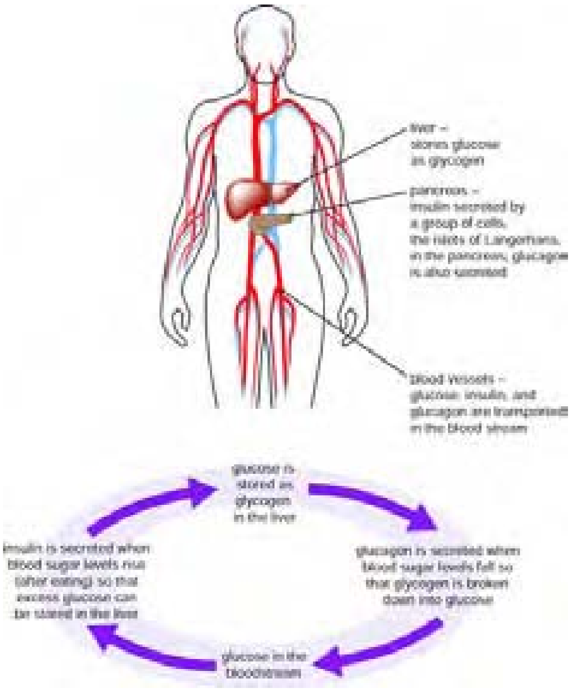
homeostasis

maintenance of a constant environment around living cells, particularly with regard to pH, salt concentration, temperature, and blood sugar levels. Stable conditions are important for the efficient functioning of the enzyme reactions within the cells. In humans, homeostasis in the blood (which provides fluid for all tissues) is ensured by several organs. The kidneys regulate pH, urea, and water concentration. The lungs regulate oxygen and carbon dioxide (see breathing). Temperature is regulated by the liver and the skin (see temperature regulation). Glucose levels in the blood are regulated by the liver and the pancreas.

Body cells need to be in surroundings where the conditions do not change much and never reach extremes that are damaging to them. The surroundings of body cells inside the body can be called an 'internal environment'. Homeostasis is the keeping of this internal environment stable. Special processes are needed to keep things stable and these may be called homeostatic processes.

Conditions that are regulated in homeostasis include blood glucose level, temperature, water content of the body, and the amount of carbon dioxide and urea being carried by the blood. Body cells are surrounded and bathed in fluid. This fluid – tissue fluid – is made from blood. This supplies the cells with mineral salts, such as glucose. As glucose is needed by cells all the time as a fuel for respiration, the level of glucose must not be allowed to fall. It is also damaging if the level gets too high. The hormone insulin is used to help keep blood glucose levels constant, by increasing its uptake into cells and stimulating the conversion of glucose into glycogen in the liver.

homeostasis


liver –
stores glucose
as glycogen
pancreas –
insulin secreted by
a group of cells,
the islets of Langerhans,
in the pancreas; glucagon
is also secreted
blood vessels –
glucose, insulin, and
glucagon are transported
in the blood stream
glucose is
stored as
glycogen
in the liver
insulin is secreted when
blood sugar levels rise
(after eating) so that
excess glucose can
be stored in the liver
glucagon is secreted when
blood sugar levels fall so
that glycogen is broken
down into glucose
glucose in the
bloodstream

(Image © Research Machines plc)

How blood-sugar levels are maintained in the body. When blood-sugar levels rise, insulin is secreted by the islets of Langerhans in the pancreas to facilitate the storage of glucose as glycogen. When blood-sugar levels fall too low, glucagon is secreted from the pancreas to facilitate the breakdown of glycogen back into glucose.

Homeostasis

Go to site

Full scientific explanation of homeostasis in animals. This page, part of a larger educational site covering many anatomical topics, includes diagrams and provides links to other sites with further related information. All the organs and body systems are covered here in detail.

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homeothermy

maintenance of a constant body temperature in endothermic (warm-blooded) animals, by the use of chemical processes to compensate for heat loss or gain when external temperatures change. Such processes include generation of heat by the breakdown of food and the contraction of muscles, and loss of heat by sweating, panting, and other means.

Mammals and birds are homeotherms, whereas invertebrates, fish, amphibians, and reptiles are cold-blooded or poikilotherms (see poikilothermy). Homeotherms generally have a layer of insulating material to retain heat, such as fur, feathers, or fat (see blubber). Their metabolism functions more efficiently due to homeothermy, enabling them to remain active under most climatic conditions. See also temperature regulation.

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homoeopathy

variant spelling of homeopathy.

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homogeneous reaction

in chemistry, a reaction where there is no interface between the components. The term applies to all reactions where only gases are involved or where all the components are in solution.

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homologous

in biology, a term describing an organ or structure possessed by members of different taxonomic groups (for example, species, genera, families, orders) that originally derived from the same structure in a common ancestor. The wing of a bat, the arm of a monkey, and the flipper of a seal are homologous because they all derive from the forelimb of an ancestral mammal.

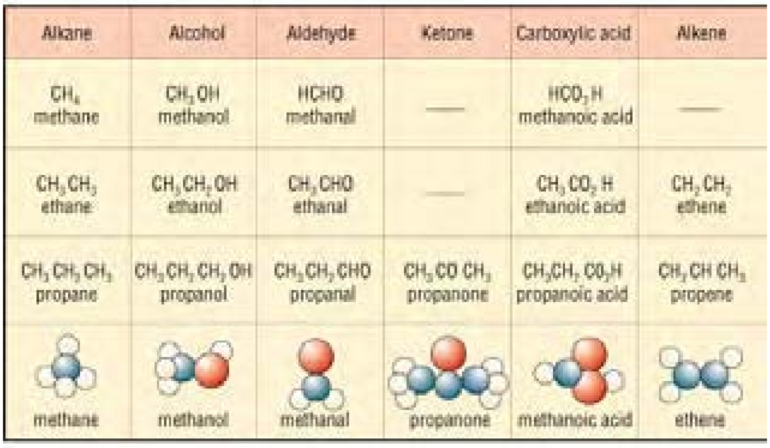
The wing of a bird and the wing of an insect are not homologous, even though they are both used for flying, because they are not derived from the same structure.

homologous series

in chemistry, any of a number of series of organic compounds with similar chemical properties in which members differ by a constant relative molecular mass.

Alkanes (paraffins), alkenes (olefins), and alkynes (acetylenes) form such series in which members differ in mass by 14, 12, and 10 atomic mass units respectively. For example, the alkane homologous series begins with methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), and pentane (C_5H_{12}), each member differing from the previous one by a CH_2 group (or 14 atomic mass units).

homologous series



Alkane	Alcohol	Aldehyde	Ketone	Carboxylic acid	Alkene
CH_4 methane	CH_3OH methanol	HCHO methanal	—	HCO_2H methanoic acid	—
CH_3CH_3 ethane	CH_3CH_2OH ethanol	CH_3CHO ethanal	—	CH_3CO_2H ethanoic acid	CH_2CH_2 ethene
$CH_3CH_2CH_3$ propane	$CH_3CH_2CH_2OH$ propanol	CH_3CH_2CHO propanal	CH_3COCH_3 propanone	$CH_3CH_2CO_2H$ propanoic acid	CH_2CHCH_3 propene
methane	methanol	methanal	propanone	methanoic acid	ethene

(Image © Research Machines plc)

Six different types of homologous series: organic chemicals with similar chemical properties in which members differ by a constant relative atomic mass. For example, all the members of the alkane series differ by a relative atomic mass of 14.

homozygous

in a living organism, having two identical alleles for a given trait. Individuals homozygous for a trait always breed true; that is, they produce offspring that resemble them in appearance when bred with a genetically similar individual; inbred varieties or species are homozygous for almost all traits. Recessive alleles are only expressed in the homozygous condition. Heterozygous organisms have two different alleles for a given trait.

honey

sweet syrup produced by honey bees from the nectar of flowers. It is stored in honeycombs and made in excess of their needs as food for the winter. Honey comprises various sugars, mainly laevulose and dextrose, with enzymes, colouring matter, acids, and pollen grains. It has antibacterial properties and was widely used in ancient Egypt, Greece, and Rome as a wound salve. It is still popular for sore throats, in hot drinks or in lozenges.

honeyeater

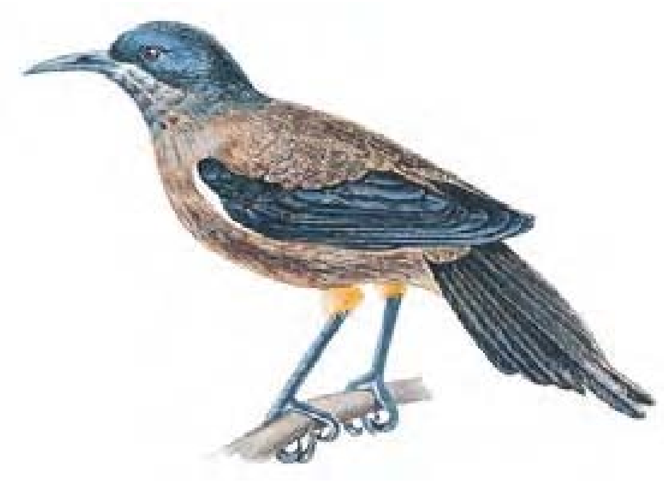
or honey-sucker

any of a group of small, brightly coloured birds with long, curved beaks and long tails, native to Australia. They have a long tongue divided into four at the end to form a brush for collecting nectar from flowers. (Family Meliphagidae.)

Larger honeyeaters, such as the **blue-faced honeyeater** (*Entomyza cyanotis*) of northeastern Australia, which is 30 cm/12 in long, also eat insects and fruit. The blood-bird is a honeyeater.

Honeyeaters from Australasia colonized Hawaii, where four distinct species evolved of which only one, the *Kauaioo*, survives; it too was thought to be extinct but was rediscovered in 1960.

honeyeater



(Image © Research Machines plc)

The Kauaioo was thought to be extinct, like the other three species of Hawaiian honeyeaters, but was rediscovered in 1960. It was saved by its relatively plain feathers; the other, more colourful, Hawaiian honeyeaters were hunted to extinction.

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honey guide

in botany, line or spot on the petals of a flower that indicate to pollinating insects the position of the nectaries (see nectar) within the flower. The orange dot on the lower lip of the butter-and-eggs flower *Linaria vulgaris* is an example. Sometimes the markings reflect only ultraviolet light, which can be seen by many insects although it is not visible to the human eye.

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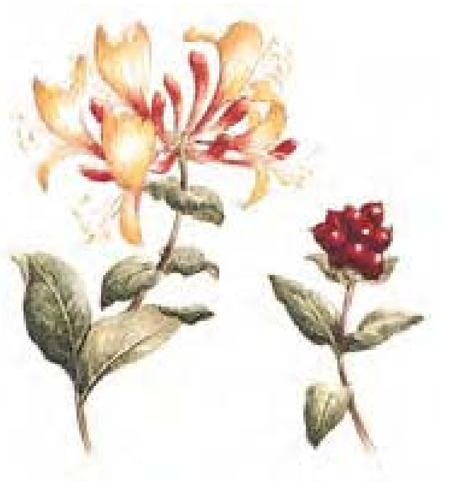
honeysuckle

vine or shrub found in temperate regions of the world. The common honeysuckle or woodbine (*L. periclymenum*) of Europe is a climbing plant with sweet-scented flowers, reddish and yellow-tinted outside and creamy white inside; it now grows in the northeastern USA. (Genus *Lonicera*, family Caprifoliaceae.)

The North American trumpet honeysuckle (*L. sempervirens*) has unusual vaselike flowers and includes scarlet and yellow varieties.

honeysuckle



(Image © Research Machines plc)

The honeysuckle produces large amounts of nectar. It has strongly scented flowers, attracting moths in the evening. In Shakespeare's time, the plant was called woodbine.

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hoof

horny covering that protects the sensitive parts of the foot of an animal. The possession of hooves is characteristic of the orders Artiodactyla (even-toed ungulates such as deer and cattle), and Perissodactyla (horses, tapirs, and rhinoceroses).

The flexibility of the hoof is promoted by a fluid secreted by the keratogenous (horn-producing) membrane. The cloven hoof of the Artiodactyla has been evolved for walking and climbing on irregular surfaces by the formation of a separate hoof on each digit of the foot. Horses walk on the third digit of the foot, while cattle walk on the third and fourth.

Hooke, Robert (1635-1703)

English scientist and inventor, originator of Hooke's law, and considered the foremost mechanic of his time. His inventions included a telegraph system, the spirit level, marine barometer, and sea gauge. He coined the term 'cell' in biology.

He studied elasticity, furthered the sciences of mechanics and microscopy, invented the hairspring regulator in timepieces, perfected the air pump, and helped improve such scientific instruments as microscopes, telescopes, and barometers. His work on gravitation and in optics contributed to the achievements of his contemporary Isaac Newton.

Hooker, Joseph Dalton (1817-1911)

English botanist who travelled to the Antarctic and India, and made many botanical discoveries. His works include *Flora Antarctica* (1844-47), *Genera plantarum* (1862-83), and *Flora of British India* (1875-97).

Hooke's law

law stating that the deformation of a body is proportional to the magnitude of the deforming force, provided that the body's elastic limit (see elasticity) is not exceeded. If the elastic limit is not reached, the body will return to its original size once the force is removed. The law was discovered by English physicist Robert Hooke in 1676.

A force applied to a spring by adding a weight to it will cause the spring to stretch in proportion to the applied force. If the force is removed and the spring returns to its original size, the material of the spring is said to be elastic. If the spring does not return to its original size, the material is said to be non-elastic. The elastic limit is the point at which a certain amount of force will deform the material so it becomes non-elastic.

For example, if a spring is stretched by 2 cm by a weight of 1 N, it will be stretched by 4 cm by a weight of 2 N, and so on. However, once the load exceeds the elastic limit for the spring, Hooke's law will no longer be obeyed and each successive increase in weight will result in a greater extension until finally the spring breaks.

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hookworm

parasitic roundworm (see worm) with hooks around its mouth. It lives mainly in tropical and subtropical regions, but also in humid areas in temperate climates. The eggs are hatched in damp soil, and the larvae bore into the host's skin, usually through the soles of the feet. They make their way to the small intestine, where they live by sucking blood. The eggs are expelled with faeces, and the cycle starts again. The human hookworm causes anaemia, weakness, and abdominal pain. It is common in areas where defecation occurs outdoors. (Genus *Necator*.)

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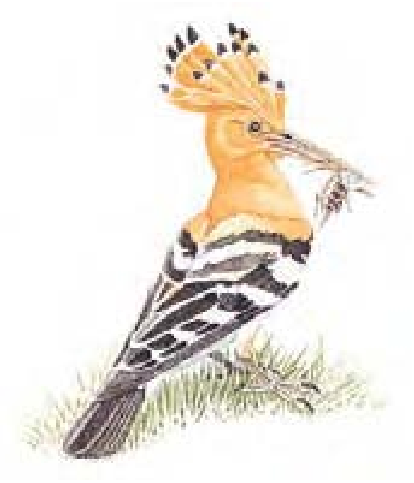
hoopoe

bird slightly larger than a thrush, with a long, thin, slightly downward-curving bill and a bright pinkish-buff crest tipped with black that expands into a fan shape on top of the head. The wings and tail are banded with black and white, and the rest of the plumage is buff-coloured. The hoopoe is found throughout southern Europe and Asia down to southern Africa, India, Malaya. (Species *Upupa epops*, family Upupidae, order Coraciiformes.)

hoopoe



(Image © Research Machines plc)

The hoopoe is the sole member of its family, the Upupidae. With its orange-pink body plumage, boldly striped wings and tail, and huge, erectile crest, it is an unmistakable bird. It feeds mainly on the ground on worms, insects, and other invertebrates.

Hoover Dam

highest concrete dam in the USA, 221 m/726 ft, on the Colorado River at the Arizona-Nevada border. It was begun during the administration of President Herbert Hoover and built 1930-36. Known as **Boulder Dam** 1933-47, under the administration of Franklin D Roosevelt, its name was restored by President Harry Truman as the reputation of Herbert Hoover was revived. It impounds Lake Mead, and has a hydroelectric power capacity of over 2,000 megawatts.

Hopkins, Frederick Gowland (1861-1947)

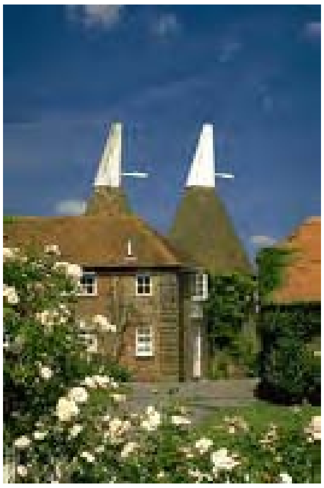
English biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1929 for his discovery of trace substances, now known as vitamins, that stimulate growth. His research into diets revealed the necessity of these vitamins for the maintenance of health. Hopkins shared the prize with Christiaan Eijkman, who had arrived at similar conclusions. He was knighted in 1925.

Hopkins also established that there are certain amino acids that the body cannot produce itself. Another discovery he took part in was that contracting muscle accumulates lactic acid.

hops

female fruit heads of the hop plant *Humulus lupulus*, family Cannabiaceae; these are dried and used as a tonic and in flavouring beer. In designated areas in Europe, no male hops may be grown, since seedless hops produced by the unpollinated female plant contain a greater proportion of the alpha acid that gives beer its bitter taste.

oast-house



(Image © Corel)

Oast-houses in Hever, Kent, England. Hops, used to flavour beer, are dried in kilns inside the oast-houses.

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horehound

any of a group of plants belonging to the mint family. The white horehound (*M. vulgare*), found in Europe, North Africa, and western Asia and naturalized in North America, has a thick hairy stem and clusters of dull white flowers; it has medicinal uses. (Genus *Marrubium*, family Labiatae.)

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horizon

in astronomy, the great circle dividing the visible part of the sky from the part hidden by the Earth.

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horizon

limit to which one can see across the surface of the sea or a level plain, that is, about 5 km/3 mi at 1.5 m/5 ft above sea level, and about 65 km/40 mi at 300 m/1,000 ft.

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hormone

in biology, a chemical secretion of the ductless endocrine glands and specialized nerve cells concerned with control of body functions. Hormones act as chemical messengers and are transported to all parts of the body by the bloodstream where they affect target organs. The major glands are the thyroid, parathyroid, pituitary, adrenal, pancreas, ovary, and testis. There are also hormone-secreting cells in the kidney, liver, gastrointestinal tract, thymus (in the neck), pineal (in the brain), and placenta. Hormones bring about changes in the functions of various organs according to the body's requirements. The hypothalamus, which adjoins the pituitary gland at the base of the brain, is a control centre for overall coordination of hormone secretion; the thyroid hormones determine the rate of general body chemistry; the adrenal hormones prepare the organism during stress for 'fight or flight'; and the sexual hormones such as oestrogen and testosterone govern reproductive functions. Plants produce chemicals that affect growth and development. These chemicals can also be called hormones (see plant hormone).

Hormones often bring about a slower response than messages sent by the nerve cells, but the response to hormones may be longer lasting.

Examples of hormones include: insulin and glucagon (produced in the pancreas), which are involved in glucose regulation; ADH (produced in the pituitary gland), which regulates the concentration of urine produced by the kidney; oestrogen and progesterone (produced in the ovaries), which regulate the growth and functioning of sex organs for sexual reproduction; testosterone (produced in the testes), which regulates male sexual development; follicle-stimulating hormone (FSH) and luteinizing hormone (LH) (from the pituitary gland), which regulate the menstrual cycle in females; and adrenaline (released from the adrenal glands), which prepares the body for increased activity.

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hormone-replacement therapy

HRT

use of oestrogen and progesterone to help limit the unpleasant effects of the menopause in women. The treatment was first used in the 1970s.

During the menopause, the ovaries cease to secrete natural oestrogen. This results in a number of symptoms, including hot flushes, anxiety, and a change in the pattern of menstrual bleeding. It is also associated with osteoporosis, or a thinning of bones, leading to an increased incidence of fractures, frequently of the hip, in older women. Oestrogen preparations, taken to replace the decline in natural hormone levels, combined with regular exercise can help to maintain bone strength in women. In order to improve bone density, however, HRT must be taken for five years, during which time the woman will continue to menstruate. Many women do not find this acceptable. In 1997 about 33% of British women and 40% of US women opted for post-menopausal HRT. A 1999 US survey revealed that white women are more likely to use hormone replacement than African-Americans or Mexican-Americans.

A 2002 study linked HRT to a number of adverse effects, most notably a very small increase in the risk of breast cancer. It was unclear whether this study was generalizable or specific to the form of hormone administration used in the study, and the debate over benefits and risks of HRT continues.

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horn

broad term for hardened processes on the heads of some members of order Artiodactyla: deer, antelopes, cattle, goats, and sheep; and the rhinoceroses in order Perissodactyla. They are used usually for sparring rather than serious fighting, often between members of the same species rather than against predators.

The structure of horn shows immense variation, some being primarily made of bone, as in the antlers of deer; others of the substance called horn, as in cattle or antelopes; and others of compressed hair, as in rhinoceroses. Antlers are usually shed and regrown every year, while true horns are grown for life.

In most horned species they are possessed by both sexes, but in some species horns are limited to males.

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hornbeam

any of a group of trees belonging to the birch family. They have oval leaves with toothed edges and hanging clusters of flowers, each with a nutlike seed attached to the base. The trunk is usually twisted, with smooth grey bark. (Genus *Carpinus*, family Betulaceae.)

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hornbill

any of a group of omnivorous birds found in Africa, India, and Malaysia. They are about 1 m/3 ft long, and have powerful down-curved beaks, usually surmounted by a bony growth or casque. During the breeding season, the female walls herself into a hole in a tree and does not emerge until the young are hatched. There are about 45 species. (Family Bucerotidae, order Coraciiformes.)

Hornbills feed chiefly on the ground, their food consisting of insects, small mammals, and reptiles. The **great hornbill** (*Buceros bicornis*) of Southeast Asia can reach up to 1.3 m/4.3 ft in length.

The **southern ground hornbill** lives in groups of about three to five birds (though sometimes as many as ten) with only one breeding pair, and the rest acting as helpers. On average, only one chick is reared successfully every nine years. Lifespan can be 40 years or more.

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hornblende

green or black rock-forming mineral, one of the amphiboles. It is a hydrous silicate composed mainly of calcium, iron, magnesium, and aluminium in addition to the silicon and oxygen that are common to all silicates. Hornblende is found in both igneous and metamorphic rocks and can be recognized by its colour and prismatic shape.

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hornet

type of wasp.

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hornfels

metamorphic rock formed by rocks heated by contact with a hot igneous body. It is fine-grained, brittle, and lacks foliation (a planar structure).

Hornfels may contain minerals only formed under conditions of great heat, such as andalusite, Al_2SiO_5, and cordierite, $(Mg,Fe)_2Al_4Si_5O_{18}$. This rock, originating from sedimentary rock strata, is found in contact with large igneous intrusions where it represents the heat-altered equivalent of the surrounding clays. Its hardness makes it suitable for road building and railway ballast.

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hornwort

nonvascular plant (with no 'veins' to carry water and food), related to the liverworts and mosses. Hornworts are found in warm climates, growing on moist shaded soil. (Class Anthocerotae, order Bryophyta.)

The name is also given to a group of aquatic flowering plants which are found in slow-moving water. They have whorls of finely divided leaves and may grow up to 2 m/7 ft long. (Genus *Ceratophyllum*, family Ceratophyllaceae.)

Like liverworts and mosses, the bryophyte hornworts exist in two different reproductive forms, sexual and asexual, which appear alternately (see alternation of generations). A leafy plant body, or gametophyte, produces gametes, or sex cells, and a small horned form, or sporophyte, which grows upwards from the gametophyte, produces spores. Unlike the sporophytes of mosses and liverworts, the hornwort sporophyte survives after the gametophyte has died.

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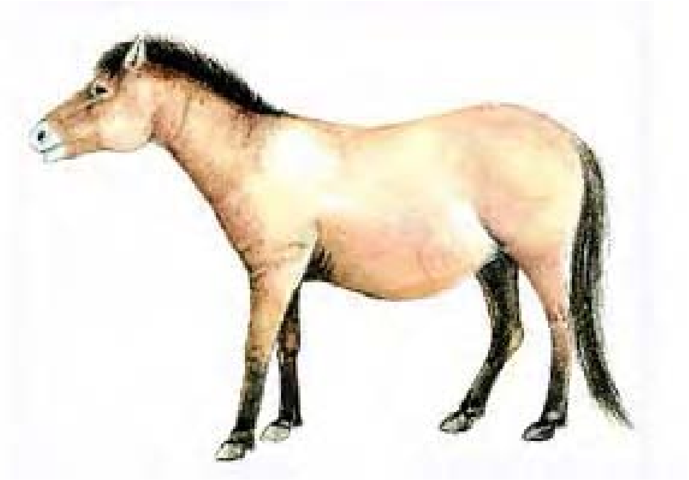
horse

hoofed, odd-toed, grazing mammal belonging to the same family as zebras and asses. The many breeds of domestic horse of Euro-Asian origin range in colour from white to grey, brown, and black. The yellow-brown **Mongolian wild horse**, or **Przewalski's horse** (*Equus przewalskii*), named after its Polish 'discoverer' in *c.* 1880, is the only surviving species of wild horse. (Species *Equus caballus*, family Equidae.)

Przewalski's horse became extinct in the wild because of hunting and competition with domestic animals for food; about 800 survive in captivity. However, in the late 1990s 55 Przewalski's horses were successfully reintroduced to the wild in Mongolia.

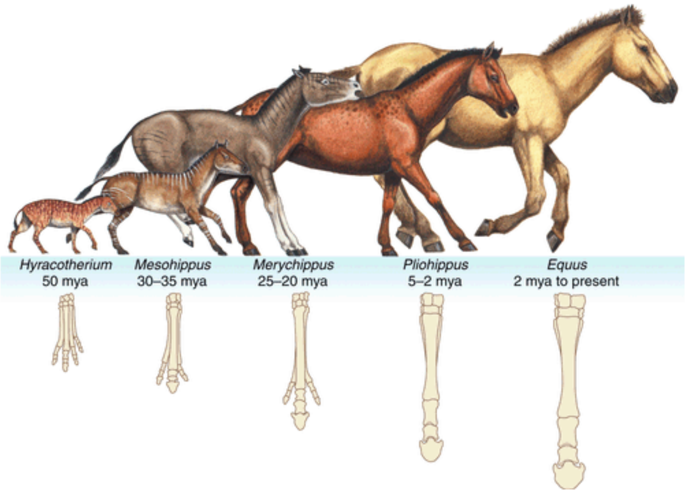
horse



(Image © Research Machines plc)

Horses have been domesticated from early in the 2nd millennium BC, probably at first to provide food. Ancient Middle Eastern civilizations used them to draw the chariots of warriors. Later, riding became important and horses were selectively bred to produce larger, stronger animals. Finally they came into use as general draught animals.

horse


Hyracotherium
50 mya
Mesohippus
30–35 mya
Merychippus
25–20 mya
Pliohippus
5–2 mya
Equus
2 mya to present

(Image © Research Machines plc)

The evolution of the modern horse has taken place over 50 million years, from the fox-sized four-toed *Hyracotherium* to the largest draught horse at 17 hands (1.73 m/5.6 ft) at the shoulder.

horse

(Image © Research Machines plc)

The shire horse is probably a descendant of the English 'Great Horse', which was praised by Julius Caesar after the Roman invasion of Britain. Several monarchs since then, recognizing the military usefulness of these large, strong horses, have instituted breeding programmes to maximize their potential. In the 19th century, the shire horse could be seen dragging heavy loads through the badly paved streets of Victorian cities.

horse

(Image © Research Machines plc)

Horses grazing in the 'Bluegrass State', Kentucky, USA. Breeding and selling thoroughbred horses is one of the state's largest sources of income. The most intensive area of breeding is around Lexington.

Breeds of Livestock - Horse Breeds

Go to site

Extensive database of horse breeds from all over the world. A typical page offers details on the origin and history of the breed, presents a description of it and a couple of photographs.

horsefly

any of over 2,500 species of fly. The females suck blood from horses, cattle, and humans; the males live on plants and suck nectar. The larvae are carnivorous. (Family Tabanidae.)

horsefly

There is a fly larva that eats toads. The horsefly larva *Tabanus punctifer* lives in the soft mud at the edges of ponds. It kills tiny, newly metamorphosed spadefoot toads by injecting them with venom, and then sucks out their body fluids.

horsepower

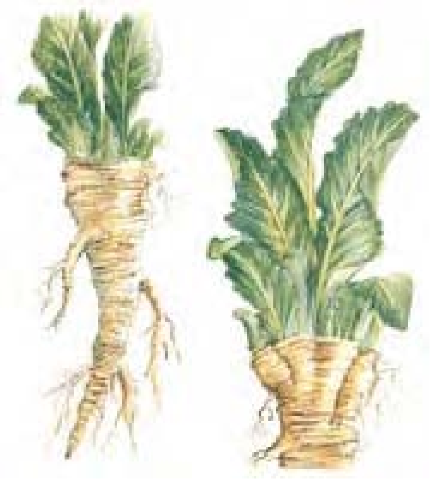
abbreviation hp

imperial unit of power, now replaced by the watt. It was first used by the engineer James Watt, who employed it to compare the power of steam engines with that of horses.

horseradish

hardy perennial plant, native to southeastern Europe but naturalized elsewhere. The thick cream-coloured root is strong-tasting and is often made into a savoury sauce to accompany food. (*Armoracia rusticana*, family Cruciferae.)

horseradish



(Image © Research Machines plc)

The horseradish is a hairy perennial with wavy, indented leaves and small white flowers. The plant grows to a height of 60-90 cm/2-3 ft and has a thick taproot. It originated on the borders of Europe and Asia.

horsetail

plant related to ferns and club mosses; some species are also called **scouring rush**. There are about 35 living species, bearing their spores on cones at the stem tip. The upright stems are ribbed and often have spaced whorls of branches. Today they are of modest size, but hundreds of millions of years ago giant treelike forms existed. (Genus *Equisetum*, order Equisetales.)

horticulture

art and science of growing flowers, fruit, and vegetables. Horticulture is practised in gardens and orchards, along with millions of acres of land devoted to vegetable farming. Some areas, like California, have specialized in horticulture because they have the mild climate and light fertile soil most suited to these crops.

Hosking, Eric (John) (1909-1990)

English wildlife photographer. He is known for his documentation of British birds, especially owls. Beginning at the age of eight and still photographing in Africa at 80, he covered all aspects of birdlife and illustrated a large number of books, published between 1940 and 1990.

hospice

residential facility specializing in palliative care for terminally ill patients and their relatives.

The aim of hospices is to control the pain of the patients, and enable them to die with dignity.

hospital

facility for the care of the sick, injured, and incapacitated.

In ancient times, temples of deities such as Aesculapius offered facilities for treatment and by the 4th century, the Christian church had founded hospitals for lepers, cripples, the blind, the sick, and the poor. The oldest surviving hospital in Europe is the 7th-century Hôtel Dieu, Paris; in Britain, the most ancient are St Bartholomew's (1123) and St Thomas's (1200) in London; and in the Americas the Hospital of Jesus of Nazareth, Mexico (1524).

Medical knowledge advanced during the Renaissance, and hospitals became increasingly secularized after the Reformation. In the 19th century, further progress was made in hospital design, administration, and staffing (Florence Nightingale played a significant role in this). In the 20th century there has been an increasing trend towards specialization and the inclusion of maternity wards. Modern hospitals have abandoned the single-room Nightingale design for wards in favour of four- or six-bedded rooms, where patients have more privacy.

Virtual Hospital

Go to site

Virtual hospital with multimedia instructional tools, contents of a wide series of medical publications, simulations of patients, patient textbooks, peer-reviewed Web resources on common medical problems, and an online continuing education service for health care providers and patients.

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host

in biology, an organism that is parasitized by another. In commensalism, the partner that does not benefit may also be called the host.

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hostname

alternative name given to a computer when it is connected to the Internet. The hostname is used instead of the unique Internet address which is in the form of four numbers separated by dots. The hostname is an alias, or nickname, and is easier to remember than the number.

One of the roles of the Domain Name Service is to maintain tables of Internet addresses and their corresponding hostnames.

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hot spot

in earth science, area where a strong current or 'plume' of magma rises upwards below the Earth's crust. The magma spreads horizontally in all directions, and may break through where the crust is thin. Hot spots occur within, rather than on the edges of, lithospheric plates. However, the magma usually reaches the surface at plate margins. Examples of hot spots include Hawaii, Iceland, and Yellowstone National Park, Wyoming, USA.

Hounsfield, Godfrey Newbold (1919-2004)

English engineer who was awarded a Nobel Prize for Physiology or Medicine in 1979 for the development of the computed axial tomography (CAT) scan, the application of computer techniques to X-raying the human body. He was knighted in 1981.

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hour

period of time comprising 60 minutes; 24 hours make one calendar day.

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housefly

fly found in and around human dwellings, especially *M. domestica*, a common worldwide species. Houseflies are grey and have mouthparts adapted for drinking liquids and sucking moisture from food and manure. (Genus *Musca*.)

housefly

In nine months, a housefly could lay enough eggs to produce a layer of flies that would cover all of Germany to a depth of 14 m/47 ft.

---

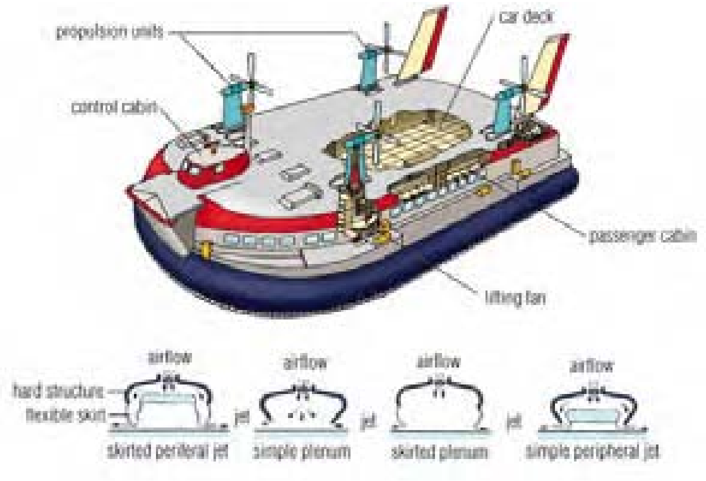
hovercraft

vehicle that rides on a cushion of high-pressure air, free from all contact with the surface beneath, invented by English engineer Christopher Cockerell in 1959. Hovercraft need a smooth terrain when operating overland and are best adapted to use on waterways. They are useful in places where harbours have not been established.

Large hovercraft (SR-N4) operated a swift car-ferry service across the English Channel 1966-2000, taking only about 35 minutes between Dover and Calais. They were fitted with a flexible 'skirt' that helps maintain the air cushion.

A military version made of fibreglass, the M-10, is tough manoeuvrable, and less noisy.

hovercraft


propulsion units
car deck
control cabin
passenger cabin
lifting fan
airflow
hard structure
flexible skirt
jet
skirted periferal jet
airflow
jet
simple plenum
airflow
jet
skirted plenum
airflow
simple peripheral jet

(Image © Research Machines plc)

There are several alternative ways of containing the cushion of air beneath the hull of a hovercraft.
The passenger-carrying hovercraft that sails across the English Channel has a flexible skirt; other systems are the open plenum and the peripheral jet.

hovercraft

HOVERTRAVEL

(Image © Corel)

A passenger hovercraft on the route from Portsmouth to Ryde on the Isle of Wight, which is off the south coast of England. Hovercraft are faster than traditional ferries.

Build a Real Working Hovercraft

Go to site

Instructions on how to build a hovercraft for your pet mouse! This site also includes a brief explanation of the theory.

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hoverfly

brightly coloured winged insect. Hoverflies usually have spots, stripes, or bands of yellow or brown against a dark-coloured background, sometimes with dense hair covering the body surface. Many resemble bees, bumble bees, and wasps (displaying Batesian mimicry) and most adults feed on nectar and pollen.
(Family Syrphidae (numbering over 2,500 species), suborder Cyclorrhapha, order Diptera, class Insecta, phylum Arthropoda.)

One of the most characteristic features of hoverflies is the presence of a longitudinal false vein in the wing.

larva

The larvae show remarkable variations in appearance and feeding habits. They may feed externally on plants or they may be internal feeders, attacking the bulbs; for example the **narcissus fly**, *Merodon equestris*.
Many are carnivorous, feeding on scale insects, greenfly (aphids), and other insects that harm commercial crops.

The larvae may also feed on rotting wood or the decaying organic matter in stagnant pools; for example the **rat-tailed maggot**, larva of the drone fly *Eristalis tenax* is found in polluted pools. They breathe by extending their tail breathing tubes to reach the surface of the water.

hoverfly

Some species of hoverfly vary their markings depending on the time of the year that they are born. Those born in spring and autumn have more black and darker yellow, to increase heat absorption, than those born in summer.

Hoyle, Fred(erick) (1915-2001)

English astronomer, cosmologist, and writer. His astronomical research dealt mainly with the internal structure and evolution of the stars. In 1948 he developed with Hermann Bondi and Thomas Gold the steady-state theory of the universe. In 1957, with William Fowler, he showed that chemical elements heavier than hydrogen and helium may be built up by nuclear reactions inside stars. He was knighted in 1972.

Fowler and Hoyle proposed that all the elements may be synthesized from hydrogen by successive fusions. When the gas cloud reaches extremely high temperatures, the hydrogen has turned to helium and neon, whose nuclei interact, releasing particles that unite to build up nuclei of new elements.

In 1964 Hoyle proposed a new theory of gravitation. According to this theory, matter is not evenly distributed throughout space, but forms self-gravitating systems. These may range in diameter from a few kilometres to a million light years. Formed from clouds of hydrogen gas, they vary greatly in density.

He has also suggested that life originated in bacteria and viruses contained in the gas clouds of space and was then delivered to the Earth by passing comets.

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hp

abbreviation for horsepower.

HTML

abbreviation for hypertext markup language

standard for structuring and describing a document on the World Wide Web. The HTML standard provides labels for constituent parts of a document (for example headings and paragraphs) and permits the inclusion of images, sounds, and 'hyperlinks' to other documents. A browser program is then used to convert this information into a graphical document on-screen. The specifications for HTML version 4, called Dynamic HTML, were adopted at the end of 1997.

HTML is a specific example of SGML (standard generalized markup language, the international standard for text encoding). As such it is not a rigid standard but is constantly being improved to incorporate new features and allow greater freedom of design.

Hubble, Edwin (Powell) (1889-1953)

US astronomer. He discovered the existence of galaxies outside our own, and classified them according to their shape. His theory that the universe is expanding is now generally accepted.

His data on the speed at which galaxies were receding (based on their red shifts) were used to determine the portion of the universe that we can never come to know, the radius of which is called the **Hubble radius**. Beyond this limit, any matter will be travelling at the speed of light, so communication with it will never be possible. The ratio of the velocity of galactic recession to distance has been named the **Hubble constant**.

Hubble discovered Cepheid variable stars in the Andromeda galaxy in 1924, proving it to lie far beyond our own Galaxy. In 1925 he introduced the classification of galaxies as spirals, barred spirals, and ellipticals. In 1929 he announced **Hubble's law**, stating that the galaxies are moving apart at a rate that increases with their distance from each other.

Hubble classification

in astronomy, scheme for classifying galaxies according to their shapes, originally devised by US astronomer Edwin Hubble in the 1920s.

Elliptical galaxies are classed from type E0 to type E7, where the figure denotes the degree of ellipticity. An E0 galaxy appears circular to an observer, while an E7 is highly elliptical (this is based on the apparent shape; the true shape, distorted by foreshortening, may be quite different).
Spiral galaxies are classed as type Sa, Sb, or Sc: Sa is a tightly wound spiral with a large central bulge, Sc is loosely wound with a small bulge, and Sb is in between. Intermediate types are denoted by Sab or Sbc.
Barred spiral galaxies, which have a prominent bar across their centres, are similarly classed as type SBa, SBb, or SBc, with intermediates SBab or SBbc.
Lenticular galaxies, which have no spiral arms, are classed as type S0.
Irregular galaxies, type Irr, can be subdivided into Irr I, which resemble poorly formed spirals, and Irr II which cannot be classified because of disturbance.

The Hubble classification was once believed to reveal an evolutionary sequence (from ellipticals to spirals) but this is now known not to be the case. Our own Milky Way is a spiral galaxy, classified as type Sb or Sc, but may have a bar.

Hubble constant

in astronomy, measure of the rate at which the universe is expanding, named after US astronomer Edwin Hubble. Observations suggest that galaxies are moving apart at a rate of 50-100 kps/30-60 mps for every million parsecs (megaparsecs) of distance. This means that the universe, which began at one point according to the Big Bang theory, is between 10 billion and 20 billion years old. Observations by the Hubble Space Telescope in 1996 produced a figure for the constant of 73 kps/45 mps per megaparsec. Measurements of the cosmic background radiation currently give a value close to 70 kps/43.5 mps per megaparsec.

Hubble's law

law that relates a galaxy's distance from us to its speed of recession as the universe expands, formulated in 1929 by US astronomer Edwin Hubble. He found that galaxies are moving apart at speeds that increase in direct proportion to their distance apart. The rate of expansion is known as the Hubble constant. Its currently accepted value is about 70 (km/s)/Mpc (70 km/s per megaparsec, or about 21.5 km/s per million light-years).

Hubble Space Telescope

HST

space-based astronomical observing facility, orbiting the Earth at an altitude of 610 km/380 mi. It consists of a 2.4 m/94 in telescope and four complementary scientific instruments, is roughly cylindrical, 13 m/43 ft long and 4 m/13 ft in diameter, and has two large solar panels. HST produces a wealth of scientific data, and allows astronomers to observe the birth of stars, find planets around neighbouring stars, follow the expanding remnants of exploding stars, and search for black holes in the centre of galaxies. HST is a cooperative programme between the European Space Agency (ESA) and the US space agency NASA, and is the first spacecraft specifically designed to be serviced in orbit as a permanent space-based observatory. It was launched in 1990. It will re-enter the Earth's atmosphere some time after 2010 and be destroyed unless more servicing missions are flown to it – missions that are currently in doubt following the *Columbia* shuttle disaster.

By having a large telescope above Earth's atmosphere, astronomers are able to look at the universe with unprecedented clarity. Celestial observations by HST are unhampered by clouds and other atmospheric phenomena that distort and attenuate starlight. In particular, the apparent twinkling of starlight, caused by density fluctuations in the atmosphere, limits the clarity of ground-based telescopes. HST performs at least ten times better than such telescopes and can see almost back to the edge of the universe and to the beginning of time (see Big Bang).

Before HST could reach its full potential, a flaw in the shape of its main mirror, discovered two months after the launch, had to be corrected. In 1993, as part of a planned servicing and instrument upgrade mission, NASA astronauts aboard the space shuttle *Endeavour* installed a set of corrective lenses to compensate for the error in the mirror figure. COSTAR (corrective optics space telescope axial replacement), a device containing ten coin-sized mirrors, now feeds a corrected image from the main mirror to three of the HST's four scientific instruments. HST is also being used to detail the distribution of dust and stars in nearby galaxies, watch the collisions of galaxies in detail, infer the evolution of galaxies, and measure the age of the universe.

Hubble Space Telescope

(Image © NASA)

Successive observations with Hubble's wide-field and planetary camera (WFPC) produced this image of the Bubble Nebula (NGC 7635). The spherical boundary region is formed as an expanding shell of particles thrown off by the star within.

Hubble Space Telescope

(Image © NASA)

The Hubble wide-field planetary camera was used to capture this image of planetary nebula NGC 6751, in the constellation of Aquila. The gases were ejected by the central star several thousand years ago.

Hubble Space Telescope

(Image © NASA)

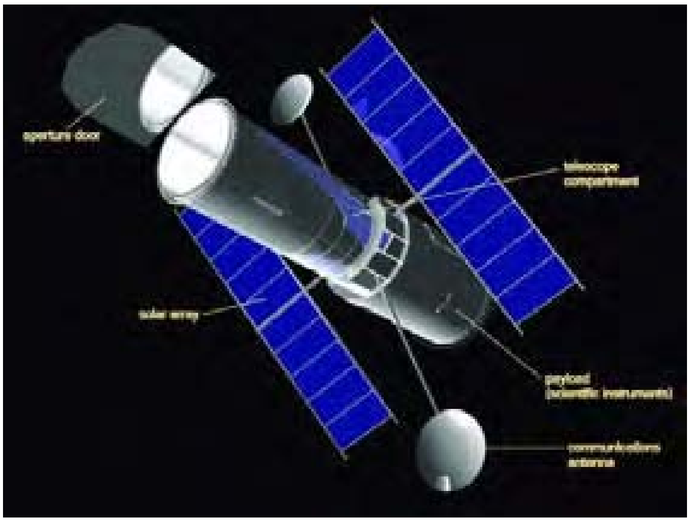
The Hubble Space Telescope photographed shortly after its release from the space shuttle *Discovery* 's robot arm, following its third servicing mission (STS-103) in December 1999. The telescope's failed gyroscopes were replaced, its computer upgraded, and other new components installed.

Hubble Space Telescope

(Image © NASA)

Golden solar arrays are lit from behind in this dramatic view of the Hubble Space Telescope as it sits in the space shuttle cargo bay during Hubble Servicing Mission 3 (STS-103). The Earth's atmosphere forms a bright streak between the telescope and the right solar panel.

Hubble Space Telescope



(Image © Research Machines plc)

The Hubble Space Telescope is powered by its solar arrays, which convert sunlight directly into 2,400 watts of electricity to run Hubble's scientific instruments, computers, and radio transmitters.

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huckleberry

berry-bearing bush closely related to the blueberry in the USA and bilberry in Britain. Huckleberry bushes have edible dark-blue berries. (Genus *Gaylussacia*, family Ericaceae.)

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human body

physical structure of the human being. It develops from the single cell of the fertilized ovum, is born at 40 weeks, and usually reaches sexual maturity between 11 and 18 years of age. The bony framework (skeleton) consists of more than 200 bones, over half of which are in the hands and feet. Bones are held together by joints, some of which allow movement. The circulatory system supplies muscles and organs with blood, which provides oxygen and food and removes carbon dioxide and other waste products. Body functions are controlled by the nervous system and hormones. In the upper part of the trunk is the thorax, which contains the lungs and heart. Below this is the abdomen, containing the digestive system (stomach and intestines); the liver, spleen, and pancreas; the urinary system (kidneys, ureters, and bladder); and, in women, the reproductive organs (ovaries, uterus, and vagina). In men, the prostate gland and seminal vesicles only of the reproductive system are situated in the abdomen, the testes being in the scrotum, which, with the penis, is suspended in front of and below the abdomen. The bladder empties through a small channel (urethra); in the female this opens in the upper end of the vulval cleft, which also contains the opening of the vagina, or birth canal; in the male, the urethra is continued into the penis. In both sexes, the lower bowel terminates in the anus, a ring of strong muscle situated between the buttocks.

skeleton

The skull is mounted on the spinal column, or spine, a chain of 24 vertebrae. The ribs, 12 on each side, are articulated to the spinal column behind, and the upper seven meet the breastbone (sternum) in front. The lower end of the spine rests on the pelvic girdle, composed of the triangular sacrum, to which are attached the hipbones (ilia), which are fused in front. Below the sacrum is the tailbone (coccyx). The shoulder blades (scapulae) are held in place behind the upper ribs by muscles, and connected in front to the breastbone by the two collarbones (clavicles).

Each shoulder blade carries a cup (glenoid cavity) into which fits the upper end of the armbone (humerus). This articulates below with the two forearm bones (radius and ulna). These are articulated at the wrist (carpals) to the bones of the hand (metacarpals and phalanges). The upper end of each thighbone (femur) fits into a depression (acetabulum) in the hipbone; its lower end is articulated at the knee to the shinbone (tibia) and calf bone (fibula), which are articulated at the ankle (tarsals) to the bones of the foot (metatarsals and phalanges). At a moving joint, the end of each bone is formed of tough, smooth cartilage, lubricated by synovial fluid. Points of special stress are reinforced by bands of fibrous tissue (ligaments).

Muscles are bundles of fibres wrapped in thin, tough layers of connective tissue (fascia); these are usually prolonged at the ends into strong, white cords (tendons, sinews) or sheets (aponeuroses), which connect the muscles to bones and organs, and by way of which the muscles do their work. Membranes of connective tissue also enfold the organs and line the interior cavities of the body. The thorax has a stout muscular floor, the diaphragm, which expands and contracts the lungs in the act of breathing.

The blood vessels of the **circulatory system**, branching into multitudes of very fine tubes (capillaries), supply all parts of the muscles and organs with blood, which carries oxygen and food necessary for life. The food passes out of the blood to the cells in a clear fluid (lymph); this is returned with waste matter through a system of lymphatic vessels that converge into collecting ducts that drain into large veins in the region of the lower neck. Capillaries join together to form veins which return blood, depleted of oxygen, to the heart.

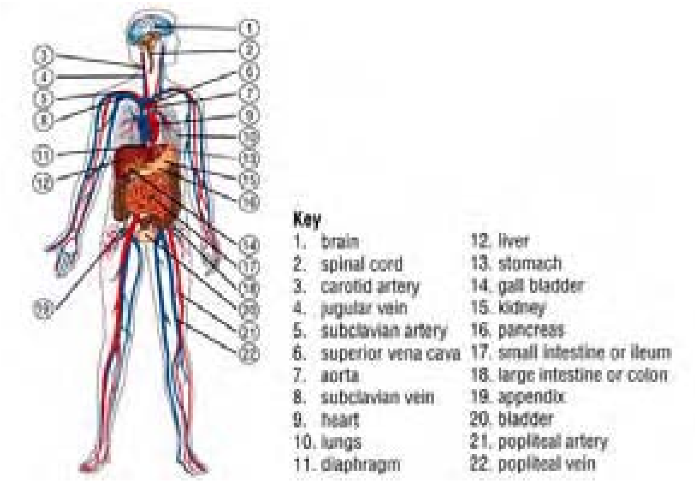
A finely branching **nervous system** regulates the function of the muscles and organs, and makes their needs known to the controlling centres in the central nervous system, which consists of the brain and spinal cord. The inner spaces of the brain and the cord contain cerebrospinal fluid. The body processes are regulated both by the nervous system and by hormones secreted by the endocrine glands. Cavities of the body that open onto the surface are coated with mucous membranes, which secrete a lubricating fluid (mucus).

The exterior surface of the body is covered with **skin**. Within the skin are the sebaceous glands, which secrete sebum, an oily fluid that makes the skin soft and pliable, and the sweat glands, which secrete water and various salts. From the skin grow hairs, chiefly on the head, in the armpits, and around the sexual organs; and nails shielding the tips of the fingers and toes; both hair and nails are modifications of skin tissue. The skin also contains nerve receptors for sensations of touch, pain, heat, and cold.

The human **digestive system** is nonspecialized and can break down a wide variety of foodstuffs. Food is mixed with saliva in the mouth by chewing and is swallowed. It enters the stomach, where it is gently churned for some time and mixed with acidic gastric juice. It then passes into the small intestine. In the first part of this, the duodenum, it is broken down further by the juice of the pancreas and duodenal glands, and mixed with bile from the liver, which splits up the fat. The jejunum and ileum continue the work of digestion and absorb most of the nutritive substances from the food. The large intestine completes the process, reabsorbing water into the body, and ejecting the useless residue as faeces.

The body, to be healthy, must maintain water and various salts in the right proportions; the process is called **osmoregulation**. The blood is filtered in the two kidneys, which remove excess water, salts, and metabolic wastes. Together these form urine, which has a yellow pigment derived from bile, and passes down through two fine tubes (ureters) into the bladder, a reservoir from which the urine is emptied at intervals (micturition) through the urethra. Heat is constantly generated by the combustion of food in the muscles and glands, and by the activity of nerve cells and fibres. It is dissipated through the skin by conduction and evaporation of sweat, through the lungs in the expired air, and in other excreted substances. Average body temperature is about 38°C/100°F (37°C/98.4°F in the mouth).

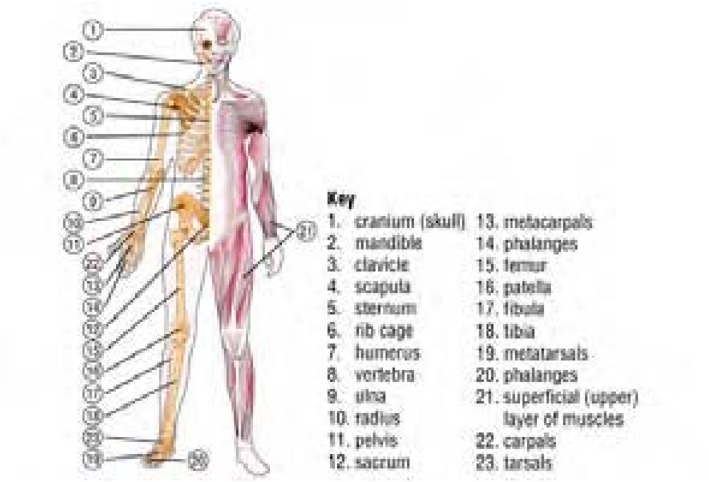
human body


Key
1. brain
2. spinal cord
3. carotid artery
4. jugular vein
5. subclavian artery
6. superior vena cava
7. aorta
8. subclavian vein
9. heart
10. lungs
11. diaphragm
12. liver
13. stomach
14. gall bladder
15. kidney
16. pancreas
17. small intestine or ileum
18. large intestine or colon
19. appendix
20. bladder
21. popliteal artery
22. popliteal vein

(Image © Research Machines plc)

The adult human body has approximately 650 muscles, 100,000 km/60,000 mi of blood vessels and 13,000 nerve cells.

human body


Key
1. cranium (skull)
2. mandible
3. clavicle
4. scapula
5. sternum
6. rib cage
7. humerus
8. vertebra
9. ulna
10. radius
11. pelvis
12. sacrum
13. metacarpals
14. phalanges
15. femur
16. patella
17. fibula
18. tibia
19. metatarsals
20. phalanges
21. superficial (upper) layer of muscles
22. carpals
23. tarsals

(Image © Research Machines plc)

There are 206 bones in the adult body, nearly half of them in the hands and feet. The adult human body also has approximately 100 joints.

Bones of the human body

Bone		Number
Cranium (skull)		
Occipital		1
Parietal: 1 pair		2
Sphenoid		1
Ethmoid		1
Inferior nasal conchae		2
Frontal: 1 pair, fused		1
Nasal: 1 pair		2
Lacrimal: 1 pair		2
Temporal: 1 pair		2
Maxilla: 1 pair, fused		1
Zygomatic: 1 pair		2
Vomer		1
Palatine: 1 pair		2
Mandible (jawbone): 1 pair, fused		1
Total		21
Ear		
Malleus (hammer)		1
Incus (anvil)		1
Stapes (stirrups)		1
Total (2 × 3)		6
Vertebral column (spine)		
Cervical vertebrae		7
Thoracic vertebrae		12
Lumbar vertebrae		5
Sacral vertebrae: 5, fused to form the sacrum		1
Coccygeal vertebrae: between 3 and 5, fused to form the coccyx		1
Total		26
Ribs		
Ribs, 'true': 7 pairs		14
Ribs, 'false': 5 pairs, of which 2 pairs are floating		10
Total		24
Sternum (breastbone)		
Manubrium, sternebrae ('body'), and xiphisternum		3
Total		3
Throat		
Hyoid		1
Total		1
Pectoral girdle		
Clavicle: 1 pair (collarbone)		2
Scapula (including coracoid): 1 pair (shoulder-blade)		2
Total		4
Upper extremity (each arm)		
Forearm	humerus	1
	radius	1
	ulna	1
Carpus (wrist)	scaphoid	1
	lunate	1
	triquetral	1
	pisiform	1
	trapezium	1
	trapezoid	1
	capitate	1
	hamate	1
	metacarpals	5
Phalanges (fingers)	first digit	2
	second digit	3
	third digit	3
	fourth digit	3
	fifth digit	3
Total (2 × 30)		60
Pelvic girdle		
Ilium, ischium, and pubis (combined): 1 pair of hip bones, innominate		2
Total		2

Lower extremity (each leg)		
Leg	femur (thighbone)	1
	tibia (shinbone)	1
	fibula	1
	patella (kneecap)	1
Tarsus (ankle)	talus	1
	calcaneus	1
	navicular	1
	cuneiform, medial	1
	cuneiform, intermediate	1
	cuneiform, lateral	1
	cuboid	1
	metatarsals (foot bones)	5
Phalanges (toes)	first digit	2
	second digit	3
	third digit	3
	fourth digit	3
	fifth digit	3
Total (2 × 30)		60
TOTAL		207

Human body: composition

Chemical element or substance	Body weight (%)
Pure elements	
Oxygen	65
Carbon	18
Hydrogen	10
Nitrogen	3
Calcium	2
Phosphorus	1.1
Potassium	0.35
Sulphur	0.25
Sodium	0.15
Chlorine	0.15
Magnesium, iron, manganese, copper, iodine, cobalt, zinc	traces
Water and solid matter	
Water	60-80
Total solid material	20-40
Organic molecules	
Protein	15-20
Lipid	3-20
Carbohydrate	1-15
Other	0-1

Brainpop - Health

Go to site

Excellent site all about the basics of health. There is heavy use of the Flash multimedia plug-in, but it is used very effectively. The user can find out all about human anatomy and how the body changes with age. Each system of the body, such as the immune and digestive systems, is broken down into separate sections, with animations and facts in each.

Human Body

Go to site

Human body Web site from the British Broadcasting Corporation (BBC). It contains articles on current biological issues, with a focus on health. The site is updated daily, so the user should check back regularly for recent issues. Links to other science-based sites, such as *Tomorrow's World* (the Web site of the BBC's forward-looking science programme), are also included.

Human Genome Project

HGP

research scheme to map the complete nucleotide (see nucleic acid) sequence of human DNA. It was begun in 1990 and a working draft of the genome (a mapping of 97% of the genome, sequencing of 85%, and completion of 24% of the human genome) was achieved in 2000, with the results being published in

February 2001. The publicly-funded Human Genome Organization (HUGO) coordinated the US$300 million project (the largest research project ever undertaken in the life sciences), which took place in over 20 centres around the world. In a competing effort, sequencing was also carried out commercially by US biotechnology company Celera Genomics, using the method of shotgun sequencing (breaking up the DNA into many small fragments, ordering the sequences of these fragments and then reassembling them). The completed detailed mapping of the genome was released on 14 April 2003. Since then, complete sequences of individual human chromosomes have been completed and published one by one.

In October 2004, researchers estimated that the human genome only contains between 20,000 and 25,000 different genes – far fewer than expected – and one gene may contain more than 2 million nucleotides. The knowledge gained from mapping all these genes is expected to help prevent or treat many crippling and lethal diseases, but there are potential ethical problems associated with knowledge of an individual's genetic make-up, and fears that it could lead to genetic discrimination.

The Human Genome Project

drafting the human genome

In April 2003, scientists announced they had completed detailed mapping of the sequence of the human genome, first published in June 2000. The international project to map the human genome started in the USA in 1990, and many scientists considered the task of sequencing the three billion nucleotides, the chemical building blocks that comprise the human genome, impractical when it was first proposed in the mid-1980s. Large-scale sequencing efforts were divided between the US and the UK.

As well as determining the nucleotide sequence, the Human Genome Project was designed to localize the estimated 27,000–40,000 (far fewer than expected) **genes** within the human genome. The scientific products of the project comprised a resource of detailed information about the structure, organization, and function of human **DNA**, information that constitutes the basic set of inherited 'instructions' for the development and functioning of a human being.

Similar efforts were also launched to map and sequence the genomes of a variety of organisms used extensively in scientific research, for example the pathogenic bacterium *Haemophilus influenzae* and the plant *Arabidopsis thaliana*.

sequence and consequence

DNA is made up of four different nucleotides characterized by the bases adenine, guanine, thymine, and cytosine. The genetic code that gives us our unique characteristics is defined by the sequence of these bases along the DNA molecule. This base sequence determines the order of building blocks (amino acids) in the proteins coded for by different genes.

Progress in DNA sequencing has been very rapid. The development of advanced automation, robotics, and computer software for large-scale DNA sequencing has proceeded at a remarkable pace. The 'shotgun' strategy coupled with automated DNA sequencing machines proved an extremely successful combination. The shotgun strategy for sequencing the entire DNA in an organism was developed by US scientist Dr Craig Venter. It involves the preparation of a 'library' of random DNA fragments by the breaking up of entire genomic DNA to make it more amenable to analysis. These fragments are then reproduced many times and a large number are sequenced from both ends until every part of the genome has been sequenced several times on average (this is determined by statistical means). Finally, the order in which the fragments fit together is established to provide the complete genome sequence.

Nonetheless, it is a huge step from elucidating the DNA sequence of the genome to knowing where within that sequence genes are located and what they do. Mere acquisition of DNA sequences conveys little more about the biology of the organisms from which they are derived than a company telephone directory can reveal about the complexities of the company's business. It is conceivable, however, that many of the major genes involved in, for example, susceptibility to heart disease and various cancers, will be identified in the near future. This will make it possible to 'type' people according to the variants of these genes that they carry and hence determine the likelihood that they will develop these diseases.

making sense of sequence

The vast amount of DNA sequence information generated by research groups around the world is stored in computer databases, connected with each other via the Internet. In extracting meaning from sequence information, scientists are faced with a task analogous to decoding an unknown language. By themselves, the letters make no sense but their particular combination into words and sentences is crucial. As in a real language, the subtlest changes, just like changing a single letter in a word, can thoroughly alter the message. DNA sequences for microbes, plants, animals, and humans from laboratories around the world can be compared and duplications can be detected. Also, similarities that point to evolutionary relationships, new classifications, and, ultimately, better understanding of life form and function can be recognized.

genetics and disease

While we all share a common genome, humans as a population are not clones. The genome is what defines us as *Homo sapiens* and alterations in DNA make us individuals. Despite our common genome, we are predisposed to different diseases, we respond to the environment in different ways, and we differ in the way we react to drugs – just as we are inherently different in our ability to perform particular tasks. Genetic explanations of the mechanism of diseases will enable the development of drugs with a more precise action, producing higher response rates and lowering the risk of adverse effects. Recent research, for example, has identified some schizophrenic patients who have a mutation in a particular neuroreceptor gene. This group of patients is not likely to benefit from the drug Clozapine, often used to treat schizophrenia. This knowledge is very valuable, as the drug is costly and can have severe side effects. However, a potential drawback for pharmaceutical companies would be the costs involved in tailoring drugs, which would then be sold to fewer customers.

genetic screening

Many genes have been mapped to their approximate positions on the **chromosomes**. These positions are determined in relation to known 'markers', DNA fragments that provide landmarks throughout the genome. Once the location of a disease gene is known, it is relatively straightforward to test for its presence in different people. This is known as genetic screening. For disorders caused by a single gene, such as cystic fibrosis and Duchenne muscular dystrophy, tests can now be applied to indicate the presence or absence of the faulty gene. Such tests may be carried out antenatally on the unborn fetus, on test-tube embryos, or on adults. If the genetic conditions contributing to multifactorial diseases are identified, it may be possible to test for increased susceptibility to predisposed illnesses, such as coronary heart disease.

Although genetic testing at the chromosome level has been in existence for some time, for example in prenatal testing for Down's syndrome, recent progress has focused attention on the sensitive issues that this type of testing entails. For example, some genetic tests permit diagnosis of disorders in patients before they have developed any symptoms. Others can identify carriers of recessive genetic diseases. Such tests can raise very difficult choices for individuals, as illustrated by the discovery of the gene for Huntingdon's disease.

Huntingdon's disease is a degenerative condition of the central nervous system that generally develops in middle age. No cure is currently available. Sufferers gradually deteriorate to a point where they require total care before death occurs. The disease affects about one in 5,000 people in the UK. The gene responsible for Huntington's disease was identified in 1993 and mapped to the tip of chromosome 4, making direct testing possible. Since testing began, it is thought that only a small minority of those who have a 50% chance of carrying the faulty gene -that is, those with a parent who has the condition – have chosen to undergo testing; probably around 5% of such people. Those who do seek testing usually undergo extensive counselling and discussion before proceeding.

Diagnosis of a single gene disorder for which no cure is currently available is one dilemma, but as the Human Genome Project progresses, new issues with consequences for the individual and for society are regularly created. For example, how do we deal with the discovery of genes that apparently predispose people towards certain kinds of behaviour, such as violence? Should the population be screened for certain genetic conditions and, if so, how do we use the information? A worst-case scenario could see the development of a genetic underclass, with people denied insurance and employment and discriminated against in society because of what is written in their genes.

gene therapy

Gene therapy involves the introduction of a healthy gene into a cell to replace a diseased gene. Unlike conventional treatments, which attempt to deal with the consequences of a defect, gene therapy aims to correct the defect itself. In order to function, the therapeutic gene must reach the nucleus of the target cell, which contains the cell's genetic material. Various vectors have been used to transfer the material into the cell. Viruses were the first to be investigated. These have a natural ability to enter a cell and can be manipulated to make them harmless. Another method involves the use of liposomes, hollow membranous spheres which encapsulate the gene. Liposomes fuse with the cell membrane, releasing their gene into the cell. Whatever the vector, gene therapy is carried out in one of two ways. In *in vivo* gene therapy, the vector is injected into the body and has to find its way to the target tissue. The other way is *ex vivo*, in which a sample of tissue, tumour cells for example, is taken from the patient, treated with the vector, and then replaced. While hundreds of trials are currently in progress, the success of gene therapy remains largely unproven.

ownership and control

The decoding of the human genome was an immense achievement and its impact on health care will be far-reaching. The major challenge that lies ahead is in ensuring appropriate management of the ownership of the new knowledge and of its potential effects on the individual.

Human Genome Project Information

Go to site

US-based site devoted to this mammoth project – with news, progress reports, a molecular genetics primer, and links to other relevant sites.

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human reproduction

production of offspring by humans. Human reproduction is an example of sexual reproduction, where the male produces sperm and the female eggs. These gametes contain only half the normal number of chromosomes, 23 instead of 46, so that on fertilization the resulting cell has the correct genetic complement. Fertilization is internal, which increases the chances of conception; unusually for mammals, pregnancy can occur at any time of the year. Human beings are also remarkable for the length of childhood and for the highly complex systems of parental care found in society. The use of contraception and the development of laboratory methods of insemination and fertilization are issues that make human reproduction more than a merely biological phenomenon.

The menstrual cycle occurs in female mammals of reproductive age. It prepares the female body for pregnancy. At the beginning of the cycle an egg (ovum) begins to develop in the ovary. At the same time the inner wall of the uterus forms a soft spongy lining. The egg is then released from the ovary, while the uterus lining (endometrium) becomes filled with blood vessels. At this stage fertilization can take place. However, if fertilization does not occur, the lining of the uterus breaks down, and is shed. This is the loss of blood that marks menstruation. The cycle then begins again.

The cycle is controlled by hormones such as oestrogen and progesterone. Human menstruation takes place from puberty to menopause, except during pregnancy, occurring about every 28 days.

Reproduction

Go to site

Information designed to help understand the human reproductive system. The site covers such topics as the anatomy of the male and female reproductive systems, the hormones that influence these systems, fertilization, sterilization, and transmission of HIV. Diagrams are also included on the site, accompanying some of the explanations.

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human species, origins of

evolution of humans from ancestral primates. The African apes (gorilla and chimpanzee) are shown by anatomical and molecular comparisons to be the closest living relatives of humans. The oldest known hominids (of the human group) had been the australopithecines, found in Africa, dating from 3.5–4.4 million years ago. But in December 2000, scientists unearthed the fossilized remains of a hominid dating back 6 million years. The first hominids to use tools appeared 2 million years ago, and hominids first used fire and moved out of Africa 1.7 million years ago. Modern humans are all believed to descend from one African female of 200,000 years ago, although there is a rival theory that humans evolved in different parts of the world simultaneously.

Miocene apes

Genetic studies indicate that the last common ancestor between chimpanzees and humans lived 5 to 10 million years ago. There are only fragmentary remains of ape and hominid fossils from this period. Dispute continues over the hominid status of *Ramapithecus*, the jaws and teeth of which have been found in India and Kenya in late Miocene deposits, dating from between 14 and 10 million years ago. The lower jaw of a fossil ape found in the Otavi Mountains, Namibia, comes from deposits dated between 10 and 15 million years ago, and is similar to finds from East Africa and Turkey. It is thought to be close to the initial divergence of the great apes and humans.

australopithecines

Australopithecus afarensis, found in Ethiopia and Kenya, date from 3.9 to 4.4 million years ago. These hominids walked upright and they were either direct ancestors or an offshoot of the line that led to modern humans. They may have been the ancestors of *Homo habilis* (considered by some to be a species of *Australopithecus*), who appeared about 2 million years later, had slightly larger bodies and brains, and were probably the first to use stone tools. Also living in Africa at the same time was *A. africanus*, a gracile hominid thought to be a meat-eater, and *A. robustus*, a hominid with robust bones, large teeth, heavy jaws, and thought to be a vegetarian. They are not generally considered to be our ancestors.

A new species of *Australopithecus* was discovered in Ethiopia in 1999. Named *A. garhi*, the fossils date from 2.5 million years ago and also share anatomical features with *Homo* species. The most complete australopithecine skeleton to date was found in South Africa in April 2000. It is about 1.8 million years old and from a female *A. robustus*.

The skull of an unknown hominid species, *Kenyanthropus platyops*, was discovered in Kenya in March 2001. Approximately 3.5 million years old, it is contemporary with the australopithecines, previously the oldest known hominids, leading to the suggestion that humans are descended from *K. platyops*, rather than the australopithecines as has been thought.

Homo erectus

Over 1.7 million years ago, *Homo erectus*, believed by some to be descended from *H. habilis*, appeared in Africa. *H. erectus* had prominent brow ridges, a flattened cranium, with the widest part of the skull low down, and jaws with a rounded tooth row, but the chin, characteristic of modern humans, is lacking. They also had much larger brains (900–1,200 cu cm), and were probably the first to use fire and the first to move out of Africa. Their remains are found as far afield as China, West Asia, Spain, and southern Britain. Modern human *H. sapiens sapiens* and the Neanderthals *H. sapiens neanderthalensis* are probably descended from *H. erectus*.

Australian palaeontologists announced the discovery of stone tools dated at about 800,000 to 900,000 years old and belonging to *H. erectus* on Flores, an island near Bali, in 1998. The discovery provided strong evidence that *H. erectus* were seafarers and had the language abilities and social structure to organize the movements of large groups to colonize new islands. In 2000 Japanese archaeologists discovered that *H. erectus* were probably building hut-like shelters around 500,000 years ago, the oldest known artificial structures.

Neanderthals

Neanderthals were large-brained and heavily built, probably adapted to the cold conditions of the ice ages. They lived in Europe and the Middle East, and disappeared about 40,000 years ago, leaving *H. sapiens sapiens* as the only remaining species of the hominid group. Possible intermediate forms between Neanderthals and *H. sapiens sapiens* have been found at Mount Carmel in Israel and at Broken Hill in Zambia, but it seems that *H. sapiens sapiens* appeared in Europe quite rapidly and either wiped out the Neanderthals or interbred with them.

The remains of a new species of human, *Homo floresiensis*, were discovered in 2004 in the Liang Bua limestone caves on Flores Island, Indonesia. The 1-m/3.2-ft-tall skeleton of a female was dated to a period as recent as 13,000 years ago. This dating shows that *Homo floresiensis* survived much later that the Neanderthals.

modern humans

There are currently two major views of human evolution: the 'out of Africa' model, according to which *H. sapiens* emerged from *H. erectus*, or a descendant species, in Africa and then spread throughout the world;

and the multiregional model, according to which selection pressures led to the emergence of similar advanced types of *H. sapiens* from *H. erectus* in different parts of the world at around the same time. Analysis of DNA in recent human populations suggests that *H. sapiens* originated about 200,000 years ago in Africa from a single female ancestor, 'Eve'. The oldest known fossils of *H. sapiens* also come from Africa, dating from around 195,000 years ago (this date was reached in 2005 by the re-dating of remains originally found in Ethiopia in 1967; the previous estimate was 130,000 years). Separation of human populations occurred later, with separation of Asian, European, and Australian populations taking place between 100,000 and 50,000 years ago.

The human genome consists of between 27,000 to 40,000 genes. Of these only about 1.5% differ between humans and the great apes.

Archaeology: The Discovery of Boxgrove Man

'the first European'

In Dec 1993, archaeologists unearthed a 35-cm/14-in fragment of what was trumpeted as 'the first European' in a gravel quarry in West Sussex, England: a broken piece of the left **tibia** (shin) of what seems to have been a powerfully built, tall man who lived about half a million years ago.

The find was made during excavation of the Boxgrove quarry near Chichester. Although now located 10 km/6 mi inland and 43 m/140 ft above sea level, at the time of its occupation - when the land was lower and the sea higher - the site was a sandy beach.

age and physique

Dated to between 515,000 and 485,000 years ago on the basis of the shape of vole teeth in the layer, and through oxygen-isotope and paleomagnetic techniques, the bone is in fact of roughly the same period as the robust Mauer or Heidelberg jaw found in Germany in 1907.

From its length and thickness, specialists have estimated the height of the leg's owner as over 180 cm/6 ft and his weight as over 76 kg/168 lb. Nicknamed Roger after the amateur archaeologist who found the fragment, he was found among flint tools (including hundreds of handaxes) and the remains of elephant, rhinoceros, hyena, deer, bear, and wolf.

classification

Although he may be classed as *Homo heidelbergensis*, due to his proximity in space and time to the Mauer jaw, he probably belongs to *Homo erectus*. His size comes as no surprise, since the skeleton of a *Homo erectus* boy from Nariokotome in E Africa, dated to 1.7 million years ago, shows that he was about 156 cm/5.25 ft when he died at the age of 11 so that he would probably have been 183 cm/6.1 ft when fully grown, and weighed about 70 kg/154 lb. Clearly this species was very tall and robust.

Evolution: Out of Africa and the Eve Hypothesis

introduction

Most palaeoanthropologists recognize the existence of two human species during the last million years - *Homo erectus*, now extinct, and *Homo sapiens*, the species which includes recent or 'modern' humans. In general, they believe that *Homo erectus* was the ancestor of *Homo sapiens*. How did the transition occur?

the multiregional model

There are two opposing views. The multiregional model says that *Homo erectus* gave rise to *Homo sapiens* across its whole range, which, about 700,000 years ago, included Africa, China, Java (Indonesia), and, probably, Europe. *Homo erectus*, following an African origin about 1.7 million years ago, dispersed around the Old World, developing the regional variation that lies at the roots of modern 'racial' variation. Particular features in a given region persisted in the local descendant populations of today.

For example, Chinese *Homo erectus* specimens had the same flat faces, with prominent cheekbones, as modern Oriental populations. Javanese *Homo erectus* had robustly built cheekbones and faces that jutted out from the braincase, characteristics found in modern Australian Aborigines. No definite representatives of *Homo erectus* have yet been discovered in Europe. Here, the fossil record does not extend back as far as those of Africa and eastern Asia, although a possible *Homo erectus* jawbone more than a million years old was recently excavated in Georgia.

Nevertheless, the multiregional model claims that European *Homo erectus* did exist, and evolved into a primitive form of *Homo sapiens*. Evolution in turn produced the Neanderthals: the ancestors of modern Europeans. Features of continuity in this European lineage include prominent noses and midfaces.

genetic continuity

The multiregional model was first described in detail by Franz Weidenreich, a German palaeoanthropologist. It was developed further by the American Carleton Coon, who tended to regard the regional lineages as genetically separate. Most recently, the model has become associated with such researchers as Milford Wolpoff (USA) and Alan Thorne (Australia), who have re-emphasized the importance of gene flow between the regional lines. In fact, they regard the continuity in time and space between the various forms of *Homo erectus* and their regional descendants to be so complete that they should be regarded as representing only one species - *Homo sapiens*.

the opposing view

The opposing view is that *Homo sapiens* had a restricted origin in time and space. This is an old idea. Early in the 20th century, workers such as Marcellin Boule (France) and Arthur Keith (UK) believed that the lineage of *Homo sapiens* was very ancient, having developed in parallel with that of *Homo erectus* and the Neanderthals. However, much of the fossil evidence used to support their ideas has been re-evaluated, and few workers now accept the idea of a very ancient and separate origin for modern *Homo sapiens*.

the Garden of Eden

Modern proponents of this approach focus on a recent and restricted origin for modern *Homo sapiens*. This was dubbed the 'Garden of Eden' or 'Noah's Ark' model by the US anthropologist William Howells in 1976 because of the idea that all modern human variation had a localized origin from one centre. Howells did not specify the centre of origin, but research since 1976 points to Africa as especially important in modern human origins.

The consequent 'Out of Africa' model claims that *Homo erectus* evolved into modern *Homo sapiens* in Africa about 100,000-150,000 years ago. Part of the African stock of early modern humans spread from the continent into adjoining regions and eventually reached Australia, Europe, and the Americas (probably by 45,000, 40,000, and 15,000 years ago respectively). Regional ('racial') variation only developed during and after the dispersal, so that there is no continuity of regional features between *Homo erectus* and present counterparts in the same regions.

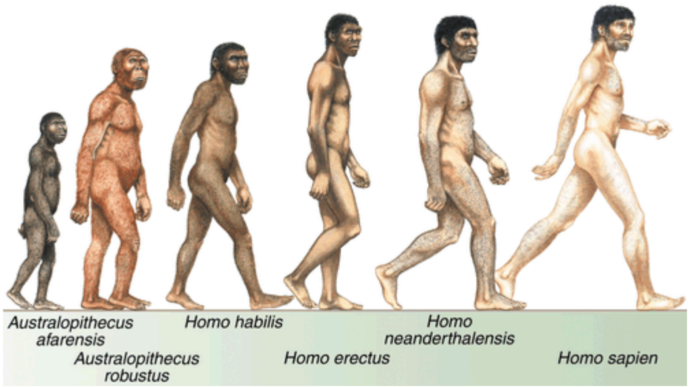
Like the multiregional model, this view accepts that *Homo erectus* evolved into new forms of human in inhabited regions outside Africa, but argues that these non-African lineages became extinct without evolving into modern humans. Some, such as the Neanderthals, were displaced and then replaced by the spread of modern humans into their regions.

) and an African Eve?

In 1987, research on the genetic material called mitochondrial DNA (mtDNA) in living humans led to the reconstruction of a hypothetical female ancestor for all present-day humanity. This 'Eve' was believed to have lived in Africa about 200,000 years ago. Recent re-examination of the 'Eve' research has cast doubt on this hypothesis, but further support for an 'Out of Africa' model has come from genetic studies of nuclear DNA, which also point to a relatively recent African origin for present-day *Homo sapiens*.

Studies of fossil material of the last 50,000 years also seem to indicate that many 'racial' features in the human skeleton have developed only over the last 30,000 years, in line with the 'Out of Africa' model, and at odds with the million-year timespan one would expect from the multiregional model.

human species, origins of



(Image © Research Machines plc)

In evolutionary terms, the period from the appearance of the early hominid *Australopithecus* 3.5-4.4 million years ago, to the development of modern humans approximately 200,000 years ago, has been fairly short.

Fossil Hominids FAQ

Go to site

Basic information about hominid species, the most important hominid fossils, and creationist arguments, plus links to related sites.

Humboldt, (Friedrich Wilhelm Heinrich) Alexander (1769-1859)

Baron von Humboldt

German geophysicist, botanist, geologist, and writer who, with French botanist Aimé Bonpland (1773-1858), explored the regions of the Orinoco and Amazon rivers in South America 1800-04, and gathered 60,000 plant specimens. He was a founder of ecology.

Humboldt aimed to erect a new science, a 'physics of the globe', analysing the deep physical interconnectedness of all terrestrial phenomena. He believed that geological phenomena were to be understood in terms of basic physical causes (for example, terrestrial magnetism or rotation).

One of the first popularizers of science, he gave a series of lectures later published as *Kosmos/Cosmos* 1845-62, an account of the relations between physical environment and flora and fauna.

Humboldt Current

former name of the Peru Current.

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hum, environmental

disturbing sound of frequency about 40 Hz, heard by individuals sensitive to this range, but inaudible to the rest of the population. It may be caused by industrial noise pollution or have a more exotic origin, such as the jet stream, a fast-flowing high-altitude (about 15,000 m/50,000 ft) mass of air.

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humerus

upper bone of the forelimb of tetrapods. In humans, the humerus is the bone above the elbow.

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humidity

quantity of water vapour in a given volume of the atmosphere (absolute humidity), or the ratio of the amount of water vapour in the atmosphere to the saturation value at the same temperature (relative humidity). At dew point the relative humidity is 100% and the air is said to be saturated. Condensation (the conversion of vapour to liquid) may then occur. Relative humidity is measured by various types of hygrometer.

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hummingbird

any of various small, brilliantly coloured birds found in the Americas. The name comes from the sound produced by the rapid vibration of their wings when hovering near flowers to feed. Hummingbirds have long, needlelike bills and tongues to obtain nectar from flowers and capture insects. They are the only birds able to fly backwards. The **Cuban bee hummingbird** (*Mellisuga helenae*), the world's smallest bird, is 5.5 cm/2 in long and weighs less than 2.5 g/0.1 oz. There are over 300 species. (Family Trochilidae, order Apodiformes.)

The long cleft tongue of a hummingbird is in the form of a double tube, which can be extended a considerable distance beyond the bill and withdrawn again very rapidly; the sternum (breastbone) is greatly developed, forming a suitable base for the wing muscles; the plumage has a metallic lustre.

Hummingbirds!

Go to site

Comprehensive source of information on the family of brightly coloured birds. There are good descriptions of natural behaviour, details of migration patterns, a large number of photographs, and latest research findings. The site also offers anecdotes about the bird and links to hummingbird societies.

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humours, theory of

theory prevalent in the West in classical and medieval times that the human body was composed of four kinds of fluid: phlegm, blood, choler or yellow bile, and melancholy or black bile. Physical and mental characteristics were explained by different proportions of humours in individuals.

An excess of phlegm produced a 'phlegmatic', or calm, temperament; of blood a 'sanguine', or passionate, one; of yellow bile a 'choleric', or irascible, one; and of black bile a 'melancholy', or depressive, one. The Greek physician Galen connected the theory to that of the four elements (see elements, the four): the phlegmatic was associated with water, the sanguine with air, the choleric with fire, and the melancholic with earth. An imbalance of the humours could supposedly be treated by diet.

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humus

component of soil consisting of decomposed or partly decomposed organic matter, dark in colour and usually richer towards the surface. It has a higher carbon content than the original material and a lower nitrogen content, and is an important source of minerals in soil fertility.

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hundredweight

symbol cwt

unit of mass, equal to 100 lb (45.36 kg) in the USA. In the UK and Canada, it equals 112 lb (50.8 kg), and is sometimes called the long hundredweight.

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hunting dog

or painted dog

wild dog (weight 23–35 kg/51–77 lb) that once roamed over virtually the whole of sub-Saharan Africa. A pack might have a range of almost 4,000 km/2,500 mi, hunting zebra, antelope, and other game. Individuals can run at 50 kph/30 mph for up to 5 km/3 mi, with short bursts of even higher speeds. The number of hunting dogs that survive has been reduced to a fraction of the original population. According to a 1997 World Conservation Union report, there were fewer than 3,000 hunting dogs remaining in the wild, with many existing populations too small to be viable. (Species *Lycaon pictus*, family Canidae.)

The maximum pack size found today is usually eight to ten, whereas in the past several hundred might have hunted together. Habitat destruction and the decline of large game herds have played a part in its decline, but the hunting dog has also suffered badly from the effects of distemper, a disease which was introduced into East Africa early in the 20th century.

hunting dog

(Image © Research Machines plc)

A pack of hunting dogs on the Tanzanian savannah. Their numbers have declined dramatically owing to disease, persecution, and loss of habitat.

Huntington's chorea

rare hereditary disease of the nervous system that usually begins in middle age. It is characterized by involuntary movements (chorea), emotional disturbances, and rapid mental degeneration progressing to dementia. There is no known cure but the genetic mutation giving rise to the disease was located in 1993, making it easier to test individuals for the disease and increasing the chances of developing a cure.

Facing Huntington's Disease

Go to site

Basic information about Huntingdon's Disease. Sympathetically presented by the British Huntington's Disease association, the guide covers how HD is passed on, how it is diagnosed, the risks to children conceived by couples at risk, and the course of this degenerative illness.

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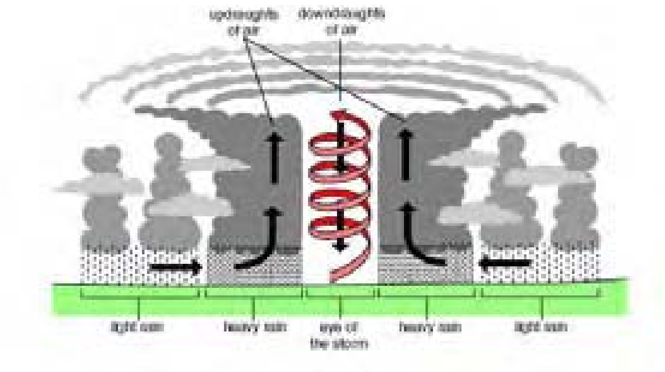
hurricane

or tropical cyclone or typhoon

a severe depression (region of very low atmospheric pressure) in tropical regions, called **typhoon** in the North Pacific. It is a revolving storm originating at latitudes between 5° and 20° north or south of the Equator, when the surface temperature of the ocean is above 27°C/80°F. A central calm area, called the eye, is surrounded by inwardly spiralling winds (anticlockwise in the northern hemisphere and clockwise in the southern hemisphere) of up to 320 kph/200 mph. A hurricane is accompanied by lightning and torrential rain, and can cause extensive damage. In meteorology, a hurricane is a wind of force 12 or more on the Beaufort scale.

During 1995 the Atlantic Ocean region suffered 19 tropical storms, 11 of them hurricanes. This was the third-worst season since 1871, causing 137 deaths. The most intense hurricane recorded in the Caribbean/Atlantic sector was Hurricane Gilbert in 1988, with sustained winds of 280 kph/175 mph and gusts of over 320 kph/200 mph.

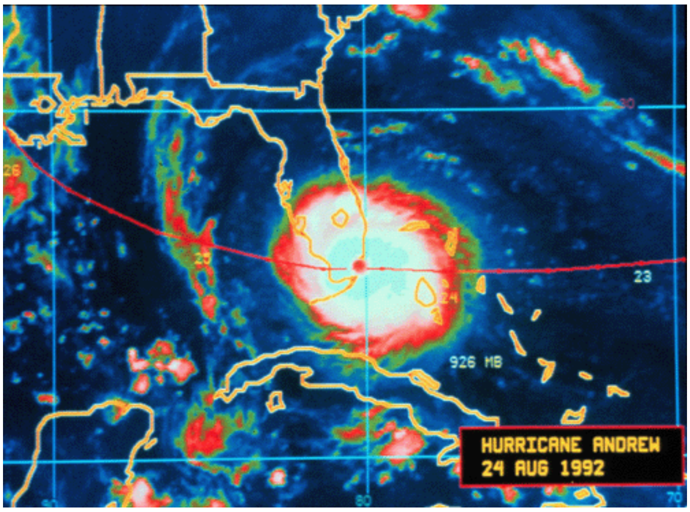
hurricane


updraughts of air
downdraughts of air
light rain
heavy rain
eye of the storm
heavy rain
light rain

(Image © Research Machines plc)

Hurricanes, also called typhoons, are violent tropical cyclones. The calm centre of the hurricane, known as the 'eye of the storm', is encircled by inwardly spiralling high winds.

huricane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HURRICANE ANDREW
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(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

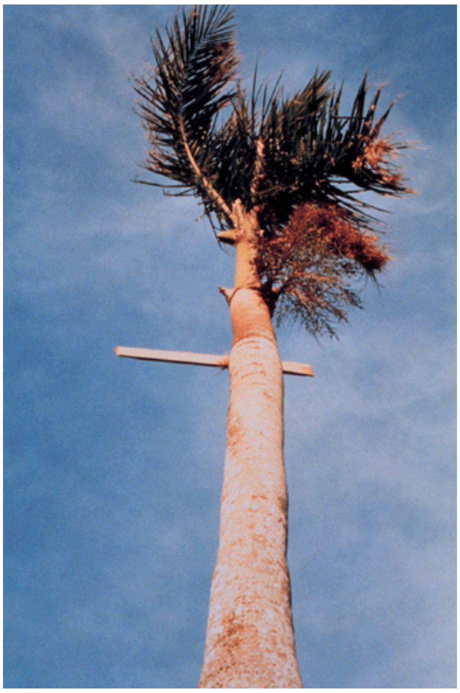
Hurricane Andrew hurtles northwest over the Florida coastline in August 1992, its spiral shape evident in this infrared satellite photo. Like water draining through an outlet, hurricanes spin clockwise in the northern hemisphere and anticlockwise in the southern – a manifestation of the Coriolis effect.

hurricane

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Hurricane Andrew reached the coastline of Florida just north of Miami in late August 1992, and caused considerable damage. Entire walls were stripped from the facades of apartment blocks, at the height of the tourist season. Nonetheless, the state of Florida is accustomed to hurricanes, and every county has contingency plans to deal competently with such emergencies.

hurricane



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Hurricanes produce winds of fearsome speed and force: here a plank from a boardwalk has been driven right through the trunk of a royal palm at some height above the ground. As the hurricane passes over, the wind appears to change direction and may finally blow with no reduction at all in strength from the entirely opposite direction.

Disasters: Panoramic Photographs, 1851-1991

Go to site

Part of the Panoramic Photo Collection of the US Library of Congress, this page features 144 panoramic photographs of natural and man-made disaster scenes, mostly in the USA, between 1851 and 1991. To narrow your search, click on New Search and enter a specific disaster or location. The images include brief notes. Click on the images to increase their size.

Hurricane & Tropical Storm Tracking

Go to site

Follow the current paths of Pacific and mid-Atlantic hurricanes and tropical storms at this site. Java animations of storms in previous years can also be viewed, and data sets for these storms may be downloaded. Current satellite weather maps can be accessed for the USA and surrounding region.

Naming of Atlantic Hurricanes

Go to site

Interesting explanation about how hurricanes are named, from the US national weather service. There is also a table that shows you what name future hurricanes will be given.

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husky

any of several breeds of sledge dog used in Arctic regions, growing up to about 60 cm/23 in high, and weighing up to about 27 kg/60 lbs, with pricked ears, thick fur, and a bushy tail. The Siberian husky is the best known.

husky

(Image © Corel)

A team of huskies pulling a sledge in the Arctic. Huskies, originally from Siberia, were introduced as sled dogs in the Arctic in the early 20th century. The dogs have a dense coat of hair, that allows them to live outdoors in extreme conditions.

Siberian Husky Club of America

Go to site

Information about the history of the breed, the breed standard, shows, veterinary advice, and many tips for owners. There is a comprehensive listing of other husky sites across the world and an extensive bibliography.

Hutton, James (1726-1797)

Scottish geologist, known as the 'founder of geology', who formulated the concept of uniformitarianism. In 1785 he developed a theory of the igneous origin of many rocks.

His *Theory of the Earth* (1788) proposed that the Earth was incalculably old. Uniformitarianism suggests that past events could be explained in terms of processes that work today. For example, the kind of river current that produces a certain settling pattern in a bed of sand today must have been operating many millions of years ago, if that same pattern is visible in ancient sandstones.

Huxley, Andrew Fielding (1917-)

English physiologist who was awarded a Nobel Prize for Physiology or Medicine in 1963 with Alan Hodgkin for work on the ionic mechanisms involved in the communication or inhibition of impulses across neuron (nerve cell) membranes impulses. He was knighted in 1974.

Huxley, Julian Sorell (1887-1975)

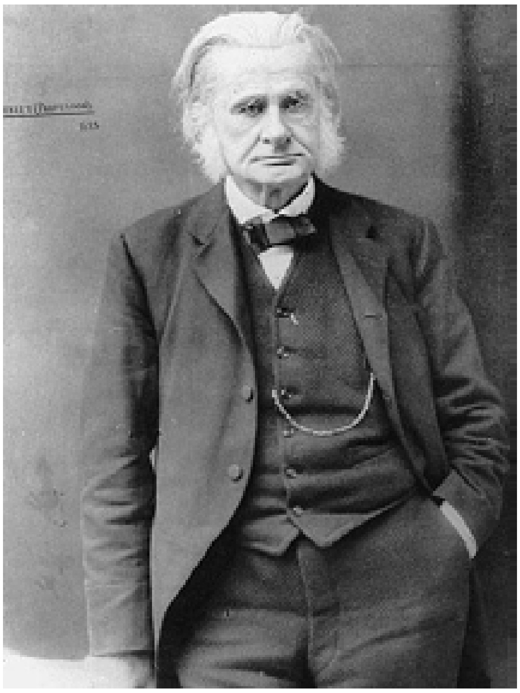
English biologist, first director general of UNESCO, and a founder of the World Wildlife Fund (now the World Wide Fund for Nature). He wrote popular science books, including *Essays of a Biologist* (1923). He was knighted in 1958.

Huxley, T(homas) H(enry) (1825-1895)

English scientist and humanist. Following the publication of Charles Darwin's *On the Origin of Species* (1859), he became known as 'Darwin's bulldog', and for many years was a prominent champion of evolution. In 1869 he coined the word 'agnostic' to express his own religious attitude, and is considered the founder of scientific humanism.

From 1846 to 1850 Huxley was the assistant ship's surgeon on HMS *Rattlesnake* on its voyage around the South Seas. The observations he made on the voyage, especially of invertebrates, were published and made his name in the UK.

Huxley



(Image © Billie Love)

English biologist and essayist, Thomas Huxley. A leading advocate of Charles Darwin's theory of evolution, Huxley combined his philosophical ideas with scientific exposition. He wrote essays from an 'agnostic' viewpoint (a term he introduced) and held that scientific discoveries had neither given support to, nor discredited, religious faith.

Huygens (or Huyghens), Christiaan (1629-1695)

Dutch mathematical physicist and astronomer. He proposed the wave theory of light, developed the pendulum clock in 1657, discovered polarization, and observed Saturn's rings. He made important advances in pure mathematics, applied mathematics, and mechanics, which he virtually founded. His work in astronomy was an impressive defence of the Copernican view of the Solar System.

mechanics

Huygens' first studies in applied mathematics dealt with mechanics, the branch of physics pertaining to motions and forces. Working on impact and collision, Huygens used the idea of relative frames of reference, considering the motion of one body relative to the other. He anticipated the law of conservation of momentum stating that in a system of bodies under impact the centre of gravity is conserved. In *De Motu Corporum* 1656, he was also able to show that the quantity $1/2mv^2$ is conserved in an elastic collision.

Huygens also studied centrifugal force and showed, in 1659, its similarity to gravitational force, although he lacked the Newtonian concept of acceleration. He considered projectiles and gravity, developing the mathematically primitive ideas of Galileo. He found an accurate experimental value for the distance covered by a falling body in one second. In fact, his gravitational theories successfully deal with several difficult points that Newton carefully avoided. In the 1670s, Huygens studied motion in resisting media, becoming convinced by experiment that the resistance in such media as air is proportional to the square of the velocity.

the pendulum clock

In 1657, Huygens developed a clock regulated by a pendulum, an idea that he published and patented. By 1658, major towns in Holland had pendulum tower clocks. Huygens worked at the theory first of the simple pendulum and then of harmonically oscillating systems throughout the rest of his life, publishing the *Horologium Oscillatorium* in 1673. He derived the relationship between the period of a simple pendulum and its length.

the theory of light

The *Traité de la Lumière/Treatise on Light* (1690) contained Huygens' famous wave or pulse theory of light. Two years earlier, Huygens had been able to use his principle of secondary wave fronts to explain reflection and refraction, showing that refraction is related to differing velocities of light in media. He theorized that light is transmitted as a pulse moving through a medium, or ether, by setting up a whole train of vibrations in the ether in a serial displacement. His publication was partly a counter to Newton's particle theory of light. The thoroughness of Huygens' analysis of this model is impressive, but although he observed the effects due to polarization, he could not yet use his ideas to explain this phenomenon.

astronomy and the telescope

Huygens' comprehensive study of geometric optics led to the invention of a telescope eyepiece that reduced chromatic aberration. It consisted of two thin plano-convex lenses, rather than one fat lens, with the field lens having a focal length three times greater than that of the eyepiece lens. Its main disadvantage was that cross-wires could not be fitted to measure the size of an image. Huygens then developed a micrometer to measure the angular diameter of celestial objects.

With a home-made telescope, he discovered Titan, one of Saturn's moons, in 1655. Later that year he observed that Titan's period of revolution was about 16 days and that it moved in the same plane as the so-called 'arms' of Saturn. This phenomenon had been somewhat of an enigma to many earlier astronomers, but because of Huygens' superior 7-m telescope, he partially unravelled the detail of Saturn's rings. In 1659, he published a Latin anagram that, when interpreted, read 'It (Saturn) is surrounded by a thin flat ring, nowhere touching and inclined to the ecliptic'. The theory behind Huygens' hypothesis followed later in *Systema Saturnium* (1659), which included observations on the planets, their satellites, the Orion nebula and the determination of the period of Mars, and provided further evidence for the Copernican view of the Solar System.

Huygens, Christiaan

Go to site

Extensive biography of the Dutch astronomer, physicist, and mathematician. The site contains a description of his contributions to astronomy, physics, and mathematics. Also included are the title page of his book *Horologium Oscillatorium* (1673) and the first page of his book *De Ratiociniis in Ludo Aleae* (1657). Several references for further reading are also listed, and the Web site also features a portrait of Huygens.

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hyacinth

any of a group of bulb-producing plants belonging to the lily family, native to the eastern Mediterranean and Africa. The cultivated hyacinth (*H. orientalis*) has large, scented, cylindrical heads of pink, white, or blue flowers. (Genus *Hyacinthus*, family Liliaceae.)

The water hyacinth, a floating plant from South America, is unrelated.

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hyaline membrane disease

former name for respiratory distress syndrome.

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hybrid

offspring from a cross between individuals of two different species, or two inbred lines within a species. In most cases, hybrids between species are infertile and unable to reproduce sexually. In plants, however, doubling of the chromosomes (see polyploid) can restore the fertility of such hybrids.

Hybrids between different genera were believed to be extremely rare (an example is the *Cupressocyparis leylandii* cypress which, like some hybrids, shows exceptional vigour, or heterosis) but research in the late 1990s shows that hybridization is much more common than traditionally represented. One British evolutionary biologist estimated in 1999 that approximately 10% of animal species and 20% of plant species produced fertile offspring through interspecies mating. Blue whales, for example, hybridize with fin whales and different species of birds of paradise also hybridize. In the wild, a 'hybrid zone' may occur where the ranges of two related species meet.

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hydathode

specialized pore, or less commonly a hair, through which water is secreted by hydrostatic pressure from the interior of a plant leaf onto the surface. Hydathodes are found on many different plants and are usually situated around the leaf margin at vein endings. Each pore is surrounded by two crescent-shaped cells and resembles an open stoma, but the size of the opening cannot be varied as in a stoma. The process of water secretion through hydathodes is known as guttation.

Hydra

in astronomy, the largest constellation, winding across more than a quarter of the sky between Cancer and Libra in the southern hemisphere. Hydra is named after the multi-headed sea serpent slain by Hercules. Despite its size, it is not prominent; its brightest star is second-magnitude Alphard.

---

hydra

in zoology, any of a group of freshwater polyps, belonging among the coelenterates. The body is a double-layered tube (with six to ten hollow tentacles around the mouth), 1.25 cm/0.5 in long when extended, but capable of contracting to a small knob. Usually fixed to waterweed, hydras feed on minute animals that are caught and paralysed by stinging cells on the tentacles. (Genus *Hydra*, family Hydridae, phylum Coelenterata, subphylum Cnidaria.)

Hydras reproduce asexually in the summer and sexually in the winter. They have no specialized organs except those of reproduction.

---

hydrangea

any of a group of flowering shrubs belonging to the saxifrage family, native to Japan. Cultivated varieties of *H. macrophylla* normally produce round heads of pink flowers, but these may be blue if there are certain chemicals in the soil, such as alum or iron. The name comes from the Greek for 'water vessel', after the cuplike seed capsules. (Genus *Hydrangea*, family Hydrangeaceae.)

---

hydrate

chemical compound that has discrete water molecules combined with it. The water is known as **water of crystallization** and the number of water molecules associated with one molecule of the compound is denoted in both its name and chemical formula: for example, $CuSO_4.5H_2O$ is copper(II) sulphate pentahydrate.

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hydration

in earth science, a form of chemical weathering caused by the expansion of certain minerals as they absorb water. The expansion weakens the parent rock and may cause it to break up.

---

hydraulic action

in earth science, the erosive force exerted by water (as distinct from erosion by the rock particles that are carried by water). It can wear away the banks of a river, particularly at the outer curve of a meander (bend in the river), where the current flows most strongly.

Hydraulic action occurs as a river tumbles over a waterfall to crash onto the rocks below. It will lead to the formation of a plunge pool below the waterfall. The hydraulic action of ocean waves and turbulent currents forces air into rock cracks, and therefore brings about erosion by cavitation. In coastal areas hydraulic action is often the most important form of erosion.

---

hydraulic radius

measure of a river's channel efficiency (its ability to move water and sediment), used by water engineers to assess the likelihood of flooding. The hydraulic radius of a channel is defined as the ratio of its cross-sectional area to its wetted perimeter (the part of the cross-section - bed and bank - that is in contact with the water).

The greater the hydraulic radius, the greater the efficiency of the channel and the less likely the river is to flood. The highest values occur when channels are deep, narrow, and semi-circular in shape.

---

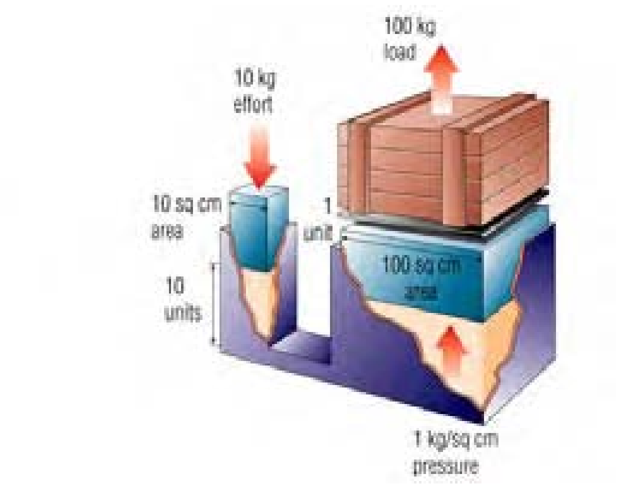
hydraulics

field of study concerned with utilizing the properties of water and other liquids, in particular the way they flow and transmit pressure, and with the application of these properties in engineering. It applies the principles of hydrostatics and hydrodynamics. The oldest type of hydraulic machine is the **hydraulic press**, invented by Joseph Bramah in England in 1795. The hydraulic principle of fluid pressure transmitting a small force over a small area in order to produce a larger force over a larger area is commonly used in vehicle braking systems, the forging press, and the hydraulic systems of aircraft and earth-moving machinery.

In a car braking system, a small force is applied at the brake pedal. This force is transmitted over a small area through the brake fluid. The force is transmitted to the master piston and acts over a larger area to produce a larger force. The master piston presses the brake pads against the brake discs to slow the movement of the car wheels. The force produced at the larger piston (2) by the smaller piston (1) can be worked out using the formula: force 1/area 1 = force 2/area 2.

A hydraulic press consists of two liquid-connected pistons in cylinders, one of narrow bore, one of large bore. A force applied to the narrow piston applies a certain pressure (force per unit area) to the liquid, which is transmitted to the larger piston. Because the area of this piston is larger, the force exerted on it is larger. Thus the original force has been magnified, although the smaller piston must move a great distance to move the larger piston only a little.

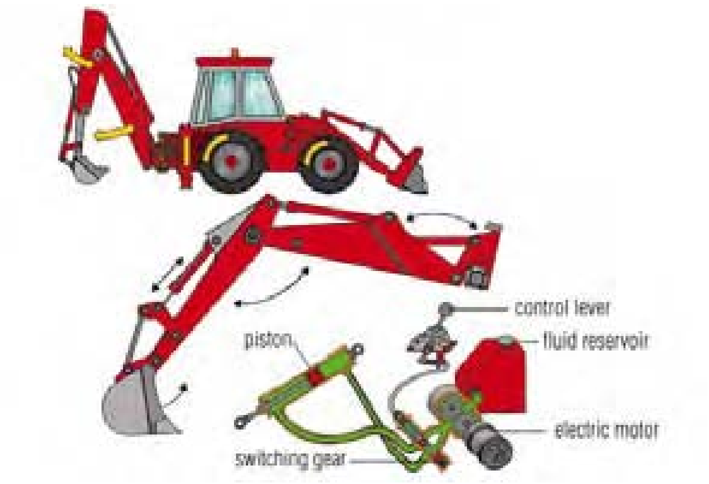
hydraulics



(Image © Research Machines plc)

The hydraulic jack transmits the pressure on a small piston to a larger one. A larger total force is developed by the larger piston but it moves a smaller distance than the small piston.

hydraulics



(Image © Research Machines plc)

The mechanical excavator utilizes hydraulic rams. The ram consists of a piston in a cylinder connected by pipes to a fluid reservoir. The lever opens a valve that admits high-pressure fluid to one side of the piston, forcing it and the digger arm which is connected to it to move.

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hydride

chemical compound containing hydrogen and one other element, and in which the hydrogen is the more electronegative element (see electronegativity).

Hydrides of the more reactive metals may be ionic compounds containing a hydride anion (H^-).

---

hydrocarbon

any of a class of chemical compounds containing only hydrogen and carbon (for example, the alkanes and alkenes). Hydrocarbons are obtained industrially principally from petroleum and coal tar.

Unsaturated hydrocarbons contain at least one double or triple carbon-carbon bond, whereas saturated hydrocarbons contain only single bonds.

hydrocarbon

In summer, in a city the size of Melbourne, Australia, the mowing of lawns increases atmospheric hydrocarbons by 10%.

Hydrocarbon

Go to site

From the 'Fact monster', a page explaining all about hydrocarbons. Starting with an explanation of what exactly a hydrocarbon is, the text then goes on to the differences between alkenes and alkanes. Common hydrocarbons are mentioned, as are common uses for them. This well-designed and neat page also contains links to other educational resources.

---

hydrocephalus

potentially serious increase in the volume of cerebrospinal fluid (CSF) within the ventricles of the brain. In infants, since their skull plates have not fused, it causes enlargement of the head, and there is a risk of brain damage from CSF pressure on the developing brain.

Hydrocephalus may be due to mechanical obstruction of the outflow of CSF from the ventricles or to faulty reabsorption. Treatment usually involves surgical placement of a shunt system to drain the fluid into the abdominal cavity. In infants, the condition is often seen in association with spina bifida. Hydrocephalus may occur as a consequence of brain injury or disease.

---

hydrochloric acid

HCl

highly corrosive solution of hydrogen chloride (a colourless, acidic gas) in water. The concentrated acid is about 35% hydrogen chloride. The acid is a typical strong, monobasic acid forming only one series of salts, the chlorides. It has many industrial uses, including recovery of zinc from galvanized scrap iron and the production of chlorine. It is also produced in the stomachs of animals for the purposes of digestion.

---

hydrocyanic acid

or prussic acid

solution of hydrogen cyanide gas (HCN) in water. It is a colourless, highly poisonous, volatile liquid, smelling of bitter almonds.

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hydrodynamics

dynamics of fluids (liquids and gases) in motion, and especially of nonviscous, incompressible fluids.

---

hydroelectric power

electricity generated by the motion (kinetic energy) of water. In a typical scheme, the potential energy of water stored in a reservoir, often created by damming a river, is converted into kinetic energy as it is piped into water turbines. The turbines are coupled to generators to produce electricity. Hydroelectric power provides about one-fifth of the world's electricity, supplying more than a billion people. Hydroelectricity is a non-polluting, renewable energy resource, produced from water that is naturally recycled.

Conventional hydroelectric power stations can provide a constant supply of electricity. They have large dams that can store enough water to last for several years. In pumped storage plants, water flowing through the turbines is recycled. At times of low energy demand, the water is pumped back into an upper reservoir and reused to generate electricity. A tidal power station exploits the rise and fall of the tides.

---

hydrofoil

wing that develops lift in the water in much the same way that an aeroplane wing develops lift in the air. A hydrofoil boat is one whose hull rises out of the water owing to the lift, and the boat skims along on the hydrofoils. The first hydrofoil was fitted to a boat in 1906. The first commercial hydrofoil went into operation in 1956. One of the most advanced hydrofoil boats is the Boeing jetfoil. Hydrofoils are now widely used for fast island ferries in calm seas.

hydrofoil

(Image © Corel)

A hydrofoil ferry. The entire hull of the boat is lifted out of the water on the hydrofoils, allowing the boat to skim more rapidly over the surface of the water.

---

hydrogen

chemical symbol H

(Greek hydro + gen 'water generator')

colourless, odourless, gaseous, non-metallic element, atomic number 1, relative atomic mass 1.00797. It is the lightest of all the elements and occurs on Earth, chiefly in combination with oxygen, as water. Hydrogen is the most abundant element in the universe, where it accounts for 93% of the total number of atoms and 76% of the total mass. It is a component of most stars, including the Sun, whose heat and light are produced through the nuclear-fusion process that converts hydrogen into helium. When subjected to a pressure 500,000 times greater than that of the Earth's atmosphere, hydrogen becomes a solid with metallic properties, as in one of the inner zones of Jupiter. Hydrogen's common and industrial uses include the hardening of oils and fats by hydrogenation, the creation of high-temperature flames for welding, and as rocket fuel. It has been proposed as a fuel for road vehicles.

Its isotopes deuterium and tritium (half-life 12.5 years) are used in nuclear weapons, and deuterons (deuterium nuclei) are used in synthesizing elements. The element's name refers to the generation of water by the combustion of hydrogen, and was coined in 1787 by French chemist Louis Guyton de Morveau (1737-1816), after having been discovered in 1766 by English physicist and chemist Henry Cavendish.

elements of life

To remember the four elements that make life's building blocks:

HONC if you like life!

Hydrogen, **o**xygen, **n**itrogen, **c**arbon

Hydrogen - Coming Soon

Go to site

Interesting, if basic, presentation about the potential for hydrogen to become a significant source of energy in the future. The dangerous effects of fossil fuels on the environment are also discussed.

---

hydrogenation

addition of hydrogen to an unsaturated organic molecule (one that contains double bonds or triple bonds). It is widely used in the manufacture of margarine and low-fat spreads by the addition of hydrogen to vegetable oils.

Vegetable oils contain double carbon-to-carbon bonds and are therefore examples of unsaturated compounds. When hydrogen is added to these double bonds, the oils become saturated and more solid in consistency.

---

hydrogen burning

in astronomy, any of several processes by which hydrogen is converted to helium by nuclear fusion in the core of a star. In the Sun, the main process is the proton-proton chain, while in heavier stars the carbon cycle is more important. In both processes, four protons are converted to a helium nucleus with the emission of positrons, neutrinos, and gamma rays. The temperature must exceed several million kelvins for hydrogen burning to start and the least massive stars (brown dwarfs) never become hot enough.

---

hydrogencarbonate

or bicarbonate

compound containing the ion HCO_3^-, an acid salt of carbonic acid (solution of carbon dioxide in water). When heated or treated with dilute acids, it gives off carbon dioxide. The most important compounds are sodium hydrogencarbonate (bicarbonate of soda), and calcium hydrogencarbonate.

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hydrogen cyanide

HCN

poisonous gas formed by the reaction of sodium cyanide with dilute sulphuric acid; it is used for fumigation.

The salts formed from it are cyanides – for example sodium cyanide, used in hardening steel and extracting gold and silver from their ores. If dissolved in water, hydrogen cyanide gives hydrocyanic acid.

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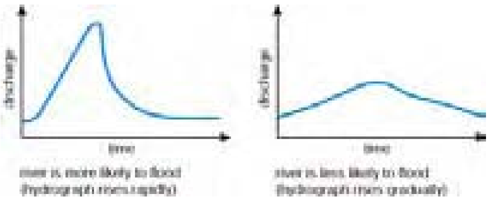
hydrograph

graph showing how the discharge of a river varies with time (generally over a matter of days). By studying hydrographs, water engineers can predict when flooding is likely and take action to prevent it.

A hydrograph shows the lag time, or delay, between peak rainfall and the resultant peak in discharge, and the length of time taken for that discharge to peak. The shorter the lag time and the higher the peak, the more likely it is that flooding will occur. The peak flow is equal to the **groundwater flow** plus the **storm flow**. Factors likely to give short lag times and high peaks include heavy rainstorms, steep slopes, deforestation, poor soil quality, and the covering of surfaces with impermeable substances such as tarmac and concrete. Actions taken by water engineers to increase lag times and lower peaks includes planting trees in the drainage basin of a river.

hydrograph



(Image © Research Machines plc)

A hydrograph shows how the amount of water flowing in a river (the discharge) changes over time. Hydrographs can help river engineers to predict when flooding will take place.

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hydrography

study and charting of Earth's surface waters in seas, lakes, and rivers.

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hydrological cycle

also known as the water cycle, by which water is circulated between the Earth's surface and its atmosphere.

---

hydrology

study of the location and movement of inland water, both frozen and liquid, above and below ground. It is applied to major civil engineering projects such as irrigation schemes, dams, and hydroelectric power, and in planning water supply. Hydrologic studies are also undertaken to assess drinking water supplies, to track water underground, and to understand the role of water in geological processes such as fault movement and mineral deposition.

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hydrolysis

chemical reaction in which the action of water or its ions breaks down a substance into smaller molecules. Hydrolysis occurs in certain inorganic salts in solution, in nearly all non-metallic chlorides, in esters, and in other organic substances. It is one of the mechanisms for the breakdown of food by the body, as in the conversion of starch to glucose.

---

hydrolysis

in earth science, a form of chemical weathering caused by the chemical alteration of certain minerals as they react with water. For example, the mineral feldspar in granite reacts with water to form a white clay called china clay.

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hydrometer

instrument used to measure the relative density of liquids (the density compared with that of water). A hydrometer consists of a thin glass tube, weighted so that it floats upright, sinking deeper into less dense liquids than into denser liquids. Hydrometers are used in brewing and to test the strength of acid in car batteries.

The hydrometer is based on Archimedes' principle.

---

hydrophilic

(Greek 'water-loving')

describing functional groups with a strong affinity for water, such as the carboxyl group (-COOH).

If a molecule contains both a hydrophilic and a hydrophobic group (a group that repels water), it may have an affinity for both aqueous and nonaqueous molecules. Such compounds are used to stabilize emulsions or as detergents.

---

hydrophily

type of pollination where the pollen is transported by water. Water-pollinated plants occur in 31 genera in 11 different families. They are found in habitats as diverse as rainforests and seasonal desert pools. Pollen is either dispersed underwater or on the water's surface.

Pollen may be released directly onto the water's surface, as in the sea grass *Halodule pinifolia*, forming pollen rafts, or as in the freshwater plant *Vallisneria*, the pollen may be released within floating male flowers. In Caribbean turtle grass, *Thalassia testudinum*, pollen is released underwater embedded in strands of mucilage. Denser than water, it is carried by the current.

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hydrophobia

another name for the disease rabies.

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hydrophobic

(Greek 'water-hating')

describing functional groups that repel water (the opposite of hydrophilic).

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hydrophone

underwater microphone and ancillary equipment capable of picking up waterborne sounds. It was originally developed to detect enemy submarines but is now also used, for example, for listening to the sounds made by whales.

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hydrophyte

plant adapted to live in water, or in waterlogged soil.

Hydrophytes may have leaves with a very reduced or absent cuticle and no stomata (since there is no need to conserve water), a reduced root and water-conducting system, and less supporting tissue since water buoys plants up. There are often numerous spaces between the cells in their stems and roots to make gas exchange with all parts of the plant body possible. Many have highly divided leaves, which lessens resistance to flowing water; an example is spiked water milfoil *Myriophyllum spicatum*.

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hydroplane

on a submarine, a movable horizontal fin angled downwards or upwards when the vessel is descending or ascending. It is also a highly manoeuvrable motorboat with its bottom rising in steps to the stern, or a hydrofoil boat that skims over the surface of the water when driven at high speed.

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hydroponics

cultivation of plants without soil, using specially prepared solutions of mineral salts. Beginning in the 1930s, large crops were grown by hydroponic methods, at first in California but since then in many other parts of the world.

Julius von Sachs (1832-1897), in 1860, and W Knop, in 1865, developed a system of plant culture in water whereby the relation of mineral salts to plant growth could be determined, but it was not until about 1930 that large crops could be grown. The term was first coined by US scientist William F Gericke in 1937.

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hydrosphere

portion of the Earth made of water, ice, and water vapour, including the oceans, seas, rivers, streams, swamps, lakes, groundwater, and atmospheric water vapour. In some cases its definition is extended to include the water locked up in the Earth's crust and mantle.

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hydrothermal

in geology, pertaining to a fluid whose principal component is hot water, or to a mineral deposit believed to be precipitated from such a fluid.

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hydrothermal vein

crack in rock filled with minerals precipitated through the action of circulating high-temperature fluids. Igneous activity often gives rise to the circulation of heated fluids that migrate outwards and move through the surrounding rock. When such solutions carry metallic ions, ore-mineral deposition occurs in the new surroundings on cooling.

---

hydrothermal vent

or smoker

crack in the ocean floor, commonly associated with an ocean ridge, through which hot, mineral-rich water flows into the cold ocean water, forming thick clouds of suspended material. The clouds may be dark or light, depending on the mineral content, thus producing 'white smokers' or 'black smokers'. In some cases the water is clear.

Seawater percolating through the sediments and crust is heated by the hot rocks and magma below and then dissolves minerals from the hot rocks. The water gets so hot that its increased buoyancy drives it back out into the ocean via a hydrothermal ('hot water') vent. When the water, anywhere from 60°C to over 400°C (kept liquid by the pressure of the ocean above) comes into contact with the frigid sea water, the sudden cooling causes these minerals to precipitate from solution, so forming the suspension. These minerals settle out and crystallize, forming stalagmite-like 'chimneys'. The chemical-rich water around a smoker gives rise to colonies of primitive bacteria that use the chemicals in the water, rather than the sunlight, for energy. Strange animals that live in such regions include huge tube worms 2 m/6 ft long, giant clams, and species of crab, anemone, and shrimp that are found nowhere else.

---

hydroxide

any inorganic chemical compound containing one or more hydroxyl (OH) groups and generally combined with a metal. Hydroxides include sodium hydroxide (caustic soda, NaOH), potassium hydroxide (caustic potash, KOH), and calcium hydroxide (slaked lime, $Ca(OH)_2$).

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hydroxyl group

atom of hydrogen and an atom of oxygen bonded together and covalently bonded to an organic molecule. Common compounds containing hydroxyl groups are alcohols and phenols.

In chemical reactions, the hydroxyl group (—OH) frequently behaves as a single entity.

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hydroxypropanoic acid

technical name for lactic acid.

hyena

any of three species of carnivorous doglike mammals living in Africa and Asia. Hyenas have extremely powerful jaws. They are scavengers, feeding on the remains of animals killed by predators such as lions, although they will also attack and kill live prey. (Genera *Hyaena* and *Crocuta*, family Hyaenidae, order Carnivora.)

The species are the **striped hyena** (*H. hyaena*) found from Asia Minor to India; the **brown hyena** (*H. brunnea*), found in South Africa; and the **spotted** or **laughing hyena** (*C. crocuta*), common south of the Sahara. The aardwolf also belongs to the hyena family.

hyena

The female spotted hyena has a higher level of the male sex hormone testosterone than the male. She is also up to 12% heavier than the male.

hygiene

the science of the preservation of health and prevention of disease through the promotion of cleanliness. It is chiefly concerned with such factors as the purity of air and water; bodily cleanliness; cleanliness in the home and workplace; and sound practice in the preparation and distribution of food.

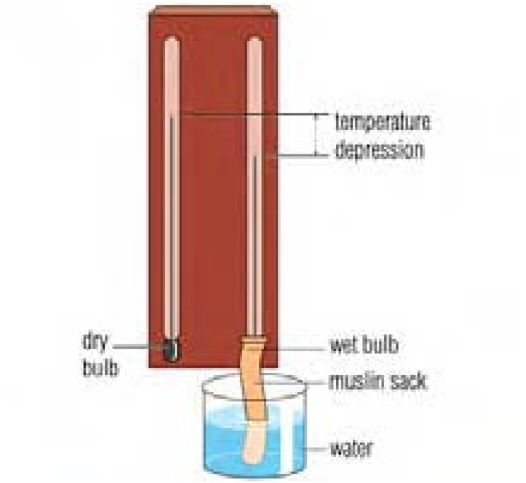
Personal hygiene includes the regular washing of clothes, hair, and body; daily brushing of teeth; and washing of hands after using the toilet to prevent buildup of bacteria.
Domestic hygiene includes keeping the home clean and tidy, preserving food safely in a refrigerator or freezer, thawing and cooking food thoroughly before eating, and disposing of waste from the home.
Community hygiene is normally the responsibility of the local council or government, and includes sewage disposal, refuse collection, inspection of hygiene standards in shops selling food, provision of programmes of vaccination, and provision of clean drinking water.

hygrometer

any instrument for measuring the humidity, or water vapour content, of a gas (usually air). A wet and dry bulb hygrometer consists of two vertical thermometers, with one of the bulbs covered in absorbent cloth dipped into water. As the water evaporates, the bulb cools, producing a temperature difference between the two thermometers. The amount of evaporation, and hence cooling of the wet bulb, depends on the relative humidity of the air.

Other hygrometers work on the basis of a length of natural fibre, such as hair or a fine strand of gut, changing with variations in humidity. In a dew-point hygrometer, a polished metal mirror is gradually cooled until a fine mist of water (dew) forms on it. This gives a measure of the dew point, from which the air's relative humidity can be calculated.

hygrometer



(Image © Research Machines plc)

The most common hygrometer, or instrument for measuring the humidity of a gas, is the wet and dry bulb hygrometer. The wet bulb records a lower temperature because water evaporates from the muslin, taking heat from the wet bulb. The degree of evaporation and hence cooling depends upon the humidity of the surrounding air or other gas.

hyoscine

or scopolamine

drug that acts on the autonomic nervous system and prevents muscle spasm. It is frequently included in premedication to dry up lung secretions and as a postoperative sedative. It is also used to treat ulcers, to relax the womb in labour, for travel sickness, and to dilate the pupils before an eye examination. It is an alkaloid, $C_{17}H_{21}NO_2$, obtained from various plants of the nightshade family (such as belladonna).

---

hyperactivity

condition of excessive activity in young children, combined with restlessness, inability to concentrate, and difficulty in learning. There are various causes, ranging from temperamental predisposition to brain disease. In some cases food additives have come under suspicion; in such instances modification of the diet may help. Mostly there is improvement at puberty, but symptoms may persist in the small proportion diagnosed as having attention-deficit hyperactivity disorder (ADHD).

---

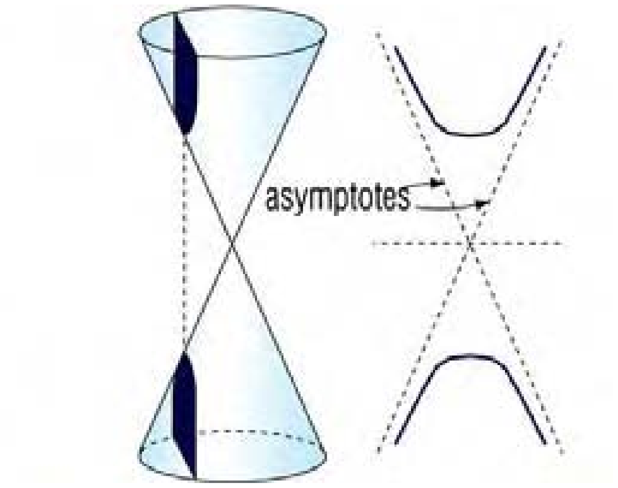
hyperbola

in geometry, a curve formed by cutting a right circular cone with a plane so that the angle between the plane and the base is greater than the angle between the base and the side of the cone. All hyperbolae are bounded by two asymptotes (straight lines to which the hyperbola moves closer and closer to but never reaches).

A hyperbola is a member of the family of curves known as conic sections.

A hyperbola can also be defined as a path traced by a point that moves such that the ratio of its distance from a fixed point (focus) and a fixed straight line (directrix) is a constant and greater than 1; that is, it has an eccentricity greater than 1.

hyperbola



(Image © Research Machines plc)

The hyperbola is produced when a cone is cut by a plane. It is one of a family of curves called conic sections: the circle, ellipse, and parabola. These curves are produced when the plane cuts the cone at different angles and positions.

Hyperbola

Go to site

Introduction to the hyperbola and links to associated curves. If you have a Java-enabled browser you can experiment interactively with this curve and its associates. There are also links to mathematicians who have studied the hyperbola, to the hyperbola's particular attributes, and to related Web sites.

---

hypercharge

in physics, a property of certain elementary particles, analogous to electric charge, that accounts for the absence of some expected behaviour (such as certain decays).

---

hypermetropia

or farsightedness

defect of vision in which a person is able to focus on objects in the distance, but not on close objects. It is caused by the failure of the lens to return to its normal rounded shape, or by the eyeball being too short, with the result that the image is focused on a point behind the retina. Hypermetropia is corrected by wearing eyeglasses fitted with converging lenses, each of which acts like a magnifying glass.

---

hypertension

abnormally high blood pressure due to a variety of causes, leading to excessive contraction of the smooth muscle cells of the walls of the arteries. It increases the risk of kidney disease, stroke, and heart attack.

Hypertension is one of the major public health problems of the developed world, affecting 15-20% of adults in industrialized countries (1996). It may be of unknown cause (**essential hypertension**), or it may occur in association with some other condition, such as kidney disease (**secondary or symptomatic hypertension**). It is controlled with a low-salt diet and drugs.

---

hypertext

in computing, a method of forming connections ('links') between different files (including office documents, graphics, and Web pages) so that the user can click on a link to jump between them. For example, a software program might display a map of a country; if the user clicks on a particular city the program displays information about that city. The linked files do not need to be on the same computer, or even in the same country, for a hyperlink to be created.

---

hyperthyroidism

or thyrotoxicosis

overactivity of the thyroid gland due to enlargement or tumour. Symptoms include accelerated heart rate, sweating, anxiety, tremor, and weight loss. Treatment is by drugs or surgery.

---

hypertrophy

abnormal increase in size of a body organ or tissue.

---

hypha

(plural **hyphae**) delicate, usually branching filament, many of which collectively form the mycelium and fruiting bodies of a fungus. Food molecules and other substances are transported along hyphae by the movement of the cytoplasm, known as 'cytoplasmic streaming'.

Typically hyphae grow by increasing in length from the tips and by the formation of side branches. Hyphae of the higher fungi (the ascomycetes and basidiomycetes) are divided by cross walls or septa at intervals, whereas those of lower fungi (for example, bread mould) are undivided. However, even the higher fungi are not truly cellular, as each septum is pierced by a central pore, through which cytoplasm, and even nuclei, can flow. The hyphal walls contain chitin, a polysaccharide.

---

hypnosis

artificially induced state of relaxation or altered attention characterized by heightened suggestibility. There is evidence that, with susceptible persons, the sense of pain may be diminished, memory of past events enhanced, and illusions or hallucinations experienced. Posthypnotic amnesia (forgetting what happened during hypnosis) and posthypnotic suggestion (performing an action after hypnosis that had been suggested during it) have also been demonstrated.

Hypnosis has a number of uses in medicine. Hypnotically induced sleep, for example, may assist the healing process, and hypnotic suggestion (hypnotherapy) may help in dealing with the symptoms of emotional and psychosomatic disorders. The Austrian physician Friedrich Anton Mesmer is said to be the discoverer of hypnosis, but he called it 'animal magnetism', believing it to be a physical force or fluid. The term 'hypnosis' was coined by James Braid (1795-1860), a British physician and surgeon who was the first to regard it as a psychological phenomenon. The Scottish surgeon James Esdaile (1805-1859), working in India, performed hundreds of operations in which he used hypnosis to induce analgesia (insensitivity to pain) or general anaesthesia (total insensitivity).

---

hypnotherapy

use of hypnotic trance and posthypnotic suggestions to relieve stress-related conditions such as insomnia and hypertension, or to break health-damaging habits or addictions.

Though it is an effective method of modifying behaviour, its effects are of short duration unless it is used as an adjunct to psychotherapy.

---

hypnotic

any substance (such as barbiturate, benzodiazepine, alcohol) that depresses brain function, inducing sleep. Prolonged use may lead to physical or psychological addiction.

---

hypo

in photography, a term for sodium thiosulphate, discovered in 1819 by John Herschel, and used as a fixative for photographic images since 1837.

---

hypocycloid

in geometry, a cusped curve traced by a point on the circumference of a circle that rolls around the inside of another larger circle. (Compare epicycloid.)

---

hypodermic syringe

instrument used for injecting fluids beneath the skin into either muscles or blood vessels. It consists of a small graduated tube with a close-fitting piston and a nozzle onto which a hollow needle can be fitted.

---

hypogeal

describing seed germination in which the cotyledons remain below ground. It can refer to fruits that develop underground, such as peanuts *Arachis hypogea*.

---

hypoglycaemia

condition of abnormally low level of sugar (glucose) in the blood, which starves the brain. It causes weakness, sweating, and mental confusion, sometimes fainting.

Hypoglycaemia is most often seen in diabetes. Low blood sugar occurs when the diabetic has taken too much insulin. It is treated by administering glucose.

---

hypotension

in medicine, abnormally low blood pressure. Postural hypotension refers to the sudden fall in blood pressure that can occur on standing up suddenly. The patient experiences dizziness and may fall. It is most common in the elderly.

---

hypotenuse

longest side of a right-angled triangle, opposite the right angle. It is of particular application in Pythagoras' theorem (the square of the hypotenuse equals the sum of the squares of the other two sides), and in trigonometry where the ratios sine and cosine are defined as the ratios opposite/hypotenuse and adjacent/hypotenuse respectively.

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hypothalamus

region of the brain below the cerebrum which regulates rhythmic activity and physiological stability within the body, including water balance and temperature. It regulates the production of the pituitary gland's hormones and controls that part of the nervous system governing the involuntary muscles.

---

hypothermia

condition in which the deep (core) temperature of the body falls below 35°C. If it is not discovered coma and death ensue. Most at risk are the aged and babies (particularly if premature).

---

hypothesis

in science, an idea concerning an event and its possible explanation. The term is one favoured by the followers of the philosopher Karl Popper, who argue that the merit of a scientific hypothesis lies in its ability to make testable predictions.

hypothesis

an unproven idea. It is part of the process of solving problems: to form a hypothesis and then test it by experiment.

hypothyroidism

or myxoedema

deficient functioning of the thyroid gland, causing slowed mental and physical performance, weight gain, sensitivity to cold, and susceptibility to infection.

This may be due to lack of iodine in the diet or a defect of the thyroid gland, both being productive of goitre; or to the pituitary gland providing insufficient stimulus to the thyroid gland. Treatment of thyroid deficiency is by the hormone thyroxine. When present from birth, hypothyroidism can lead to cretinism if untreated.

hypoventilation

in medicine, an abnormally slow resting respiratory rate characterized by shallow breathing. It can result in a lack of oxygen in the blood and can lead to organ damage and death if it is severe and remains untreated. Injury to the respiratory centre and some drugs, such as opioid analgesics, can cause hypoventilation.

hypsometer

(Greek hypsos 'height')

instrument for determining altitude by measuring the boiling point, inferring the local atmospheric pressure, and hence determining the height.

hyrax

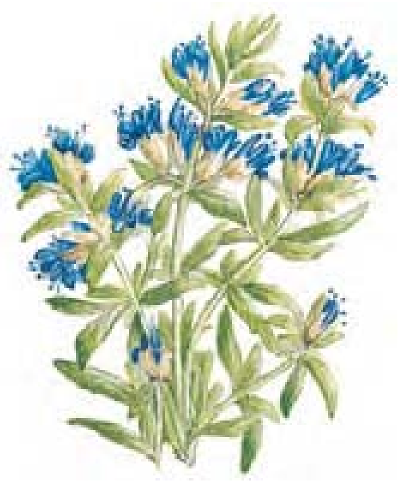
any of a group of small, rodentlike, herbivorous mammals that live among rocks in desert areas, and in forests in Africa, Arabia, and Syria. They are about the size of a rabbit, with a plump body, short legs, short ears, brownish fur, and long, curved front teeth. (Family Procaviidae, order Hyracoidea.)

They have four toes on the front limbs, and three on the hind limbs, each of which has a tiny hoof. There are nine species of hyrax. They are related to elephants.

hyssop

aromatic herb belonging to the mint family, found in Asia, southern Europe, and around the Mediterranean. It has blue flowers, oblong leaves, and stems that are woody near the ground but herbaceous (fleshy) above. (*Hyssopus officinalis*, family Labiatae.)

hyssop



(Image © Research Machines plc)

The hyssop is a bushy herb formerly used in medicine. It is also used, like its relation mint, in cooking. Leaves are used in soups and teas, and, with flowers, in salads.

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hysterectomy

surgical removal of all or part of the uterus (womb). The operation is performed to treat fibroids (benign tumours growing in the uterus) or cancer; also to relieve heavy menstrual bleeding. A woman who has had a hysterectomy will no longer menstruate and cannot bear children.

Instead of a full hysterectomy it is sometimes possible to remove the lining of the womb, the endometrium, by a 'keyhole' procedure known as endometrial resection, using either diathermy or a laser. This procedure avoids the complications, such as infections, that can occur after hysterectomy.

Hz

in physics, the symbol for hertz.

Iapetus Ocean

or Proto-Atlantic

sea that existed in early Palaeozoic times between the continent that was to become Europe and that which was to become North America. The continents moved together in the late Palaeozoic, obliterating the ocean. When they moved apart once more, they formed the Atlantic.

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iatrogenic

caused by medical treatment; the term 'iatrogenic disease' may be applied to any pathological condition or complication that is caused by the treatment, the facilities, or the staff.

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ibex

any of various wild goats found in mountainous areas of Europe, northeastern Africa, and Central Asia. They grow to 100 cm/3.5 ft, and have brown or grey coats and heavy horns. They are herbivorous and live in small groups.

---

ibis

any of various wading birds, about 60 cm/2 ft tall, belonging to the same family as spoonbills. Ibises have long legs and necks, and long, downward-curved beaks, rather blunt at the end; the upper part is grooved. Their plumage is generally black and white. Various species occur in the warmer regions of the world. (Family Threskiornidae, order Ciconiiformes.)

The **scarlet ibis** (*Guara ruber*), a South American species, is brilliant scarlet with a few black patches. The scarlet colour is caused by an accumulation of pigment from the aquatic invertebrates that it feeds on.

IBM

abbreviation for International Business Machines

multinational company, the largest manufacturer of computers in the world. The company is a descendant of the Tabulating Machine Company, formed in 1896 by US inventor Herman Hollerith to exploit his punched-card machines. It adopted its present name in 1924. By 1991 it had an annual turnover of US$64.8 billion and employed about 345,000 people, but in 1992 and 1993 it made considerable losses. The company acquired Lotus Development Corporation in 1995. By 1997 IBM had, under new management, recovered financially. In the fourth quarter of 2003, IBM's revenue was US$25.9 billion, of which services accounted for US$11.4 billion and software US$4.3 billion. The company's net revenue for the quarter was US$2.7 billion.

In 2003, IBM's chairman and chief executive, Sam Palmisano, unveiled the company's 'big bet' for the future, e-business on demand. On-demand computing envisages corporate applications working together with those of other companies using World Wide Web services, and with shortfalls in computing capacity being remedied through access to online data centres.

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ibuprofen

in medicine, a non-steroidal anti-inflammatory drug (NSAID) that is used to relieve pain and inflammation.

Ibuprofen acts by inhibiting the formation of prostaglandins that mediate inflammation and so is used to treat conditions that are characterized by pain and inflammation, such as arthritic conditions, dental pain, period pain, sprains, and sports injuries. It is usually taken by mouth. Adverse effects include irritation of the gut, which can be reduced by taking ibuprofen at the same time as food. It should not be taken by patients with gastric ulceration and caution is required in patients with allergic disorders. Creams and gels are available that can be applied directly to the inflamed area. Ibuprofen can also slow the development of Alzheimer's disease, but only at high doses that can be toxic.

IC

abbreviation for integrated circuit.

Icarus

in astronomy, Apollo asteroid 1.5 km/1 mi in diameter, discovered in 1949 by German-born US astronomer Walter Baade. It orbits the Sun every 409 days at a distance of 28-300 million km/18-186 million mi (0.19-2.0 astronomical units). It was the first asteroid known to approach the Sun closer than does the planet Mercury. In 1968 it passed within 6 million km/3.7 million mi of the Earth.

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ice

solid formed by water when it freezes. It is colourless and its crystals are hexagonal. The water molecules are held together by hydrogen bonds.

The freezing point of water at 1.013 bar, used as a standard for measuring temperature, is 0° for the Celsius and Réaumur scales and 32° for the Fahrenheit scale. Ice expands in the act of freezing (hence burst pipes), becoming less dense than water (0.9175 at 5°C/41°F). There are at least six different modifications of ice, some of which can only exist at very high pressures. These forms are identified by Roman numerals, thus the 'ordinary' ice formed at atmospheric pressure is technically known as ice I.

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ice

form of methamphetamine that is smoked for its stimulating effect; its use has been illegal in the USA since 1989. Its use may be followed by a period of depression and psychosis.

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ice age

any period of extensive glaciation (in which icesheets and icecaps expand over the Earth) occurring in the Earth's history, but particularly that in the Pleistocene epoch (last 2 million years), immediately preceding historic times. On the North American continent, glaciers reached as far south as the Great Lakes, and an icesheet spread over northern Europe, leaving its remains as far south as Switzerland. In Britain ice reached as far south as a line from Bristol to Banbury to Exeter. There were several glacial advances separated by interglacial (warm) stages, during which the ice melted and temperatures were higher than today. We are currently in an interglacial phase of an ice age.

Other ice ages have occurred throughout geological time: there were four in the Precambrian era, one in the Ordovician, and one at the end of the Carboniferous and beginning of the Permian. The occurrence of an ice age is governed by a combination of factors (the **Milankovitch hypothesis**): (1) the Earth's change of attitude in relation to the Sun – that is, the way it tilts in a 41,000-year cycle and at the same time wobbles on its axis in a 22,000-year cycle, making the time of its closest approach to the Sun come at different seasons; and (2) the 92,000-year cycle of eccentricity in its orbit around the Sun, changing it from an elliptical to a near circular orbit, the severest period of an ice age coinciding with the approach to circularity. There is a possibility that the Pleistocene ice age is not yet over. It may reach another maximum in another 60,000 years.

Ice age: major ice ages

name	date (years ago)
Pleistocene	1.64 million-10,000
Permo-Carboniferous	330-250 million
Ordovician	440-430 million
Varangian	615-570 million
Sturtian	820-770 million
Gnejso	940-880 million
Huronian	2,700-1,800 million

Cracking the Ice Age

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page provides information about glaciation, the natural changes in climate over the past 60 million years, the greenhouse effect, global warming, and continental movement. There is also a list of related links.

Ice Age, Little

period of particularly severe winters that gripped northern Europe between the 13th and 17th centuries. Contemporary writings and paintings show that Alpine glaciers were much more extensive than at present, and rivers such as the Thames, which do not ice over today, were so frozen that festivals could be held on them.

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iceberg

floating mass of ice, about 80% of which is submerged, rising sometimes to 100 m/300 ft above sea level. Glaciers that reach the coast become extended into a broad foot; as this enters the sea, masses break off and drift towards temperate latitudes, becoming a danger to shipping.

iceberg

(Image © Corel)

An iceberg in Baffin Bay. Icebergs are a danger to shipping, making the Bay unnavigable for around nine months of the year.

iceberg

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Icebergs in the Antarctic assume many fantastic shapes. Near the shore these are mainly the result of accretion, as bergs jostle and fuse together. Further out, however, it is a matter of erosion, through thawing and melting, which may leave arches hanging between more compacted ice masses.

iceberg, Baffin Island

(Image © Corel)

Iceberg at the flow edge, Baffin Island, Northwest Territories, Canada.

iceberg, Tanquary Ford

(Image © Corel)

Iceberg, Tanquary Ford, Northwest Territories, Canada.

iceberg with arch

(Image © Corel)

Iceberg with arch.

Iceland spar

form of calcite, $CaCO_3$, originally found in Iceland. In its pure form Iceland spar is transparent and exhibits the peculiar phenomenon of producing two images of anything seen through it (birefringence or double refraction). It is used in optical instruments. The crystals cleave into perfect rhombohedra.

iceman

nickname given to the preserved body of a prehistoric man discovered in a glacier on the Austrian-Italian border in 1991. On the basis of the clothing and associated artefacts, the body was at first believed to be 4,000 years old, from the Bronze Age. Carbon dating established its age at about 5,300 years. The discovery led to a reappraisal of the boundary between the Bronze and the Stone Age.

ichneumon fly

any of a large group of parasitic wasps. There are several thousand species in Europe, North America, and other regions. They have slender bodies, and the females have unusually long, curved ovipositors (egg-laying instruments) that can pierce several inches of wood. The eggs are laid in the eggs, larvae, or pupae of other insects, usually butterflies or moths. (Family Ichneumonidae.)

icon

in computing, a small picture on the computer screen, or VDU, representing an object or function that the user may manipulate or otherwise use. It is a feature of graphical user interface (GUI) systems. Icons make computers easier to use by allowing the user to point to and click with a mouse on pictures, rather than type commands.

icosahedron

plural icosahedra

regular solid with 20 equilateral (equal-sided) triangular faces. It is one of the five regular polyhedra, or Platonic solids.

id

in Freudian psychology, the mass of motivational and instinctual elements of the human mind, whose activity is largely governed by the arousal of specific needs. It is regarded as the unconscious element of the human psyche, and is said to be in conflict with the ego and the superego.

idiot savant

(French 'knowledgeable idiot')

person who has a specific mental skill that has developed at the expense of general intelligence. An idiot savant is educationally slow but may be able to calculate the day of the week for any date, or memorize a large quantity of text. Most idiots savants are male.

igneous rock

rock formed from the cooling and solidification of molten rock called magma. The acidic nature of this rock type means that areas with underlying igneous rock are particularly susceptible to the effects of acid rain. Igneous rocks that crystallize slowly from magma below the Earth's surface have large crystals. Examples include dolerite and granite.

ignis fatuus

another name for will-o'-the-wisp.

ignition coil

transformer that is an essential part of a petrol engine's ignition system. It consists of two wire coils wound around an iron core. The primary coil, which is connected to the car battery, has only a few turns. The secondary coil, connected via the distributor to the spark plugs, has many turns. The coil takes in a low voltage (usually 12 volts) from the battery and transforms it to a high voltage (about 15,000-20,000 volts) to ignite the fuel.

When the engine is running, the battery current is periodically interrupted by means of the contact breaker in the distributor. The collapsing current in the primary coil induces a current in the secondary coil, a phenomenon known as electromagnetic induction. The induced current in the secondary coil is at very high voltage. This passes to the spark plugs to create sparks.

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ignition temperature

or fire point

minimum temperature to which a substance must be heated before it will spontaneously burn independently of the source of heat; for example, ethanol has an ignition temperature of 425°C/798°F and a flash point of 12°C/54°F.

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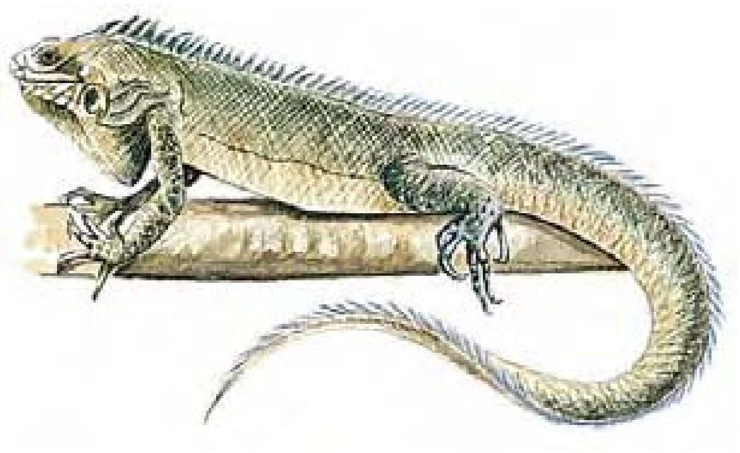
iguana

any of about 700 species of lizard, chiefly found in the Americas. The **common iguana** (*I. iguana*) of Central and South America is a vegetarian and may reach 2 m/6 ft in length. (Especially genus *Iguana*, family Iguanidae.)

iguana



(Image © Research Machines plc)

The common iguana lives mainly in trees but is an excellent swimmer. It has a characteristic crest of comblike spines running down the length of its back. Young animals are bright green, becoming darker with age.

Complete Guide to Keeping Giant Green Iguanas in Captivity

Go to site

All there is to know about the many difficulties of keeping a giant iguana. There is comprehensive information on behaviour, diet, housing, and common veterinary problems. There is a bibliography and listings of reptile veterinarians and other iguana sites around the world.

---

iguanodon

plant-eating dinosaur whose remains are found in deposits of the Lower Cretaceous age, together with the remains of other dinosaurs of the same order (ornithiscians) such as stegosaurus and triceratops. It was 5-10 m/16-32 ft long and, when standing upright, 4 m/13 ft tall. It walked on its hind legs, using its long tail to balance its body. (Order *Ornithiscia*.)

---

ileum

part of the small intestine of the digestive system, between the duodenum and the colon, that absorbs digested food.

Its wall is muscular so that waves of contraction (peristalsis) can mix the food and push it forward. Numerous fingerlike projections, or villi, point inwards from the wall, increasing the surface area available for absorption. The ileum has an excellent blood supply, which receives the food molecules passing through the wall and transports them to the liver via the hepatic portal vein.

Ilium

in classical mythology, an alternative name for the city of Troy, taken from its founder Ilus.

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illumination

or illuminance

the brightness or intensity of light falling on a surface. It depends upon the brightness and distance of light sources and the angle at which the light strikes the surface. The SI unit is the lux.

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ilmenite

oxide of iron and titanium, iron titanate ($FeTiO_3$); an ore of titanium. The mineral is black, with a metallic lustre. It is found as an accessory mineral in mafic igneous rocks and in sands.

ILS

abbreviation for instrument landing system, an automatic system for assisting aircraft landing at airports.

---

image

picture or appearance of a real object, formed by light that passes through a lens or is reflected from a mirror. If rays of light actually pass through an image, it is called a **real image**. Real images, such as those produced by a camera or projector lens, can be projected onto a screen. An image that cannot be projected onto a screen, such as that seen in a flat mirror, is known as a **virtual image**.

In a pinhole camera, rays of light travelling from the object through the pinhole of the camera form a real image on the screen of the camera. The image is upside down, or inverted.

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imaginary number

term often used to describe the non-real element of a complex number. For the complex number $(a + ib)$, ib is the imaginary number where $i = \sqrt{(-1)}$, and b any real number.

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imago

sexually mature stage of an insect.

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immediate access memory

in computing, memory provided in the central processing unit to store the programs and data in current use.

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immiscible

describing liquids that will not mix with each other, such as oil and water. When two immiscible liquids are shaken together, an emulsion is produced. This normally forms separate layers on being left to stand. Immiscible liquids may be separated using a separating funnel.

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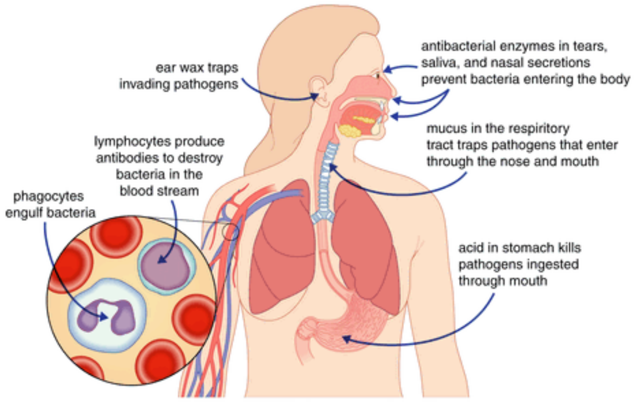
immunity

protection that organisms have against foreign micro-organisms, such as bacteria and viruses, and against cancerous cells (see cancer). The cells that provide this protection are called white blood cells, or leucocytes, and make up the immune system. They include neutrophils and macrophages, which can engulf invading organisms and other unwanted material, and natural killer cells that destroy cells infected by viruses and cancerous cells. Some of the most important immune cells are the B cells and T cells. Immune cells coordinate their activities by means of chemical messengers or lymphokines, including the antiviral messenger interferon. The lymph nodes play a major role in organizing the immune response.

immunity


ear wax traps invading pathogens
antibacterial enzymes in tears, saliva, and nasal secretions prevent bacteria entering the body
lymphocytes produce antibodies to destroy bacteria in the blood stream
phagocytes engulf bacteria
mucus in the respiritory tract traps pathogens that enter through the nose and mouth
acid in stomach kills pathogens ingested through mouth

(Image © Research Machines plc)

How the body's defence mechanisms keep out invading pathogens or destroy those that succeed in entering the body.

---

immunization

process of conferring immunity to infectious disease by artificial methods, in other words making someone not liable to catch a disease. The most widely used technique is vaccination (see vaccine). Immunization is an important public health measure. If most of the population has been immunized against a particular disease, it is impossible for an epidemic to take hold.

In vaccination people can be immunized against a disease by introducing small quantities of dead or inactive forms of the disease-causing micro-organism into the body. In the vaccine are chemicals which act as antigens. These stimulate the white blood cells to produce antibodies. Antibodies are capable of binding to disease-causing bacteria, resulting in their destruction. If the body is effectively 'warned' about the antigen by this means, the body is then able to produce enough of the appropriate antibody whenever the living disease-causing organism enters the body. The micro-organism can then be killed before it harms the body. The person contacted by the disease will probably feel well all the time and will be unaware that he or she has been in contact with the disease. This is called active immunity.

Vaccination can be used to protect against diseases caused by viruses. It is, in fact, the best way to deal with virus diseases, because antibiotics are not effective against them. An example is the MMR vaccine used to protect children against measles, mumps, and rubella. A study of thousands of children in Finland who have had the MMR vaccine has shown that there is only a very low risk of damage being caused to a child as a result of having the vaccine. The risk is much lower than the damage caused by catching one of the diseases.

If vaccination covers a large proportion of the population at risk, a disease can become very rare, or even die out. Smallpox was eliminated in this way. The worries over MMR vaccine have reduced the numbers of children being vaccinated, which increases the risk of measles, mumps, or rubella breaking out in an epidemic.

current research

US researchers conducted the first human trials of a vaccine administered by eating genetically engineered potatoes in 1995. In animal trials, mice fed on the potatoes received protection against some common gut infections.

Immunization: key events

AD 23-79	Pliny the Elder suggests using liver from mad dogs as protection against rabies.
1500s	Asian physicians immunize against smallpox using the crusts from pustules. This is only partially successful.
1720s	Lady Mary Wortley Montagu introduces smallpox immunization into Europe from Turkey.
1796	British physician Edward Jenner develops a safe smallpox vaccine using the cowpox virus.
1853	Vaccination against smallpox is made compulsory in Britain.
1885	French microbiologist Louis Pasteur develops a vaccine for rabies.
1894-1904	German immunologist Emil von Behring and Japanese bacteriologist Kitasato Shibasaburo successfully test vaccines for diphtheria and tetanus.
1896	A E Wright develops typhoid vaccine.
1914	Tetanus vaccine becomes available on a large scale.
1920s	Tuberculosis vaccine produced.
1937	South African-born US microbiologist Max Theiler develops vaccine 17-D, still the main form of protection against yellow fever.
1949	Whooping cough vaccine licensed.
1952	US microbiologist Jonas Salk develops the first successful vaccine for poliomyelitis.
1960s	Measles and rubella vaccines produced.
1961	The oral vaccine for poliomyelitis, developed by Russian-born virologist Albert Sabin, becomes widely available.
1967	The World Health Organization (WHO) begins its global campaign against smallpox.

1970s	Vaccines produced for meningococcal diseases and chickenpox. The WHO begins constructing its 'cold chain' to ensure adequate transport and refrigeration for vaccines, which can take up to two years to reach their target in a developing country.
1974	WHO launches the Expanded Programme on Immunization, as fewer than 5% of children in developing countries are currently immunized.
1978	Pulmonary disease vaccine is developed.
1980s	Vaccine for hepatitis B and a combination vaccine for measles, mumps, and rubella (MMR) become available.
1980	Smallpox virtually eradicated.
1984	Leprosy vaccine developed.
1989–90	More than 100 children die when a measles epidemic sweeps through several large cities in the USA, highlighting the failure of the immunization programme. Three-quarters of the 45,000 children affected have not been vaccinated.
1990	Vaccine introduced for *Hemophilus influenzae*, a cause of meningitis.
1991	WHO estimates 80% of the world's children are immunized against diphtheria, whooping cough, tetanus, measles, polio, and tuberculosis. A US survey of nine major cities finds that less than half of school-age children have been fully vaccinated against infectious diseases by their second birthday.
1994	Fear of a measles epidemic in the UK leads to a vaccination programme for all children aged 5-16.
1995	First human trials of a vaccine administered by eating genetically engineered potatoes.
1996	Heat-sensitive chemical monitors used on polio vaccine containers from January. If the monitor changes colour health workers will know that high temperatures have destroyed the vaccine. A vaccine for salmonella for use in poultry is approved in Australia.
1998	Controversy arises over the use of the combined MMR vaccine owing to the claims of a UK paediatrician that there is a slight risk of immunized children developing autism in later life. In India, the government authorizes the sale of the world's first leprosy vaccine; in 1998 there are an estimated 1.5 million cases of leprosy of which 60% are in India. The vaccine is only effective for 6-12 months.
2001	New research provides strong statistical evidence that the MMR vaccine and autism are not linked.

Immunology

Go to site

Excellent and easy-to-understand introduction to the science of immunology. The clearly written text describes how the immune system works and the function of antibodies. The site also explains what happens when the immune system fails to work, or works too well, and the problems of allergies and hypersensitivity.

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immunization for travel

in medicine, advised immunization for travellers. Although immunization against infectious diseases is rarely an essential legal requirement to enter a country, immunization is often advisable to protect the traveller from diseases not encountered at home. It is necessary to plan ahead for immunizations as some require more than one dose of vaccine and some cannot be given at the same time. General practitioners and travel health centres provide the most up-to-date advice on the immunizations recommended for travelling.

In general, travellers to all countries should have immunity to tetanus and poliomyelitis and childhood immunizations should be up to date. Additional immunizations are required in non-European areas surrounding the Mediterranean, in Africa, the Middle East, Asia, and South America.

typhoid

Typhoid vaccine is indicated for travellers to areas where typhoid is endemic, such as Asia and South America. However, vaccination is no substitution for good hygiene. Food should be freshly prepared and hot and uncooked vegetables, including salads, should be avoided. Fruit should be peeled. Drinking water should be bottled, boiled or treated with water sterilising tablets.

cholera

Cholera vaccine provides little protection against this disease and good hygiene is particularly important in countries where cholera is endemic.

meningitis

There is a high incidence of meningococcal meningitis in some Asian countries and in southern sub-Saharan Africa and vaccination is recommended for these areas.

hepatitis A

Immunization against hepatitis A is advisable for people visiting Asia and Africa.

yellow fever

International certificates of vaccination against yellow fever are still required for travel to many countries in Africa and South America.

malaria

In addition to vaccination, travellers should take a course of antimalarial tablets if they are visiting areas in which malaria is endemic. Resistance to older antimalarial drugs has developed in some areas, such as central Africa, and it is essential to take this into account when requesting drugs for malaria prophylaxis.

The risks of being in contact with diseases such as hepatitis and typhoid are reduced for people staying for a short time in first-class accommodation. Immunization is especially important for people who are planning long backpacking trips or for those who are intending to work in rural areas of the countries visited. Additional immunizations, such as rabies vaccine and Japanese encephalitis vaccine, may be needed for people visiting very remote areas.

---

immunocompromised

lacking a fully effective immune system. The term is most often used in connection with infections such as AIDS where the virus interferes with the immune response (see immunity).

Other factors that can impair the immune response are pregnancy, diabetes, old age, malnutrition, and extreme stress, making someone susceptible to infections by micro-organisms (such as listeria) that do not affect normal, healthy people. Some people are immunodeficient; others could be on immunosuppressive drugs.

---

immunodeficient

lacking one or more elements of a working immune system. Immune deficiency is the term generally used for patients who are born with such a defect, while those who acquire such a deficiency later in life are referred to as immunocompromised or immunosuppressed.

A serious impairment of the immune system is sometimes known as SCID, or severe combined immune deficiency. At one time children born with this condition would have died in infancy. They can now be kept alive in a germ-free environment, then treated with a bone-marrow transplant from a relative, to replace the missing immune cells. At present, the success rate for this type of treatment is still fairly low. See also gene therapy.

---

immunoglobulin

human globulin protein that can be separated from blood and administered to confer immediate immunity on the recipient. It participates in the immune reaction as the antibody for a specific antigen (disease-causing agent).

Normal immunoglobulin (gamma globulin) is the fraction of the blood serum that, in general, contains the most antibodies, and is obtained from plasma pooled from about a thousand donors. It is given for short-term (two to three months) protection when a person is at risk, mainly from hepatitis A (infectious hepatitis), or when a pregnant woman, not immunized against German measles, is exposed to the rubella virus.

Specific immunoglobulins are injected when a susceptible (nonimmunized) person is at risk of infection from a potentially fatal disease, such as hepatitis B (serum hepatitis), rabies, or tetanus. These immunoglobulins are prepared from blood pooled from donors convalescing from the disease.

---

immunosuppressive

any drug that suppresses the body's normal immune responses to infection or foreign tissue. It is used in the treatment of autoimmune disease (see autoimmunity); as part of chemotherapy for leukaemias, lymphomas, and other cancers; and to help prevent rejection following organ transplantation. Immunosuppressed patients are at greatly increased risk of infection.

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impact printer

computer printer that creates characters by striking an inked ribbon against the paper beneath. Examples of impact printers are dot-matrix printers, daisywheel printers, and most types of line printer.

Impact printers are noisier and slower than nonimpact printers, such as ink-jet and laser printers, but can be used to produce carbon copies.

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impala

African antelope found from Kenya to South Africa in savannahs and open woodland. The body is sandy brown. Males have lyre-shaped horns up to 75 cm/2.5 ft long. Impala grow up to 1.5 m/5 ft long and 90 cm/3 ft tall. They live in herds and spring high in the air when alarmed. (Species *Aepyceros melampus*, family Bovidae.)

impala

(Image © Corel)

An impala at Hwange National Park, Zimbabwe, southern Africa. The park is home to more than a hundred species of game, including almost 6,000 impala.

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impedance

symbol Z

total opposition of a circuit to the passage of alternating electric current. It includes the resistance R and the reactance X (caused by capacitance or inductance); the impedance can then be found using the equation $Z^2 = R^2 + X^2$.

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imperial system

traditional system of units developed in the UK, based largely on the foot, pound, and second (f.p.s.) system.

Imperial and metric conversion factors

Imperial to metric		**Metric to imperial**	
To convert from	**Multiply by**	**To convert from**	**Multiply by**
Length			
inches to millimetres	25.4	millimetres to inches	0.0393701
feet to metres	0.3048	metres to feet	3.28084
yards to metres	0.9144	metres to yards	1.09361
furlongs to kilometres	0.201168	kilometres to furlongs	4.97097
miles to kilometres	1.609344	kilometres to miles	0.621371
Area			
square inches to square centimetres	6.4516	square centimetres to square inches	0.1550
square feet to square metres	0.092903	square metres to square feet	10.7639
square yards to square metres	0.836127	square metres to square yards	1.19599
square miles to square kilometres	2.589988	square kilometres to square miles	0.386102
acres to square metres	4,046.856422	square metres to acres	0.000247
acres to hectares	0.404685	hectares to acres	2.471054
Volume/capacity			
cubic inches to cubic centimetres	16.387064	cubic centimetres to cubic inches	0.061024
cubic feet to cubic metres	0.028317	cubic metres to cubic feet	35.3147
cubic yards to cubic metres	0.764555	cubic metres to cubic yards	1.30795
cubic miles to cubic kilometres	4.1682	cubic kilometres to cubic miles	0.239912
fluid ounces (imperial) to millilitres	28.413063	millilitres to fluid ounces (imperial)	0.035195
fluid ounces (US) to millilitres	29.5735	millilitres to fluid ounces (US)	0.033814
pints (imperial) to litres	0.568261	litres to pints (imperial)	1.759754
pints (US) to litres	0.473176	litres to pints (US)	2.113377
quarts (imperial) to litres	1.136523	litres to quarts (imperial)	0.879877
quarts (US) to litres	0.946353	litres to quarts (US)	1.056688
gallons (imperial) to litres	4.54609	litres to gallons (imperial)	0.219969
gallons (US) to litres	3.785412	litres to gallons (US)	0.364172
Mass/weight			
ounces to grams	28.349523	grams to ounces	0.035274
pounds to kilograms	0.453592	kilograms to pounds	2.20462

stones (14 lb) to kilograms	6.350293	kilograms to stones (14 lb)	0.157473
tons (imperial) to kilograms	1,016.046909	kilograms to tons (imperial)	0.000984
tons (US) to kilograms	907.18474	kilograms to tons (US)	0.001102
tons (imperial) to metric tonnes	1.016047	metric tonnes to tons (imperial)	0.984207
tons (US) to metric tonnes	0.907185	metric tonnes to tons (US)	1.10231
Speed			
miles per hour to kilometres per hour	1.609344	kilometres per hour to miles per hour	0.621371
feet per second to metres per second	0.3048	metres per second to feet per second	3.28084
Force			
pounds-force to newtons	4.44822	newtons to pounds-force	0.224809
kilograms-force to newtons	9.80665	newtons to kilograms-force	0.101972
Pressure			
pounds-force per square inch to kilopascals	6.89476	kilopascals to pounds-force per square inch	0.145038
tons-force per square inch (imperial) to megapascals	15.4443	megapascals to tons-force per square inch (imperial)	0.064779
atmospheres to newtons per square centimetre	10.1325	newtons per square centimetre to atmospheres	0.098692
atmospheres to pounds-force per square inch	14.695942	pounds-force per square inch to atmospheres	0.068948
Energy			
calories to joules	4.1868	joules to calories	0.238846
watt hours to joules	3,600	joules to watt hours	0.000278
Power			
horsepower to kilowatts	0.7457	kilowatts to horsepower	1.34102
Fuel consumption			
miles per gallon (imperial) to kilometres per litre	0.3540	kilometres per litre to miles per gallon (imperial)	2.824859
miles per gallon (US) to kilometres per litre	0.4251	kilometres per litre to miles per gallon (US)	2.3521
gallons per mile (imperial) to litres per kilometre	2.824859	litres per kilometre to gallons per mile (imperial)	0.3540
gallons per mile (US) to litres per kilometre	2.3521	litres per kilometre to gallons per mile (US)	0.4251

Units in the imperial system

Length	
1 foot	= 12 inches
1 yard	= 3 feet
1 rod, pole, perch	= 51/2 yards (= 161/2 feet)
1 chain	= 4 rods (= 22 yards)
1 furlong	= 10 chains (= 220 yards)
1 mile	= 5,280 feet (=1,760 yards/8 furlongs)
Nautical	
1 fathom	= 6 feet
1 cable length	= 100 fathoms (UK)/120 fathoms (USA)
1 nautical mile (UK)[1]	= 6,080 feet
1 nautical mile (international)	= 6,076 feet
Area	
1 square foot	= 144 square inches
1 square yard	= 9 square feet
1 square rod	= 301/4 square yards
1 rood	= 1,210 square yards
1 acre	= 4,840 square yards (= 4 roods)
1 square mile	= 640 acres
Volume	
1 cubic foot	= 1,728 cubic inches
1 cubic yard	= 27 cubic feet
Shipping	
1 register ton	= 100 cubic feet
Capacity	
1 fluid ounce	= 8 fluid drachms
1 gill	= 5 fluid ounces
1 pint	= 4 gills (= 20 fluid ounces)
1 quart	= 2 pints
1 gallon	= 4 quarts (= 8 pints)
1 peck	= 2 gallons
1 bushel	= 4 pecks (= 8 gallons)
1 quarter	= 8 bushels (= 64 gallons)
Weight (avoirdupois)	
1 ounce	= 4371/2 grains
1 ounce	= 16 drams
1 pound	= 16 ounces

1 stone	= 14 pounds
1 quarter	= 2 stones (= 28 pounds)
1 hundredweight	= 4 quarters (= 112 pounds (UK)/100 pounds (USA))
1 ton (UK long ton)	= 20 hundredweights (= 2,240 pounds)
1 ton (US short ton)	= 20 hundredweights (= 2,000 pounds)

[1] Obsolete since 1970 when the international nautical mile was adopted in the UK by the Ministry of Defence.

impetigo

skin infection with either streptococcus or staphylococcus bacteria, characterized by encrusted yellow sores on the skin. Particularly common in infants and small children, it is highly contagious but curable with antibiotics.

Childhood Infections - Impetigo

Go to site

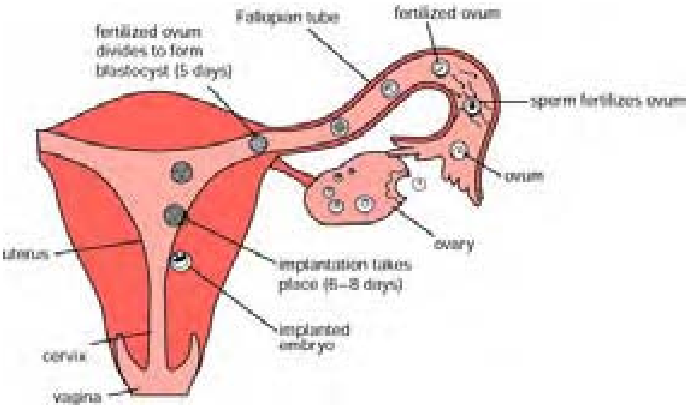
Useful information about impetigo. There is a detailed, illustrated description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

implantation

in mammals, the process by which the developing embryo attaches itself to the wall of the mother's uterus and stimulates the development of the placenta. In humans it occurs 6-8 days after ovulation.

In some species, such as seals and bats, implantation is delayed for several months, during which time the embryo does not grow; thus the interval between mating and birth may be longer than the gestation period.

implantation



(Image © Research Machines plc)

The fertilization of an ovum and its implantation in the uterus lining. The process usually takes 6-8 days from fertilization to implantation.

import file

in computing, a file that can be read by a program even though it was produced as an export file by a different program or make of computer.

impotence

in medicine, a physical inability to perform sexual intercourse (the term is not usually applied to women). Impotent men fail to achieve an erection, and this may be due to illness, the effects of certain drugs, or psychological factors.

The US Food and Drug Administration (FDA) approved the drug Viagra for prescription to people who suffer from impotence in March 1998. Viagra works by dilating the blood vessels of the penis and must be taken about an hour before intercourse. Side effects include headaches and fainting (due to dilation of blood vessels elsewhere), and blue tinted vision.

imprinting

in ethology, the process whereby a young animal learns to recognize both specific individuals (for example, its mother) and its own species.

Imprinting is characteristically an automatic response to specific stimuli at a time when the animal is especially sensitive to those stimuli (the **sensitive period**). Thus, goslings learn to recognize their mother by following the first moving object they see after hatching; as a result, they can easily become imprinted on other species, or even inanimate objects, if these happen to move near them at this time. In chicks, imprinting occurs only between 10 and 20 hours after hatching. In mammals, the mother's attachment to her infant may be a form of imprinting made possible by a sensitive period; this period may be as short as the first hour after giving birth.

impulse

in mechanics, the product of a force and the time over which it acts. An impulse applied to a body causes its momentum to change and is equal to that change in momentum. It is measured in newton seconds (N s).

For example, the impulse J given to a football when it is kicked is given by:

$J = Ft$

where F is the kick force in newtons and t is the time in seconds for which the boot is in contact with the ball.

impulse

in biology, a means of carrying information between different parts of the body. Nerve impulses travel at speed along nerve cells (neurones). A sequence of impulses carries information.

A stimulus from the environment may cause impulses to be sent from the receptor receiving the stimulus, along a sensory neurone, and to the brain or spinal cord. For example, a touch receptor in the skin of a finger will send impulses that tell the brain an object has been touched. Alternatively, information may be carried from the brain or spinal cord to a muscle or gland along a motor neurone. For example, the information may be carried in a sequence of impulses which causes the contraction of a muscle which causes the finger to be moved away from the object.

A simple example of these processes involving all steps from stimulus to muscle response occurs in any reflex arc.

in

abbreviation for inch, a measure of distance.

inbreeding

in genetics, the mating of closely related individuals. It is considered undesirable because it increases the risk that offspring will inherit copies of rare deleterious recessive alleles (genes) from both parents and so suffer from disabilities.

incandescence

emission of light from a substance in consequence of its high temperature. The colour of the emitted light from liquids or solids depends on their temperature, and for solids generally the higher the temperature the whiter the light. Gases may become incandescent through ionizing radiation, as in the glowing vacuum discharge tube.

The oxides of cerium and thorium are highly incandescent and for this reason are used in gas mantles. The light from an electric filament lamp is due to the incandescence of the filament, rendered white-hot when a current passes through it.

inch

imperial unit of linear measure, a twelfth of a foot, equal to 2.54 centimetres.

It was defined in statute by Edward II of England as the length of three barley grains laid end to end.

incisor

sharp tooth at the front of the mammalian mouth. Incisors are used for biting or nibbling, as when a rabbit or a sheep eats grass. Rodents, such as rats and squirrels, have large continually-growing incisors, adapted for gnawing. The elephant tusk is a greatly enlarged incisor. In humans, the incisors are the four teeth at the front centre of each jaw.

inclination

in astronomy, angle between the ecliptic and the plane of the orbit of a planet, asteroid, or comet. In the case of satellites orbiting a planet, it is the angle between the plane of orbit of the satellite and the equator of the planet.

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inclusive fitness

in genetics, the success with which a given variant (or allele) of a gene is passed on to future generations by a particular individual, after additional copies of the allele in the individual's relatives and their offspring have been taken into account. The concept was formulated by W D Hamilton as a way of explaining the evolution of altruism in terms of natural selection. See also fitness and kin selection.

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incontinence

failure or inability to control evacuation of the bladder or bowel (or both in the case of double incontinence). It may arise as a result of injury, childbirth, disease, or senility.

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indeterminacy principle

alternative name for uncertainty principle.

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index

plural indices

(Latin 'sign', 'indicator')

in mathematics, another term for exponent, the number that indicates the power to which a term should be raised.

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index notation

plural indices notation

the index, or power of a number indicates how many times the number is to be multiplied by itself. For example, 4^2 (four squared) = 4 × 4 = 16; 2^3 (two cubed) = 2 × 2 × 2 = 8; and 5^4 (five to the power four) = 5 × 5 × 5 × 5 = 625. In these examples, 4^2, 2^3, and 5^4 are all written in index notation.

There are three important rules for the use of indices:

(i) $a^m \times a^n = a^{m+n}$

(ii) $a^m \div a^n = a^{m-n}$

(iii) $(a^m)^n = a^{mn}$

In all these three rules, m and n are assumed to be positive whole numbers and in rule (ii), a is not zero and $m > n$. For example:

$3^3 \times 3^4 = 3^{3+4} = 3^7$; $5^4 \div 5^2 = 5^{4-2} = 5^2$; $(2^3)^4 = 2^{3\times4} = 2^{12}$

When using fractional indices, $x^{1/n} = \sqrt[n]{x}$, so $x^{1/2} = \sqrt[2]{x}$ and $x^{1/4} = \sqrt[4]{x}$; also $x^{m/n} = (\sqrt[n]{x})^m$ or $\sqrt[n]{(x^m)}$. The same rules apply when using fractional indices as for whole number indices.

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indicator

in chemistry, a compound that changes its structure and colour in response to its environment. The commonest chemical indicators detect changes in pH (for example, litmus and universal indicator) or in the oxidation state of a system (redox indicators).

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indicator species

plant or animal whose presence or absence in an area indicates certain environmental conditions, such as soil type, high levels of pollution, or, in rivers, low levels of dissolved oxygen. Many plants show a preference for either alkaline or acid soil conditions, while certain trees require aluminium, and are found only in soils where it is present. Some lichens are sensitive to sulphur dioxide in the air, and absence of these species indicates atmospheric pollution.

indigo

violet-blue vegetable dye obtained from various tropical plants such as the anil, but now replaced by a synthetic product. It was once a major export crop of India. (Plant genus *Indigofera*, family Leguminosae.)

indium

chemical symbol In

(Latin indicum 'indigo')

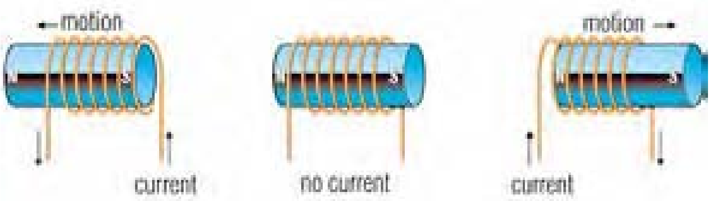
soft, ductile, silver-white, metallic element, atomic number 49, relative atomic mass 114.82. It occurs in nature in some zinc ores, is resistant to abrasion, and is used as a coating on metal parts. It was discovered in 1863 by German metallurgists Ferdinand Reich (1799-1882) and Hieronymus Richter (1824-1898), who named it after the two indigo lines of its spectrum.

induced current

electric current that appears in a closed circuit when there is relative movement of its conductor in a magnetic field. The effect is known as the **dynamo effect**, and is used in all dynamos and generators to produce electricity. See electromagnetic induction.

The magnitude of the induced current depends upon the rate at which the magnetic flux is cut by the conductor, and its direction is given by Fleming's right-hand rule (see Fleming's rules).

induced current



(Image © Research Machines plc)

Movement of a magnet in a coil of wire induces a current.

inductance

in physics, phenomenon in which a changing current in a circuit builds up a magnetic field which induces an electromotive force either in the same circuit and opposing the current (self-inductance) or in another circuit (mutual inductance). The SI unit of inductance is the henry (symbol H).

A component designed to introduce inductance into a circuit is called an inductor (sometimes inductance) and is usually in the form of a coil of wire. The energy stored in the magnetic field of the coil is proportional to its inductance and the current flowing through it. See electromagnetic induction.

induction

in obstetrics, deliberate intervention to initiate labour before it starts naturally; then it usually proceeds normally. Induction involves rupture of the fetal membranes (amniotomy) and the use of the hormone oxytocin to stimulate contractions of the womb. In biology, induction is a term used for various processes, including the production of an enzyme in response to a particular chemical in the cell, and the differentiation of cells in an embryo in response to the presence of neighbouring tissues.

In obstetrics, induction is recommended as a medical necessity where there is risk to the mother or baby in waiting for labour to begin of its own accord.

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induction

in physics, an alteration in the physical properties of a body that is brought about by the influence of a field. See electromagnetic induction and magnetic induction.

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induction coil

type of electrical transformer, similar to an ignition coil, that produces an intermittent high-voltage alternating current from a low-voltage direct current supply.

It has a primary coil consisting of a few turns of thick wire wound around an iron core and subjected to a low voltage (usually from a battery). Wound on top of this is a secondary coil made up of many turns of thin wire. An iron armature and make-and-break mechanism (similar to that in an electric bell) repeatedly interrupts the current to the primary coil, producing a high-voltage, rapidly alternating current in the secondary circuit.

An **induction motor** employs alternating current. It comprises a stationary current-carrying coil (stator) surrounding another coil (rotor), which rotates because of the current induced in it by the magnetic field created by the stator; it thus requires no commutator.

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inductor

device included in an electrical circuit because of its inductance.

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industrial diseases

in medicine, diseases connected with the workplace. Examples include lung diseases that develop following the chronic inhalation of dust, silica, and asbestos; back injuries due to heavy lifting; and dermatitis following the handling of irritant substances.

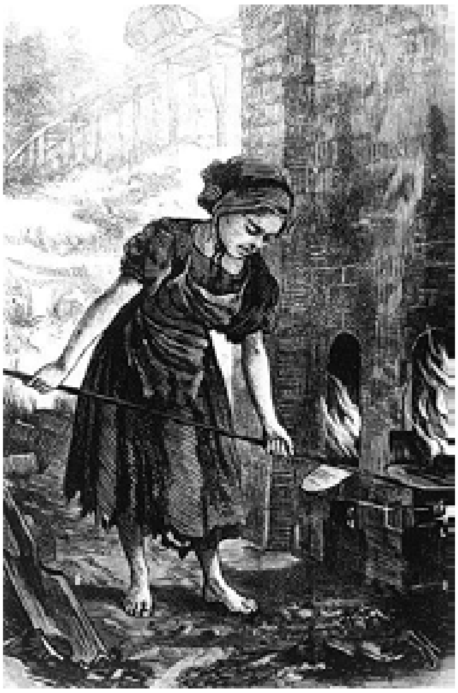
Occupational diseases can also affect office workers. These include repetitive strain injury because of excessive keyboard use and the cluster of symptoms described by workers who occupy 'sick buildings' (see sick building syndrome).

Industrial Revolution

acceleration of technical and economic development that took place in Britain in the second half of the 18th century. The traditional agricultural economy was replaced by one dominated by machinery and manufacturing, made possible through technical advances such as the steam engine. This transferred the balance of political power from the landowner to the industrial capitalist (for example, a factory owner) and created an urban working class. As the first country to have an industrial revolution, Britain for a while was the 'workshop of the world'. The Industrial Revolution, therefore, became the basis of 19th-century British world power and the British Empire. From 1830 to the early 20th century, the Industrial Revolution spread throughout Europe and the USA, and to Japan and the various colonial empires.

The term 'Industrial Revolution' has been criticized on the grounds that it implies a sudden and dramatic change, whereas the process of industrialization was long-drawn-out, erratic, and varied from industry to industry and from region to region.

Industrial Revolution



(Image © Billie Love)

A young girl working in a brickyard in Victorian England, 1871. Factory owners exploited children, sometimes just five or six years of age, to work long, hard hours in poor conditions. In 1878 the first significant legislation against child labour banned the employment of children under 10 years of age and restricted the hours of those aged between 10 and 14.

Industrial Revolution: key events

1701	The seed drill is invented by Jethro Tull. This is a critical point of the agrarian revolution which frees labour from the fields and lowers crop prices.
1709	Abraham Darby introduces coke smelting to his ironworks at Coalbrookdale in Shropshire.
1712	The first workable steam-powered engine is developed by Thomas Newcomen.
1740	Crucible steelmaking is discovered by Benjamin Huntsman, a clockmaker of Doncaster.
1759	The first Canal Act is passed by the British Parliament; this leads to the construction of a national network of inland waterways for transport and industrial supplies. By 1830 there are 6,500 km/4,000 mi of canals in Britain.
c. 1764	The spinning jenny, which greatly accelerates cotton spinning, is invented by James Hargreaves in Blackburn.
1764	Pierre Trosanquet, a French engineer, develops a new method of road building. Similar techniques are used by Thomas Telford in Britain to build modern roads from 1803.
1769	James Watt patents a more reliable and efficient version of the Newcomen engine.
1779	The spinning mule, which makes the production of fine yarns by machine possible, is developed in Bolton by Samuel Crompton.
1785	The power loom marks the start of the mechanized textile industry.
1794	The problem of supplying cotton fast enough for the textile industry is solved by Eli Whitney's cotton gin.
1797	The first true industrial lathe is invented, virtually simultaneously, by Henry Maudslay in England and David Wilkinson in the USA.
1798	Techniques of mass production of interchangeable parts are developed by the arms industry in the USA, led by Eli Whitney.
1802	The first electric battery capable of mass production is designed by William Cruickshank in England.
1811–16	Textile workers known as Luddites stage widespread protests against low pay and unemployment in Nottinghamshire, which involve destroying new machines.
c. 1812	The population of Manchester passes 100,000.
c. 1813	Industrial employment overtakes agricultural employment in England for the first time.
1825	The first regular railway services start between Stockton and Darlington in northeast England.
1826	The Journeymen Steam Engine Fitters, the first substantial industrial trade union, is established in Manchester.
1829	With his steam locomotive *Rocket*, English engineer George Stephenson wins a contest to design locomotives for the new Manchester-Liverpool railway.
1831–52	British industrial production doubles.
1832	Hippolyte Pixii of France produces a prototype electricity generator using magnets.
1832	The Reform Act concerning elections to the British Parliament gives representation to the industrial cities.
1833	The first effective Factory Act is passed in Britain regulating child labour in cotton mills.
c. 1840	The USA becomes the world leader for railroads, with over 5,000 km/3,000 mi laid. By 1860 this will rise to 50,000 km/30,000 mi.
1840s	Cornelius Vanderbilt and John Jacob Astor become the most prominent millionaires of the industrial age.
1842	Cotton-industry workers in England stage a widespread strike.
1846	Repeal of the Corn Law in Britain reduces agricultural prices, thereby helping industry.
1851	Britain celebrates its industrial achievements in the Great Exhibition.

1852–80	British industrial production doubles again.
1858	The 'great stink' of London dramatizes the increasing pollution in the cities.
c. 1860	New York City becomes the first US city with over 1 million inhabitants.

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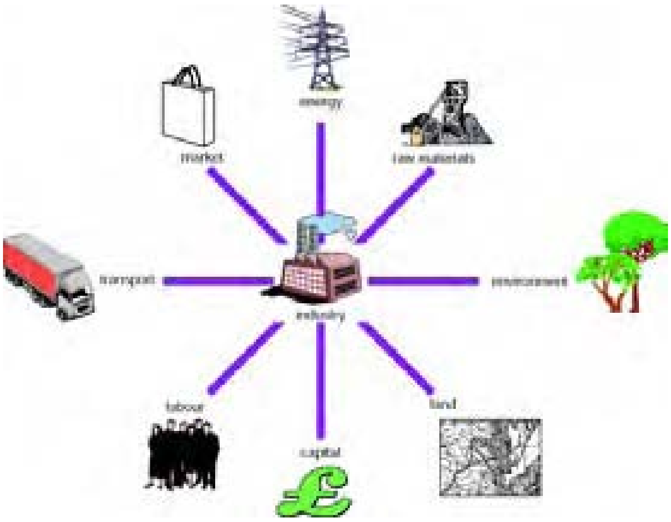
industry

the extraction and conversion of raw materials, the manufacture of goods, and the provision of services. Industry can be either low technology, unspecialized, and labour-intensive, as in countries with a large unskilled labour force, or highly automated, mechanized, and specialized, using advanced technology, as in the industrialized countries. Major recent trends in industrial activity have been the growth of electronic, robotic, and microelectronic technologies, the expansion of the offshore oil industry, and the prominence of Japan and other Pacific-region countries in manufacturing and distributing electronics, computers, and motor vehicles.

industry



(Image © Research Machines plc)

The location of an industry is crucial to its profitability. Proximity to the industry's raw materials – and to the market where the product will be sold – will reduce transportation costs. The local labour force needs to be of the right size and have the requisite level of skills to suit the industry. The availability of the right size and type of land will be a major factor, as will a suitable transport system.

Industry Week

Go to site

Find out what's happening in the world of trade and commerce with this site. The information is easy to find, with sections on latest industry news, articles, and details of conferences and subscriptions. There is also an interactive 'Climb the corporate ladder' game for would-be management.

Indus Valley civilization

one of the four earliest ancient civilizations of the Old World (the other three being the Sumerian civilization of 3500 BC; Egypt 3000 BC; and China 2200 BC), developing in the northwest of the Indian subcontinent *c.* 2500 BC.

Mohenjo-Daro and Harappa were the two main city complexes, but many more existed along the Indus Valley, now in Pakistan. Remains include grid-planned streets with municipal drainage, public and private buildings, baths, temples, and a standardized system of weights and measures – all of which testify to centralized political control. Evidence exists for trade with Sumer and Akkad. The Aryan invasion of *c.* 1500 BC probably led to its downfall.

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inert gas

any gas that can be used in the laboratory to protect sensitive substances from reacting with the oxygen of the air. Pure nitrogen can be used in principle, but a noble gas such as argon is usually preferred.

---

inertia

in physics, the tendency of an object to remain in a state of rest or uniform motion until an external force is applied, as described by Isaac Newton's first law of motion (see Newton's laws of motion).

infant mortality rate

measure of the number of infants dying under one year of age, usually expressed as the number of deaths per 1,000 live births. Improved sanitation, nutrition, and medical care have considerably lowered figures throughout much of the world; for example, in the 18th century in the USA and UK infant mortality was about 500/1,000 compared with under 10/1,000 in 1989. The lowest infant mortality rate is in Japan, at 4.5/1,000 live births. In much of the developing world, however, the infant mortality rate remains high.

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infarct

or infarction

death and scarring of a portion of the tissue in an organ, as a result of congestion or blockage of a blood vessel serving it. Myocardial infarction is the technical term for a heart attack.

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infection

invasion of the body by disease-causing organisms (pathogens, or germs) that become established, multiply, and produce symptoms. Bacteria and viruses cause most diseases, but diseases are also caused by other micro-organisms, protozoans, and other parasites.

Most pathogens enter and leave the body through the digestive or respiratory tracts. Polio, dysentery, and typhoid are examples of diseases contracted by ingestion of contaminated foods or fluids. Organisms present in the saliva or nasal mucus are spread by airborne or droplet infection; fine droplets or dried particles are inhaled by others when the affected individual talks, coughs, or sneezes. Diseases such as measles, mumps, and tuberculosis are passed on in this way.

A less common route of entry is through the skin, either by contamination of an open wound (as in tetanus) or by penetration of the intact skin surface, as in a bite from a malaria-carrying mosquito. Relatively few diseases are transmissible by skin-to-skin contact. Glandular fever and herpes simplex (cold sore) may be passed on by kissing, and the group now officially bracketed as sexually transmitted diseases (STDs) are mostly spread by intimate contact.

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inferiority complex

in psychology, a complex or cluster of repressed fears, described by Alfred Adler, based on physical inferiority. The term is popularly used to describe general feelings of inferiority and the overcompensation that often ensues.

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inferior planet

planet (Mercury or Venus) whose orbit lies within that of the Earth, best observed when at its greatest elongation from the Sun, either at eastern elongation in the evening (setting after the Sun) or at western elongation in the morning (rising before the Sun).

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inferno

in astrophysics, a unit for describing the temperature inside a star. One inferno is 1 billion K, or approximately 1 billion °C.

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infertility

in medicine, inability to reproduce. In women, this may be due to blockage in the Fallopian tubes, failure of ovulation, a deficiency in sex hormones, or general ill health. In men, impotence, an insufficient number of sperm or abnormal sperm may be the cause of infertility. Clinical investigation will reveal the cause of the infertility in about 75% of couples and assisted conception may then be appropriate.

Certain bacterial infections can cause loss of mobility in sperm and therefore lead to infertility in men. Hungarian biologists estimated in 1998 that around 60% of men may have anaerobic bacteria in their reproductive systems often at levels too low to present symptoms, so treatment with broad spectrum antibiotics may help some men with infertility problems.

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infestation

in medicine, occurrence of animal parasites in the intestine, hair, or clothing. Examples include head lice and scabies.

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infinite series

in mathematics, a series of numbers consisting of a denumerably infinite sequence of terms. The sequence n, n^2, n^3, ... gives the series $n + n^2 + n^3 + \ldots$. For example, 1 + 2 + 3 + ... is a divergent infinite arithmetic series, and 8 + 4 + 2 + 1 + 1/2 + ... is a convergent infinite geometric series that has a sum to infinity of 16.

---

infinity

symbol ∞

mathematical quantity that is larger than any fixed assignable quantity. By convention, the result of dividing any number by zero is regarded as infinity.

---

inflammation

defensive reaction of the body tissues to disease or damage, including redness, swelling, and heat. Denoted by the suffix *-itis* (as in appendicitis), it may be acute or chronic, and may be accompanied by the formation of pus. This is an essential part of the healing process.

Inflammation occurs when damaged cells release a substance (histamine) that causes blood vessels to widen and leak into the surrounding tissues. This phenomenon accounts for the redness, swelling, and heat. Pain is due partly to the pressure of swelling and also to irritation of nerve endings. Defensive white blood cells congregate within an area of inflammation to engulf and remove foreign matter and dead tissue.

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inflation

in cosmology, a phase of extremely fast expansion thought to have occurred within 10^{-32} seconds of the Big Bang and in which almost all the matter and energy in the universe was created. The inflationary model based on this concept accounts for the density of the universe being very close to the critical density, the smoothness of the cosmic background radiation, and the homogeneous distribution of matter in the universe. Inflation was proposed by US astrophysicist Alan Guth in the early 1980s.

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inflorescence

in plants, a branch, or system of branches, bearing two or more individual flowers. Inflorescences can be divided into two main types: cymose (or definite) and racemose (or indefinite). In a **cymose inflorescence**, the tip of the main axis produces a single flower and subsequent flowers arise on lower side branches, as in forget-me-not *Myosotis* and chickweed *Stellaria*; the oldest flowers are, therefore, found at the tip. A **racemose inflorescence** has an active growing region at the tip of its main axis, and bears flowers along its length, as in hyacinth *Hyacinthus*; the oldest flowers are found near the base or, in cases where the inflorescence is flattened, towards the outside. The stalk of the inflorescence is called a peduncle; the stalk of each individual flower is called a pedicel.

Types of racemose inflorescence include the **raceme**, a spike of similar, stalked flowers, as seen in lupin *Lupinus*. A **corymb**, seen in candytuft *Iberis amara*, is rounded or flat-topped because the pedicels of the flowers vary in length, the outer pedicels being longer than the inner ones. A **panicle** is a branched inflorescence made up of a number of racemes; such inflorescences are seen in many grasses, for example, the oat *Avena*. The pedicels of an **umbel**, seen in members of the carrot family (Umbelliferae), all arise from the same point on the main axis, like the spokes of an umbrella. Other types of racemose inflorescence include the **catkin**, a pendulous inflorescence, made up of many small stalkless flowers; the **spadix**, in which tiny flowers are borne on a fleshy axis; and the capitulum, in which the axis is flattened or rounded, bears many small flowers, and is surrounded by large petal-like bracts.

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influenza

any of various viral infections primarily affecting the air passages, accompanied by systemic effects such as fever, chills, headache, joint and muscle pains, and lassitude. Treatment is with bed rest and analgesic drugs such as aspirin or paracetamol.

Depending on the virus strain, influenza varies in virulence and duration, and there is always the risk of secondary (bacterial) infection of the lungs (pneumonia). Vaccines are effective against known strains but will not give protection against newly evolving viruses. The 1918-19 influenza pandemic (see epidemic) killed about 20 million people worldwide.

Influenza 1918

Go to site

Companion site to the PBS television programme *The American Experience*, this page provides information about the influenza pandemic of 1918 that killed 20 million people worldwide. It provides a history of the epidemic and accounts of survivors, and broaches the subject of whether it could happen again. You can also download a transcript of the television programme and listen to audio clips.

information technology

IT

collective term for the various technologies involved in processing and transmitting information. They include computing, telecommunications, and microelectronics. The term became popular in the UK after the Government's 'Information Technology Year' in 1972.

Word processing, databases, and spreadsheets are just some of the computing software packages that have revolutionized work in the office environment. Email and the internet have revolutionized business communications, and not only can work be done more quickly than before, but IT has given decision makers the opportunity to consider far more data when making decisions.

Do I.T.

Go to site

Online Information Technology foundation course for students. A good general site for ICT, the site is split into relevant topics, including computer languages, hardware, software, and networks. Additional resources such as downloadable worksheets, multiple choice test questions, and a glossary are also available.

Free Training with Beginners.com

Go to site

Over 200 free online ICT training courses. The site features professionally developed, high-quality pages for a wide range of software packages. They can all be viewed online for free using the latest Adobe Acrobat Reader.

SamLearning - IT

Go to site

Interactive exam revision service for GCSE ICT students. There are multiple choice questions covering key revision points that can be marked online. In addition there are four test exam papers that can be downloaded, completed offline, and then checked against the correct answers provided on the site.

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infrared absorption spectrometry

technique used to determine the mineral or chemical composition of artefacts and organic substances, particularly amber. A sample is bombarded by infrared radiation, which causes the atoms in it to vibrate at frequencies characteristic of the substance present, and absorb energy at those frequencies from the infrared spectrum, thus forming the basis for identification.

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infrared astronomy

study of infrared (IR) radiation produced by relatively cool gas and dust in space, as in the areas around forming stars. Objects at normal temperatures emit infrared radiation, so some critical parts of telescopes designed to observe IR radiation have to be cooled to very low temperatures. IR telescopes are located on high mountains, above most of the IR-absorbing water vapour in the atmosphere, or in space.

In 1983 the US-Dutch-British Infrared Astronomy Satellite (IRAS) surveyed almost the entire sky at infrared wavelengths. It found five new comets, thousands of galaxies undergoing bursts of star formation, and the possibility of planetary systems forming around several dozen stars.

Planets and gas clouds emit their light in the far- and mid-infrared regions of the spectrum. The Infrared Space Observatory (ISO), launched in 1995, observed a broad wavelength (3-200 micrometres) in these regions. It is 10,000 times more sensitive than IRAS, and searches for brown dwarfs (cool masses of gas smaller than the Sun).

The Spitzer Space Telescope, launched in December 2003, is wholly devoted to IR astronomy. It was positioned more than 8 million km/5 million mi from the Earth, trailing our planet in its orbit and far from the Earth's warmth. Among other discoveries it has shown that our galaxy has a pronounced bar across its centre.

The European Space Agency Herschel Space Observatory will be launched in 2007. It will be stationed 1.5 million km/930,000 mi from the Earth. Its 3.5-m/11.5-ft mirror will gather IR radiation from objects much fainter than ever observed before.

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infrared radiation

i.r.

electromagnetic radiation of wavelength between about 700 nanometres and 1 millimetre – that is, between the limit of the red end of the visible spectrum and the shortest microwaves. All bodies above the absolute zero of temperature absorb and radiate infrared radiation. Infrared radiation is used in medical photography and treatment, and in industry, astronomy, and criminology.

The human eye cannot detect infrared, but its effects can be demonstrated. For example, an electric hob operates at high temperatures and only the visible light it gives out can be seen. As it cools down, the visible light is no longer seen. However, the heat (infrared radiation) that continues to be given out can be felt. Infrared absorption spectra are used in chemical analysis, particularly for organic compounds. Objects that radiate infrared radiation can be photographed or made visible in the dark on specially sensitized emulsions. This is important for military purposes and in detecting people buried under rubble. The strong absorption by many substances of infrared radiation is a useful method of applying heat.

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infrared telescope

in astronomy, telescope designed to receive electromagnetic waves in the infrared part of the spectrum. Infrared telescopes are always reflectors (glass lenses are opaque to infrared waves) and are normally of the Cassegrain telescope type.

Since all objects at normal temperatures emit strongly in the infrared, careful design is required to ensure that the weak signals from the sky are not swamped by radiation from the telescope itself. Infrared telescopes are sited at high mountain observatories above the obscuring effects of water vapour in the atmosphere. Modern large telescopes are often designed to work equally well in both visible and infrared light.

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ingestion

process of taking food into the mouth. The method of food capture varies but may involve biting, sucking, or filtering. Many single-celled organisms have a region of their cell wall that acts as a mouth. In these cases surrounding tiny hairs (cilia) sweep food particles together, ready for ingestion.

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inhalant

in medicine, formulation of a drug that is designed to deliver it directly to the lungs. Traditional inhalants involve the dispersion of the drug in hot water and inhalation of the steam. Drugs can be inhaled from aerosols that have been developed for the treatment of asthma.

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inhibition, neural

in biology, the process in which activity in one nerve cell suppresses activity in another. Neural inhibition in networks of nerve cells leading from sensory organs, or to muscles, plays an important role in allowing an animal to make fine sensory discriminations and to exercise fine control over movements.

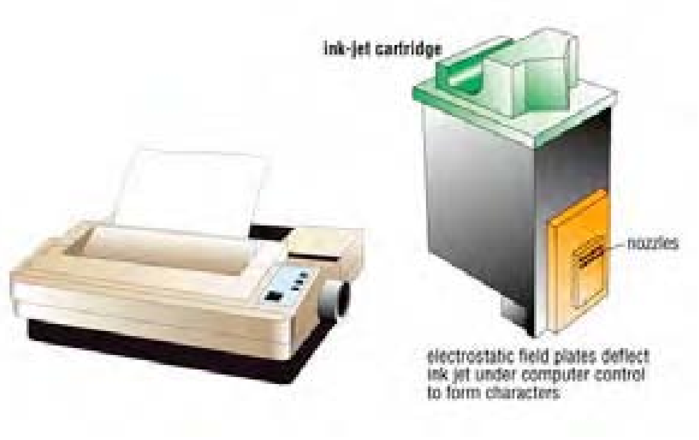
---

ink-jet printer

computer printer that creates characters and graphics by spraying very fine jets of quick-drying ink onto paper. Ink-jet printers range in size from small machines designed to work with microcomputers to very large machines designed for high-volume commercial printing.

Because they produce very high-quality printing and are virtually silent, small ink-jet printers (along with laser printers) have largely replaced impact printers, such as dot-matrix and daisywheel, for use with microcomputers.

ink-jet printer


ink-jet cartridge
nozzles
electrostatic field plates deflect ink jet under computer control to form characters

(Image © Research Machines plc)

High-quality print images are produced by ink-jet printers by squirting ink through a series of nozzles.

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inoculation

injection into the body of dead or weakened disease-carrying organisms or their toxins (vaccine) to produce immunity by inducing a mild form of a disease.

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inorganic chemistry

branch of chemistry dealing with the chemical properties of the elements and their compounds, excluding the more complex covalent compounds of carbon, which are considered in organic chemistry.

The origins of inorganic chemistry lay in observing the characteristics and experimenting with the uses of the substances (compounds and elements) that could be extracted from mineral ores. These could be classified according to their chemical properties: elements could be classified as metals or non-metals; compounds as acids or bases, oxidizing or reducing agents, ionic compounds (such as salts), or covalent compounds (such as gases). The arrangement of elements into groups possessing similar properties led to Mendeleyev's periodic table of the elements, which prompted chemists to predict the properties of undiscovered elements that might occupy gaps in the table. This, in turn, led to the discovery of new elements, including a number of highly radioactive elements that do not occur naturally.

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inorganic compound

chemical compound that does not contain carbon and is not manufactured by living organisms. Water, sodium chloride, and potassium are inorganic compounds because they are widely found outside living cells. However, carbon dioxide is considered inorganic, contains carbon, and is manufactured by organisms during respiration. Carbonates and carbon monoxide are also regarded as inorganic compounds. See organic compound.

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input device

device for entering information into a computer. Input devices include keyboards, joysticks, mice, light pens, touch-sensitive screens, scanners, graphics tablets, speech-recognition devices, and vision systems. The input into an electronic system is usually through switches or sensors. Compare with an output device.

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insanity

in medicine and law, any mental disorder in which the patient cannot be held responsible for their actions. The term is no longer used to refer to psychosis.

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insect

any of a vast group of small invertebrate animals with hard, segmented bodies, three pairs of jointed legs, and, usually, two pairs of wings; they belong among the arthropods and are distributed throughout the world. An insect's body is divided into three segments: head, thorax, and abdomen. On the head is a pair of feelers, or antennae. The legs and wings are attached to the thorax, or middle segment of the body. The abdomen, or end segment of the body, is where food is digested and excreted and where the reproductive organs are located. (Class Insecta.)

Insects vary in size from 0.02 cm/0.007 in to 35 cm/13.5 in in length. The world's smallest insect is believed to be a 'fairy fly' wasp in the family Mymaridae, with a wingspan of 0.2 mm/0.008 in.

Many insects hatch out of their eggs as larvae (an immature stage, usually in the form of a caterpillar, grub, or maggot) and have to pass through further major physical changes (metamorphosis) before reaching adulthood. An insect about to go through metamorphosis hides itself or makes a cocoon in which to hide, then rests while the changes take place; at this stage the insect is called a pupa, or a chrysalis if it is a butterfly or moth. When the changes are complete, the adult insect emerges.

The **classification** of insects is largely based upon characteristics of the mouthparts, wings, and metamorphosis. Insects are divided into two subclasses (one with two divisions) and 29 orders. More than 1 million species are known, and several thousand new ones are discovered each year.

The study of insects is called **entomology**.

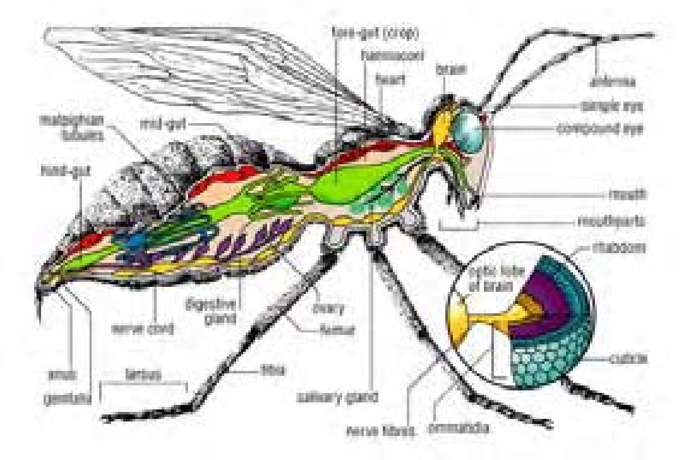
bug: blood consumption

The assassin bug consumes six times its body mass of blood (300 microlitres) in the 15 minutes it takes to feed. The human equivalent would be 256 l/450 pt of beer.

insect

The world's smallest winged insect is smaller than the eye of a house fly. It is the Tanzanian parasitic wasp, which has a wingspan of 0.2 mm/0.008 in.

insect


fore-gut (crop)
haemocoel
heart
brain
antenna
simple eye
compound eye
malpighian tubules
mid-gut
hind-gut
mouth
mouthparts
rhabdom
optic lobe of brain
digestive gland
nerve cord
ovary
femur
cuticle
anus
genitalia
tarsus
tibia
salivary gland
nerve fibres
ommatidia

(Image © Research Machines plc)

Body plan of an insect. The general features of the insect body include a segmented body divided into head, thorax, and abdomen, jointed legs, feelers or antennae, and usually two pairs of wings. Insects often have compound eyes with a large field of vision.

insects

To remember the parts of an insect's leg:

Cockroaches **t**ravel **f**ast **t**owards **t**heir **c**hildren

Coxa, **t**rochanter, **f**emur, **t**ibia, **t**arsus, **c**law

Classification of insects

Order	Number of species	Examples
Class: Insecta		
Subclass: Apterygota (wingless insects)		
Collembola[1]	2,000	springtails
Diplura	660	two-pronged bristletails, campodeids, japygids
Protura	120	minute insects living in soil
Thysanura	600	three-pronged bristletails, silverfish
Subclass: Pterygota (winged or secondarily wingless insects), incorporating two superorders:		
Superorder: Exopterygota (young resemble adults but have externally developing wings)		
Ephemeroptera	2,000	mayflies
Odonata	5,000	dragonflies, damselflies
Grylloblattodea	12	wingless soil-living insects of North America
Plecoptera	3,000	stoneflies
Zoraptera	20	tiny insects living in decaying plants
Isoptera	2,000	termites
Dermaptera	1,500	earwigs
Embioptera	200	web-spinners
Dictyoptera	3,700	cockroaches, praying mantises
Orthoptera	24,000	crickets, grasshoppers, locusts, mantids, roaches
Phasmida	2,500	stick insects, leaf insects
Psocoptera	1,600	booklice, barklice, psocids
Mallophaga	2,500	biting lice, mainly parasitic on birds
Anoplura	250	sucking lice, mainly parasitic on mammals
Hemiptera	39,500	true bugs, including shield- and bedbugs, froghoppers, pond skaters, water boatmen
Homoptera	45,000	aphids, cicadas, hoppers, whiteflies
Thysanoptera	5,000	thrips
Superorder: Endopterygota (young are unlike adults and undergo sudden metamorphosis)		
Neuroptera	4,500	lacewings, alderflies, snakeflies
Mecoptera	450	scorpion flies
Lepidoptera	138,000	butterflies, moths
Trichoptera	7,000	caddisflies
Diptera	150,000	true flies, including bluebottles, mosquitoes, leatherjackets, midges
Siphonaptera	1,750	fleas
Hymenoptera	130,000	bees, wasps, ants, sawflies, chalcids

Coleoptera	250,000	beetles, including weevils, ladybirds, glow-worms, woodworms, chafers

[1] Some zoologists recognize the Collembola taxon as a class rather than an order.

Introduction to Insect Anatomy

Go to site

Wealth of colourful facts and illustrations about the anatomy of the insect world. The page is divided into various sections giving detailed information about the basic similarities and differences between various insects. The page begins with an explanation of the main insect body parts – head, thorax, and abdomen – and is illustrated with a useful diagram of a grasshopper.

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insecticide

any chemical pesticide used to kill insects. Among the most effective insecticides are synthetic organic chemicals such as DDT and dieldrin, which are chlorinated hydrocarbons. These chemicals, however, have proved persistent in the environment and are also poisonous to all animal life, including humans, and are consequently banned in many countries. Other synthetic insecticides include organic phosphorus compounds such as malathion. Insecticides prepared from plants, such as derris and pyrethrum, are safer to use but need to be applied frequently and carefully.

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insectivore

any animal whose diet is made up largely or exclusively of insects. In particular, the name is applied to mammals of the order Insectivora, which includes shrews, hedgehogs, moles, and tenrecs.

According to the Red List of endangered species published by the World Conservation Union for 1996, 36% of insectivore species are threatened with extinction.

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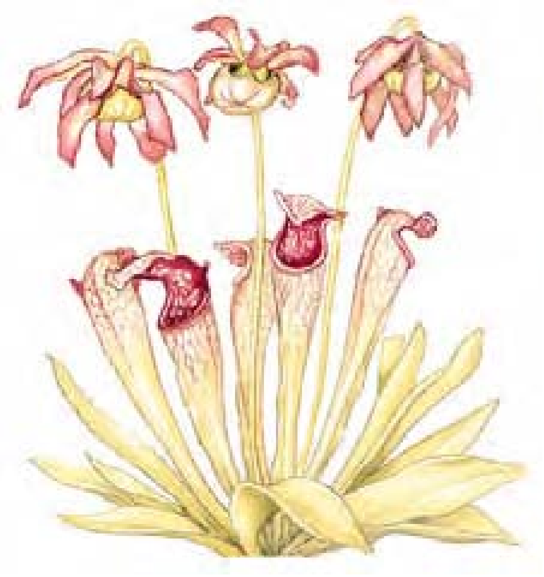
insectivorous plant

plant that can capture and digest live prey (normally insects), to obtain nitrogen compounds that are lacking in its usual marshy habitat. Some are passive traps, for example, the pitcher plants *Nepenthes* and *Sarracenia*. One pitcher-plant species has container-traps holding 1.6 l/3.5 pt of the liquid that 'digests' its food, mostly insects but occasionally even rodents. Others, for example, sundews *Drosera*, butterworts *Pinguicula*, and Venus flytraps *Dionaea muscipula*, have an active trapping mechanism. Insectivorous plants have adapted to grow in poor soil conditions where the number of micro-organisms recycling nitrogen compounds is very much reduced. In these circumstances other plants cannot gain enough nitrates to grow. See also leaf.

Near-carnivorous plants are unable to digest insects, but still trap them on their sticky coated leaves. The insects die and decay naturally, with the nutrients eventually becoming washed into the soil where they finally benefit the plant.

insectivorous plant



(Image © Research Machines plc)

The insect traps of North American pitcher plants are modified leaves. Insects are lured into the pitchers by sweet secretions and then tumble into the fluid at the base, where they drown and are slowly digested.

---

inselberg

or kopje

(German 'island mountain')

prominent steep-sided hill of resistant solid rock, such as granite, rising out of a plain, usually in a tropical area. Its rounded appearance is caused by so-called onion-skin weathering (exfoliation), in which the surface is eroded in successive layers.

The Sugar Loaf in Rio de Janeiro harbour in Brazil, and Ayers Rock in Northern Territory, Australia, are well-known examples.

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insemination, artificial

see artificial insemination.

---

instant messaging

IM

messaging program that uses peer-to-peer networking over the Internet to let users send messages instantly to people on a buddy list. As well as allowing text to be sent, IM enables voice chat, videoconferencing, SMS (short message service) paging, and shared access to documents, files, and pictures.

The first instant messaging program was ICQ, released in November 1996, and bought in June 1998 by America Online, which had already launched its own IM service in May 1997. Yahoo launched a service in 1998 and Microsoft in 1999. These IM services are normally incompatible, but a program called Trillian allows users to chat to friends on all of them concurrently.

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instinct

in ethology, behaviour found in all equivalent members of a given species (for example, all the males, or all the females with young) that is presumed to be genetically determined.

Examples include a male robin's tendency to attack other male robins intruding on its territory and the tendency of many female mammals to care for their offspring. Instincts differ from reflexes in that they involve very much more complex actions, and learning often plays an important part in their development.

---

instrument landing system (ILS)

landing aid for aircraft that uses radio beacons on the ground and instruments on the flight deck. One beacon (localizer) sends out a vertical radio beam along the centre line of the runway. Another beacon (glide slope) transmits a beam in the plane at right angles to the localizer beam at the ideal approach-path angle. The pilot can tell from the instruments how to manoeuvre to attain the correct approach path.

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insulator

any poor conductor of heat, sound, or electricity. Most substances lacking free (mobile) electrons, such as non-metals, are electrical or thermal insulators that resist the flow of electricity or heat through them. Plastics and rubber are good insulators. Usually, devices of glass or porcelain, called insulators, are used for insulating and supporting overhead wires.

The electrons in the outer shells of the atoms of insulators are strongly attracted by the positively-charged nucleus. When external energy is supplied, these electrons are not easily removed from the outer shells of the atoms, which gives these materials their insulating properties.

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insulin

protein hormone, produced by specialized cells in the islets of Langerhans in the pancreas, which regulates the metabolism (rate of activity) of glucose, fats, and proteins. In this way it helps to regulate the concentration of glucose in the blood of mammals. If the blood glucose concentration is too high, the pancreas releases insulin into the blood. This causes blood glucose levels to fall. This is partly due to increased uptake of glucose into most body cells (except liver and brain) but also because the liver converts glucose into insoluble glycogen and stores it instead of making glucose. In diabetes, a person's blood glucose may rise to such a high concentration that it can kill. This may be because the pancreas does not make enough insulin, or because the body cells respond less to the insulin.

Normally, insulin is secreted in response to rising blood sugar levels (after a meal, for example), stimulating the body's cells to store the excess. Failure of this regulatory mechanism in diabetes mellitus requires treatment with insulin injections or capsules taken by mouth. Types vary, from pig and beef insulins to synthetic and bioengineered ones. They may be combined with other substances to make them longer- or shorter-acting. Implanted, battery-powered insulin pumps deliver the hormone at a preset rate, to eliminate the unnatural rises and falls that result from conventional, subcutaneous (under the skin) delivery.

Insulin was discovered by Canadian physician Frederick Banting and Canadian physiologist Charles Best, who pioneered its use in treating diabetes.

History of Insulin

introduction

The term 'diabetes' (from the Ionian Greek 'to pass through'), together with a succinct clinical description of this once-fatal disease, was bequeathed to us by Aretaeus of Cappadocia. In the 2nd century AD he wrote: 'Diabetes is a dreadful affliction, not very frequent among men, being a melting down of the flesh and limbs into urine. The patients never stop making water and the flow is incessant, like the opening of aqueducts. Life is short, unpleasant and painful, thirst unquenchable, drinking excessive...' 'One cannot stop them either from drinking or making water. If for a while they abstain from drinking, their mouths become parched and their bodies dry; the viscera seem scorched up, the patients are affected by nausea, restlessness and a burning thirst, and within a short time they expire.'

a kidney problem?

Although Eastern physicians had noted the sweet taste of the urine in diabetes a thousand years earlier, in Europe the connection between sugar in the urine and diabetes was only made in 1670 by an English physician, Thomas Willis. In 1776, Liverpool physician Matthew Dobson showed that the blood serum of diabetic patients also contains a sweet-tasting substance. He proved that this is sugar and deduced that it is formed in the serum rather than in the kidneys. This was the first indication that diabetes is a systemic disease (pervading the whole body) rather than a specific kidney problem as some people had thought.

mellitus

Soon after, another English physician, John Rollo, was among the first to attach the adjective 'mellitus' (from the Greek and Latin roots for 'honey') to distinguish diabetes from other conditions where there is copious urine output. The next major observation, published in the *London Medical Journal* in 1788, was that diabetes may ensue from damage to the pancreas. In Strasbourg a century later, Oskar Minkowski and Josef von Mering were able to produce experimental diabetes in a dog by removing its pancreas. This firm association of diabetes with pancreatic deficiency prompted researchers to begin looking for the actual substance involved in order to develop a treatment. In 1893, a Frenchman, Edouard Laguesse, suggested that the pancreatic 'islets of Langerhans 'might be implicated. He named these after the distinguished German pathologist, Paul Langerhans, who, at the age of 22, had been the first person to describe them (1869).

introduction of the term insulin

A Belgian physician, Jean de Meyer, gave the name *insuline* (from the Latin insula, meaning island) to the as yet hypothetical blood sugar-lowering substance in 1909. The British physiologist Edward Sharpey Schafer, who argued that the islets must secrete a substance which governs carbohydrate metabolism, used the word 'insulin' for this notional substance in 1916, but the term did not immediately become current: Banting and Best and their collaborators, who discovered insulin in 192l, at first called it 'isletin'.

impact of suffering from diabetes

By the early years of the 20th century then, it was known that diabetes mellitus arises from a lack of this unknown substance. Meanwhile, people developing the disease lived brief, wretched lives. Those who sought treatment were put on starvation diets. The effect of this was to lower blood glucose and produce emaciation; the extension it won to the patient's life was at best a few months.

Banting, Macleod, and Collip

At this time a number of scientists were on the track of insulin and an unknown Canadian doctor, 29-year-old Frederick Grant Banting, also developed an interest in the hormone. He approached J J R Macleod, then Professor of Physiology at the University of Toronto (and an expert on sugar metabolism), for facilities to conduct experiments in a bid to isolate insulin. Macleod made available laboratory space and experimental dogs for Banting's use; he also offered one of his students as an assistant, Charles H Best (who had won the opportunity to work alongside Banting on the toss of a coin). But it was the addition of biochemist James B Collip which would ensure their success.

first trials

The first trial of the team's pancreatic extract was on 14-year-old Leonard Thompson, who was dying of diabetes in Toronto General Hospital, on January 1, 1922. This failed to relieve his symptoms and, moreover, caused an abscess to form at the injection site. However, a further extract, injected on January 23, brought the boy's blood sugar down to normal. In May, when the group reported the outcome of this modest trial to a meeting of the Association of American Physicians in Washington, DC, they received a standing ovation.

availability of insulin

From October 1923, once a commercially viable extraction process had been developed, insulin became widely available throughout North America and Europe. Now, for diabetic patients who would otherwise have been doomed, the issue was no longer one of survival but of quality of life on insulin treatment.

first diabetic organization

Among the people who witnessed the introduction of the life-saving extract into clinical use was a Portuguese doctor, Ernesto Roma, who was on a visit to Boston. Returning to Lisbon in 1926, he set up the world's first diabetic organization, the Portuguese Association for the Protection of Poor Diabetics, which provided insulin free of charge. The British Diabetic Association was founded in 1934 by a doctor whose life had been saved by insulin, Robin Lawrence, and the writer H G Wells, who also had the disease.

Nobel prizewinners

Controversially, only Banting and Macleod received the Nobel prize for the discovery of insulin, in 1923 (in what was one of the Nobel committee's quickest ever recognitions). Despite the acrimony which had arisen within the group, the two men shared the award money with their collaborators. Frederick Banting, whose vision had driven the project, became a world hero and received a knighthood and a generous annuity from the Canadian government. He died in an air crash in Newfoundland in 194l. Leonard Thompson, the original insulin 'guinea pig', survived until 1935 and at least two of the children who had been treated in Toronto in the trial period outlived all four of the men who had worked on the discovery of insulin. One of these, Ted Ryder, lived until 1993, reaching the age of 76.

insulin

To remember the role of insulin:

Remember that **in**sulin gets sugar **in**to cells. Without insulin, a person can have excess sugar in his blood yet die of lack of sugar

Discovery of Insulin

Go to site

Details the discovery of the hormone insulin. This site includes brief descriptions of the lives of the team that made the discovery. An overview of insulin and diabetes is also included here, describing the hormone and the disease, as well as current developments in the continuing research programmes around the world.

Endocrine System

Go to site

A good basic introduction to the human endocrine system which is also suitable for more advanced students. Fundamental concepts are followed by a tour of the endocrine system, complete with tables and diagrams showing the location and function of the glands and the hormones that they produce.

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integer

any whole number. Integers may be positive or negative; 0 is an integer, and is often considered positive. Formally, integers are members of the set

Z = {... -3, -2, -1, 0, 1, 2, 3, ⟩ }

This is the integer set of the number line.

Fractions, such as 1/2 and the decimal 0.35, are known as non-integral numbers ('not integers').

The addition (their sum) and subtraction (their difference) of two integers will always result in an integer. The multiplication of two integers (their product) will always result in an integer; however, the division of integers may result in a non-integer.

A Plus Maths

Go to site

Interactive site to test maths skills. In the 'Game room', play 'Matho', and 'Hidden picture' or 'Concentration' to test multiplication and division skills. Create your own maths word puzzle or check homework is correct with the 'Homework helper'.

BEATCALC: Beat the Calculator

Go to site

Handy site containing quick ways to calculate difficult sums, such as dividing six-digit numbers, and squaring. It includes more than 250 BEATCALC methods, plus a page of calculation practice to test mental arithmetic.

Order and Operations of Integers

Go to site

Excellent site covering the order and operations of integers. Methodical and clear, each of the eight lessons contain problems solved using integers, summaries of the key points, examples, and exercises.

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integral calculus

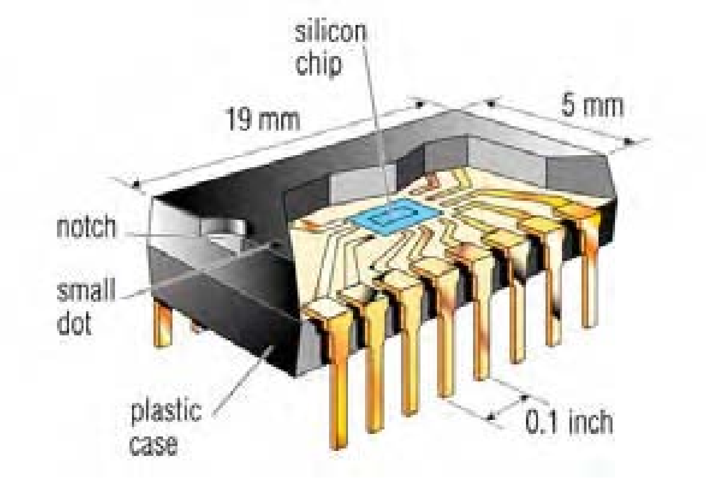
branch of mathematics using the process of integration. It is concerned with finding volumes and areas and summing infinitesimally small quantities.

integrated circuit

IC; or silicon chip

miniaturized electronic circuit produced on a single crystal, or chip, of a semiconducting material - usually silicon. It may contain many millions of components and yet measure only 5 mm/0.2 in square and 1 mm/0.04 in thick. The IC is encapsulated within a plastic or ceramic case, and linked via gold wires to metal pins with which it is connected to a printed circuit board and the other components that make up such electronic devices as computers and calculators.

integrated circuit



(Image © Research Machines plc)

An integrated circuit (IC), or silicon chip.

Integrated Services Digital Network

ISDN

internationally developed telecommunications network for sending signals in digital format that offers faster data transfer rates than traditional analogue telephone circuits. It involves converting the 'local loop' - the link between the user's telephone (or private automatic branch exchange) and the digital telephone exchange - from an analogue system into a digital system, thereby greatly increasing the amount of information that can be carried. The words 'integrated services' refer to the capacity for ISDN to make two connections simultaneously, in any combination of data (voice, video, and fax), over a single line. The data is sent and received in 'digital' format and ISDN is described as a 'network' because it extends from the local telephone exchange to the remote user. The first large-scale use of ISDN began in Japan in 1988.

ISDN has advantages in higher voice quality, better quality faxes, and the possibility of data transfer between computers faster than current modems. Speeds of roughly 128 kilobits per second are theoretically possible using existing telephone lines. With ISDN's **Basic Rate Access**, a multiplexer divides one voice telephone line into three channels: two B bands and a D band. Each B band offers 64 kilobits per second and can carry one voice conversation or 50 simultaneous data calls at 1,200 bits per second. The D band is a data-signalling channel operating at 16 kilobits per second. With **Primary Rate Access**, ISDN provides 30 B channels.

ISDN Tutorial

Go to site

Guide to Integrated Services Digital Network (ISDN), a system that allows data to be transmitted across the world. The guide caters for both beginners and advanced users - it begins with a definition of ISDN and a description of its benefits, and moves on to the various interfaces and protocols. There are also numerous links to related Web sites and resources.

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integration

in mathematics, a method in calculus of determining the solutions of definite or indefinite integrals. An example of a definite integral can be thought of as finding the area under a curve (as represented by an algebraic expression or function) between particular values of the function's variable. In practice, integral calculus provides scientists with a powerful tool for doing calculations that involve a continually varying quantity (such as determining the position at any given instant of a space rocket that is accelerating away from Earth). Its basic principles were discovered in the late 1660s independently by the German philosopher Leibniz and the British scientist Newton.

integument

in seed-producing plants, the protective coat surrounding the ovule. In flowering plants there are two, in gymnosperms only one. A small hole at one end, the micropyle, allows a pollen tube to penetrate through to the egg during fertilization.

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intelligence

in psychology, a general concept that summarizes the abilities of an individual in reasoning and problem solving, particularly in novel situations. These consist of a wide range of verbal and nonverbal skills and therefore some psychologists dispute a unitary concept of intelligence.

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intelligence test

test that attempts to measure innate intellectual ability, rather than acquired ability.

It is now generally believed that a child's ability in an intelligence test can be affected by his or her environment, cultural background, and teaching. There is scepticism about the accuracy of intelligence tests, but they are still widely used as a diagnostic tool when children display learning difficulties. 'Sight and sound' intelligence tests, developed by Christopher Brand in 1981, avoid cultural bias and the pitfalls of improvement by practice. Subjects are shown a series of lines being flashed on a screen at increasing speed, and are asked to identify in each case the shorter of a pair; and when two notes are relayed over headphones, they are asked to identify which is the higher. There is a close correlation between these results and other intelligence test scores.

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intensity

in physics, power (or energy per second) per unit area carried by a form of radiation or wave motion. It is an indication of the concentration of energy present and, if measured at varying distances from the source, of the effect of distance on this. For example, the intensity of light is a measure of its brightness, and may be shown to diminish with distance from its source in accordance with the inverse square law (its intensity is inversely proportional to the square of the distance).

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intensive agriculture

farming system where large quantities of inputs, such as labour or fertilizers, are involved over a small area of land; market gardening is an example. Yields are often much higher than those obtained from extensive agriculture.

intensive agriculture

(Image © Garret Nagle)

Fields near Saga, Japan, used for the intensive cultivation of rice. Almost all low-lying areas in Japan are used for farming, and as there is a shortage of flat land, the high-labour practice of terracing is used to irrigate successive rice fields.

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interactive computing

in computing, a system for processing data in which the operator is in direct communication with the computer, receiving immediate responses to input data. In batch processing, by contrast, the necessary data and instructions are prepared in advance and processed by the computer with little or no intervention from the operator.

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interactive video

IV

computer-mediated system that enables the user to interact with and control information (including text, recorded speech, or moving images) stored on video disk. IV is most commonly used for training purposes, using analogue video disks, but has wider applications with digital video systems such as CD-I (Compact Disc Interactive, from Philips and Sony) which are based on the CD-ROM format derived from audio compact discs.

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intercostal

in biology, the nerves, blood vessels, and muscles that lie between the ribs.

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interface

in computing, the point of contact between two programs or pieces of equipment. The term is most often used for the physical connection between the computer and a peripheral device, which is used to compensate for differences in such operating characteristics as speed, data coding, voltage, and power consumption. For example, a **printer interface** is the cabling and circuitry used to transfer data from a computer to a printer, and to compensate for differences in speed and coding.

Common standard interfaces include the **Centronics interface**, used to connect parallel devices, and the RS-232 interface, USB, and 1394 interfaces are used to connect serial devices. For example, in many microcomputer systems, an RS-232 interface is used to connect the microcomputer to a modem, and a Centronics device is used to connect it to a printer.

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interference

in physics, the phenomenon of two or more wave motions interacting and combining to produce a resultant wave of larger or smaller amplitude (depending on whether the combining waves are in or out of phase with each other).

Interference of white light (multiwavelength) results in coloured bands; for example, the iridescent colours of oil films seen on water or soap bubbles (demonstrated by Newton's rings). Interference of sound waves of similar frequency produces the phenomenon of beats, often used by musicians when tuning an instrument. With monochromatic light (of a single wavelength), interference produces patterns of light and dark bands. This is the basis of holography, for example. Interferometry can also be applied to radio waves, and is a powerful tool in modern optical and radio astronomy.

Professor Bubbles' Official Bubble Home Page

Go to site

Lively information about how to blow the best bubbles, and answers to frequently asked questions about bubbles – such as 'Why are bubbles always round?' and 'Why do bubbles have colour?'

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interferometer

in physics, a device that splits a beam of light into two parts, the parts being recombined after travelling different paths to form an interference pattern of light and dark bands. Interferometers are used in many branches of science and industry where accurate measurements of distances and angles are needed.

In the Michelson interferometer, a light beam is split into two by a semisilvered mirror. The two beams are then reflected off fully silvered mirrors and recombined. The pattern of dark and light bands is sensitive to small alterations in the placing of the mirrors, so the interferometer can detect changes in their position to within one ten-millionth of a metre. Using lasers, compact devices of this kind can be built to measure distances, for example to check the accuracy of machine tools.

In radio astronomy, interferometers consist of separate radio telescopes, each observing the same distant object, such as a galaxy, in the sky. The signal received by each telescope is fed into a computer. Because the telescopes are in different places, the distance travelled by the signal to reach each differs and the overall signal is akin to the interference pattern in the Michelson interferometer. Computer analysis of the overall signal can build up a detailed picture of the source of the radio waves.

In space technology, interferometers are used in radio and radar systems. These include space-vehicle guidance systems, in which the position of the spacecraft is determined by combining the signals received by two precisely spaced antennae mounted on it.

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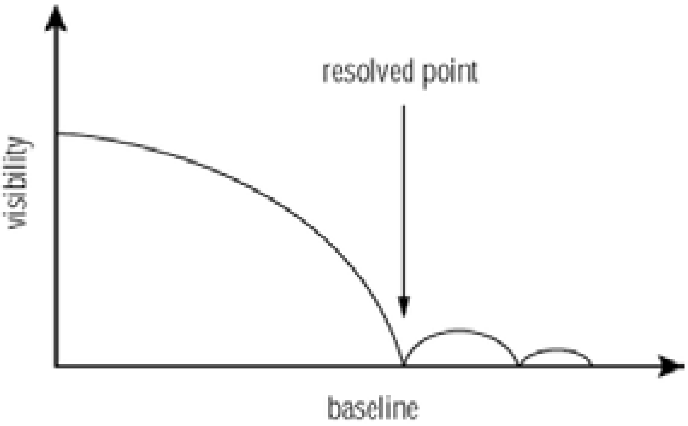
interferometry

in astronomy, any of several techniques using interference between multiple beams to obtain high-resolution images or spectra of astronomical objects. The very long-baseline interferometry system is an example. NASA plans to put radio telescopes, infrared telescopes, and visible-light telescopes in formation in space to produce images of planets around neighbouring stars.

interferometry



(Image © Research Machines plc)

The baseline in astronomical interferometry is the distance between a pair of flat mirrors. The visibility is the difference in brightness between a light fringe (where the light wave crests and troughs come together) and the relative darkness between fringes. If visibility is plotted against the baseline, the maximum visibility occurs at baseline zero and decreases as the baseline increases. At the resolved point visibility is zero.

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interferon

or IFN

naturally occurring cellular protein that makes up part of mammalian defences against viral disease. Three types (alpha, beta, and gamma) are produced by infected cells and enter the bloodstream and uninfected cells, making them immune to virus attack.

Interferon was discovered in 1957 by Scottish virologist Alick Isaacs. Interferons are cytokines, small molecules that carry signals from one cell to another. They can be divided into two main types: **type I** (alpha, beta, tau, and omega) interferons are more effective at bolstering cells' ability to resist infection; **type II** (gamma) interferon is more important to the normal functioning of the immune system. Alpha interferon may be used to treat some cancers; interferon beta 1b has been found useful in the treatment of multiple sclerosis.

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interleukin

in medicine, polypeptide produced by an activated lymphocyte and involved in signalling between cells in the immune system as part of the immune response and in the formation of blood. There are several different interleukins with different activities and some have applications in the treatment of diseases, such as cancer.

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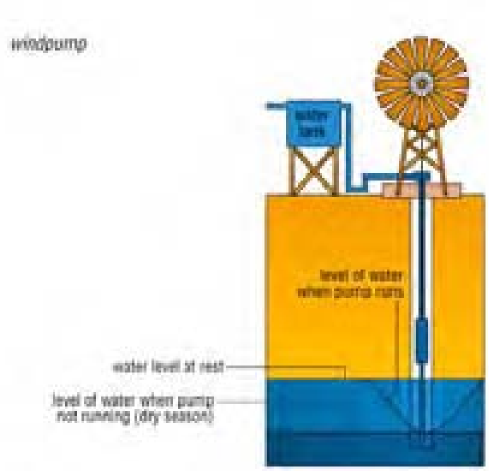
intermediate technology

application of machines and other technologies, based on inventions and designs developed in the developed world, but utilizing materials, assembly, and maintenance methods found in less developed regions.

Intermediate technologies aim to allow developing countries to benefit from new techniques and inventions of the 'First World', without the burdens of costly maintenance and supply of fuels and spare parts that in the developing world would represent an enormous and probably uneconomic overhead. Such technologies are described as being 'appropriate'.

intermediate technology


windpump
water tank
level of water when pump runs
water level at rest
level of water when pump not running (dry season)

(Image © Research Machines plc)

The simple wind pump is an example of intermediate technology if it utilizes local materials and traditional design. In this way, there is no need for complex maintenance and repair, nor expensive spare parts.

intermediate vector boson

member of a group of elementary particles, W^+, W^-, and Z, which mediate the weak nuclear force. This force is responsible for, among other things, beta decay.

intermolecular force

or van der Waals' force

force of attraction between molecules. Intermolecular forces are relatively weak; hence simple molecular compounds are gases, liquids, or low-melting-point solids.

internal-combustion engine

heat engine in which fuel is burned inside the engine, contrasting with an external-combustion engine (such as the steam engine) in which fuel is burned in a separate unit. The diesel engine and petrol engine are both internal-combustion engines. Gas turbines and jet and rocket engines are also considered to be internal-combustion engines because they burn their fuel inside their combustion chambers.

The Internal Combustion Engine

introduction

The steam engine was the first reliable source of power. By the early 1800s, the steam engine had developed to the point where it could propel carriages along the road at reasonable speeds, and undertake long journeys. But the quest was on for a lighter, more powerful engine.

Lebon's contribution

The idea of an internal combustion engine seems to have occurred around 1800 to French inventor Philippe Lebon. He argued that an engine that burnt fuel inside a cylinder would waste less heat and be more efficient than an engine, like the steam engine, which had a separate furnace in which the fuel was burnt. He proposed an engine in which a compressed mixture of gas and air was burnt in a cylinder, the heated gas driving a piston. Unfortunately, Lebon met an untimely end before he could build the engine. He was attacked and stabbed on the Champs Elysées in Paris and died of his wounds. After Lebon, several inventors tried to build internal combustion engines but failed, mainly because of difficulties with ignition of the fuel-air mixture inside the cylinder.

early experimentation

In 1807 Swiss inventor Isaac de Rivas built an engine which he used to move a trolley. However, the engine was too inefficient to be of any use. In 1829, the Reverend William Cecil read a paper at Cambridge University about his experiments, and William Barnet in 1839 also laid claims to the invention. In 1853 Italians Eugenio Barsanti and Felice Mattecci patented a design, but they never built a working engine. It was not until 1860 that an efficient engine was built by Belgian engineer Etienne Lenoir.

the two-stroke engine

Lenoir's engine consisted of a single cylinder with a storage battery for electrical ignition of the fuel-air mixture. It was a two-stroke engine, producing its power in two strokes, or movements, of the piston. It was fuelled by coal gas, as used then for domestic purposes and street lighting. The engine developed a feeble two horsepower. This was just enough power to drive a road vehicle and in 1863 Lenoir took a 10 km/6 mi journey in the first car powered by an internal combustion engine. The trip took 3 h to complete. The real value of the Lenoir engine was for powering small machines, and by 1865 more than 400 were in use in Paris, driving printing presses, lathes and water pumps. However, technical weaknesses, especially low compression, limited the potential of the Lenoir engine.

the four-stroke engine

The next step forward was taken by German engineer Nikolaus Otto. In 1876, Otto patented the four-stroke engine, which produced its power using four movements of the piston. It used only half the fuel consumed by the Lenoir engine and was more powerful. The Otto engine was an immediate success; more than 35,000 were made in a few years. They were large engines and developed over 450 kW/600 hp. Unfortunately for him, Otto's patent was invalidated in 1886 when his competitors dug up an earlier patent taken out by French inventor Alphonse Beau de Rochas in 1862. Rochas had described the four-stroke cycle in his patent. A court battle ensued, lasting two years, after which Otto's patent was declared invalid. This gave the go-ahead to other inventors to use the basic ideas without hindrance. German Karl Benz refined the Lenoir engine and introduced the use of liquid fuel, such as alcohol or petrol. He fitted his engine into a three-wheeled vehicle and in July 1886 at Mannheim the first petrol-driven motor car took to the roads. The trip covered about 1.6 km/1 mi mile at a speed of 14.5 kph/9 mph. Meanwhile, just 100 km/60 mi away in Cannstadt, Gottlieb Daimler was building his four-wheeled petrol-driven motor car. He completed a successful test run in August 1886.

the diesel engine

A different type of internal combustion engine was invented by German engineer Karl Diesel in 1892. In the diesel engine, the compression used in the piston is much higher than in the petrol engine. This compression raises the temperature of air in the cylinder so high that electric ignition is not needed – the fuel ignites spontaneously when injected into the cylinder. This arrangement avoided the problems associated with electrical ignition and produced a simpler engine. Working with such high pressures, Diesel was lucky to escape being killed when the cylinder head blew off one of his prototype engines. Undeterred he carried on to perfect the engine, and in 1899 he set up a factory to manufacture the engines. The factory flourished despite Diesel having little business sense. In 1913, at the height of his success, he vanished from the decks of a steamer crossing from Antwerp to England. His body was never found.

International Atomic Energy Agency

IAEA

agency of the United Nations established in 1957 to advise and assist member countries in the development and peaceful application of nuclear power, and to guard against its misuse. It jointly won the 2005 Nobel Peace Prize with its director general, Mohamed El Baradei, for its work in nuclear non-proliferation and the promotion of the safe use of nuclear energy during peacetime.

It has its headquarters in Vienna, and is responsible for research centres in Austria and Monaco, and the International Centre for Theoretical Physics, Trieste, Italy, established in 1964. It expanded its nuclear safety programmes after the Chernobyl nuclear disaster in 1986 and conducts inspections of nuclear installations in countries suspected of developing nuclear weapons, for example Iraq and North Korea.

World Atom - International Atomic Energy Agency

Go to site

Public information source of the UN agency charged with monitoring and assisting the peaceful uses of nuclear energy. This well organized and easily navigable site is highly informative about the work of the IAEA and the many uses to which nuclear energy is put. The site is regularly updated and has many useful links.

International Date Line

IDL

imaginary line that approximately follows the 180° line of longitude. The date is put forward a day when crossing the line going west, and back a day when going east. The IDL was chosen at the International Meridian Conference in 1884.

International Organization for Standardization

or ISO

(Greek isos 'equal')

global federation of national standards bodies from over 130 countries, with one body for each country. The ISO is a non-governmental organization, established in 1947, and its mission is to promote globally the development of standardization of technical terms, specifications, and units, and other related activities. The work of the ISO results in international agreements, which are published as International Standards. Its headquarters are in Geneva, Switzerland.

Welcome to ISO Online

Go to site

International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from some 100 countries that aims to reduce trade barriers by applying technological standards internationally. This site contains information about the organization's structure, history, purpose and future plans.

International Space Station

ISS

430-tonne orbiting space station being constructed by the USA, Russia, Japan, Canada, Brazil, and the 17 member nations of the European Space Agency. The final cost was expected to be more than US$90 billion. The complete station, orbiting at an altitude of around 378 km/235 mi, will measure 88.4 m/290 ft in length, 108.5 m/356 ft across its solar wings, and 43.6/143 ft in height. It is hoped that teams of up to seven astronauts will live and work for a period of three to six months in an area equivalent to the passenger cabins of two 747 jumbo jets, although a maximum of three crew members per mission is envisaged until at least 2007. The *ISS* was originally intended to be completed by 2004 or 2005; it is now scheduled for completion in 2010, after 45 launches and 160 space walks. It is expected to be used until at least 2016. The first crew arrived at *ISS* in November 2000 under the command of NASA astronaut Bill Shepherd.

In November 1998, the *ISS* 's first component was launched from Baikonur Cosmodrome; this was the Russian control module *Zarya* (Russian 'sunrise'), providing initial propulsion and power. *Unity*, the six-sided US node (intersection point) that will connect the various modules was bolted on to *Zarya* the following month. Russia's *Zvezda* (Russian 'star') module, housing initial living quarters and flight controls, was connected in July 2000. The 'Expedition One' crew of three became the first long-term (four-month) residents on 2 November 2000 and chose their own name for the *ISS*: *Space Station Alpha*. In February 2001, NASA launched the US science laboratory module *Destiny*, the centrepiece of the station. In April, the *ISS* added the robotic Canadarm and was visited by US industrialist Dennis Tito, the first space tourist, who was reported to have paid around US$20 million to take part in the mission. By October 2001, the *ISS* was an estimated US$4.5 billion over budget. By 2004, it had reached a weight of 186,880 kg/412,000 lb with a habitable volume of 425 cu m/15,000 cu ft. Its width was 73 m/240 ft across solar arrays, the length 44.5 m/146 ft, and the height 27.5 m/90 ft. Shuttle flights to the *ISS* were interrupted after the *Columbia* disaster of February 2003. Another flight was made by the shuttle *Columbia* in July/August 2005, but because of safety worries, further flights were postponed for at least a year.

International Space Station

(Image © NASA)

One of the first images of the entire *International Space Station* with its solar panels fully deployed. It was taken from the space shuttle *Endeavour*, which had just completed an hour-long undocking manoeuvre after nearly seven days at the space station.

International Space Station

Go to site

Breaking news, reports, and articles about the *International Space Station*. There are details of expeditions to the space station and the on-board scientific investigations. A sophisticated calculator and graphical simulator can be used to determine the visibility and path of the space station in the night sky from your location.

International Union for the Conservation of Nature

IUCN

alternative name for the World Conservation Union.

Internet

global public computer network that provides the communication infrastructure for applications such as e-mail, the World Wide Web, and FTP. The Internet is not one individual network, but an interconnected system of smaller networks using common protocols to pass packets of information from one computer to another.

Early work on the Internet began in the 1960s at the Advanced Research Projects Agency (ARPA), in the USA. It was based on theories of packet switching, particularly those of Leonard Kleinrock. In 1967 work by Lawrence Roberts, Vinton Cerf, and Bob Kahn led to the publishing of plans for the ARPANET network. They were put into practice in 1969, when the ARPANET was used to connect four university computers. In 1972 the ARPANET had its first public demonstration at the International Computer Communication Conference. In the same year, Ray Tomlinson designed the first application for this new network: e-mail.

The ARPANET had used a protocol called NCP, but it had compatibility problems. Engineers needed to design protocols that could meet the needs of an open-architecture network. Roberts and Cerf then led the team that created the Transmission Control Protocol/Internet Protocol (TCP/IP), which swiftly became the standard Internet protocol. In 1983 the ARPANET switched from using NCP to TCP/IP, and the network was separated into military (MILNET) and non-military systems. By 1985 the Internet was well established among scientific researchers and developers, and was beginning to be used for daily computer communications. By the early 1990s, access had become cheap enough for domestic users to have their own links on home personal computers.

The impact of the Internet on the economy has been huge. In 2002 Internet-related activities accounted for nearly 10 million jobs. By 2006, it was estimated that there were more than 1 billion Internet users worldwide.

Beginners' Guide to Using the Internet

browsing the World Wide Web

The World Wide Web was invented in 1990 by Tim Berners-Lee and Robert Caillau, researchers at CERN (European Laboratory for Particle Physics) in Geneva, Switzerland, as an easy way of accessing information on computers connected to the Internet. The Web only began to be used in a big way, however, three years later, when Mosaic, the first Web **browser** program for Microsoft Windows, was written by Marc Andreessen and Eric Bina of the University of Illinois's National Center for Supercomputing Applications (NCSA). The two main Web browsers in use today are Microsoft Internet Explorer and Netscape Navigator, both based on Mosaic.

By 2000, the Web had over 1.2 billion pages, containing just about anything you might possibly be interested in, and quite a lot that you would think hardly anyone would want to know about! These Web pages are grouped together into **Web sites** (nearly three million of them publicly accessible), each of which has a unique address, known as a **uniform resource locator** or URL. Most URLs begin with the letters 'www' and end in standardized suffixes that identify the type and location of the organization. For example, 'co' indicates a company, and 'uk' that its location is in the United Kingdom.

Organizations large and small have put up sites on the Web. Big corporations usually have several linked sites for different countries in their own languages, often containing video and audio clips. Vast numbers of private individuals have also created their own sites with information on different aspects of their lives, usually illustrated with photographs. Sometimes, an individual's Web site will be there to display examples of their work, but mostly it will be just for fun, perhaps containing information on a particular hobby or interest, or general information on their life. The *Hutchinson Directory of Web Sites* contains information about over 5,000 educational and family-oriented Web sites.

To get to a particular Web site, you just type the address of its opening page (or **home page**) into the address line of the browser and press the return key, and the home page should appear on your screen. You don't have to remember lots of addresses, though, because you can store them as 'favorites' (in Explorer) or 'bookmarks' (in Navigator) and select the addresses from there next time. You can group the addresses together, so that you can easily find them again.

You can normally specify which Web site you want your browser to go to each time you open it to **log on** to the Internet. Your Internet Service Provider (ISP) will probably have selected its own Web site as a default, and sometimes you are not allowed to change that. Usually, the ISP's site will be a **portal** providing a number of services such as news, Web e-mail, shopping, and auctions.

To reach these services, or other linked Web sites, you need only click on a **link**, often an underlined URL on the page you're looking at. In addition, when you move the mouse pointer across the page, you'll sometimes see the pointer change to a hand and a Web address appear at the bottom of the browser screen. Again, you only have to click with your mouse and you'll be taken to the relevant site.

choosing a modem

You can't get onto the Internet without a modem (short for modulator/demodulator), which converts the digital data from your computer into analogue signals for the telephone line, and vice versa. Most home computers these days come with a modem built in. If your PC or Macintosh doesn't already have one, however, you can fairly easily add an internal modem by plugging one into your computer's main board. Adding an internal modem is not a task for the complete novice, however, as some of your computer's existing settings may have to be changed. If you're in doubt, it's best to get a dealer to do it for you.

The modem plugs into the telephone system through a standard telephone socket. Ideally, you'll be using a different telephone line for Internet access from the one you use for voice calls. If you don't want to pay for a second line, you need a small device to route your incoming calls to your phone, computer, or fax machine. Otherwise, you might find that, when someone tries to call you, your phone doesn't ring, although the caller hears a ringing tone on their phone. You might also have problems with your answering machine.

A modem in a new computer should transmit at a speed of 56 Kilobits per second (Kbps) to **V.90** standard, and that's what you should be looking for too. Anything slower than that will work for e-mail, but not for Web browsing, where even 56 Kbps can seem fairly slow. This is what people jokingly refer to as the 'World Wide Wait'.

getting a faster connection

The type of modem mentioned above is for standard **dial-up** access, using an ordinary telephone line. As this is not very fast, you may want to consider a connection using Integrated Services Digital Network (ISDN), which can transmit at a rate of 128 Kbps. Instead of a modem, ISDN uses a **terminal adapter**, which is more expensive, and the charges for ISDN rental and calls are likely to be higher than for a standard phone line.

For much faster **broadband** access, you could try Asymmetric Digital Subscriber Line (ADSL), which can provide a connection rate ranging from 512 Kbps to 6 Megabits per second (Mbps). Speeds of between 1.5 and 2.7 Mbps can be reached using a cable modem but, as with ADSL, the actual speeds obtained depend on the number of other users on the line at the time. ISDN, ADSL, and cable modems provide an 'always on' service, whereas it takes about half a minute to log on via a dial-up service.

It is worth pointing out that even a fast connection will not remove delays that are due to 'traffic jams' on the main Internet **backbone** cable or satellite links, or at the other end of the connection, if a Web site is particularly popular.

choosing an Internet service provider Once you have a modem in your computer, you need the services of an Internet Service Provider (ISP). This is a company that your computer phones up, which connects it to the Internet. If you live in a country like the UK, where even local telephone calls are metered, you can end up paying some fairly hefty phone bills, once you start logging onto the Internet regularly.

What you should be looking for is completely free, unmetered Internet access, with no charges even for your connecting phone calls. The next best thing is paying a flat fee to the ISP and getting free calls. If you don't pay any money to the ISP, but you do pay for phone calls, you still need to be careful how long you spend online. The phone calls are usually the most expensive part of the cost of Internet access.

Some ISPs merely connect you to the Internet, without providing any added value. Others, such as America Online (AOL) and CompuServe (owned by AOL), are better described as Online Service Providers, with a great deal of content (information and services) accessible to their subscribers alone. Before you choose whom to connect through, you need to look carefully at the competing offers available from different ISPs.

downloading software

Among the programs you're likely to want to download onto your computer are the latest versions of the Explorer or Navigator browsers. At the Microsoft or Netscape Web sites, you will find instructions on how to download the software free of charge. How long it will take depends on the speed at which your modem operates and the size of the program you're downloading. With a 56-Kbps modem, even a very large program will only take about half an hour to transfer to your PC or Macintosh.

As well as new browser versions, you can also download free versions of other software, such as RealPlayer, which will play audio and video files. These can be either **streaming** (playing as you download them from the Internet) or files you already have on your PC or Macintosh. Alternatively, you may want to download new games to play on your computer, or perhaps listen to music, in which case you can first download player software such as WinAmp, and then some music files compressed in MP3 format.

There are special programs, such as WS-FTP or CuteFTP, that use File Transfer Protocol (FTP) to enable you to download from (and upload to) Web sites, but you can do basic downloads over the Web using a browser.

searching for information

A big problem with the Internet is that, although there are all those millions of Web sites, it can be very difficult to find the information you want. To make this easier, there are a number of sites that feature what is known as a **search engine**. You enter a description of the information you want to find (for example 'online banking'), and the search engine will list all the Web pages containing these words. The trouble is that you're more likely to find half a million than half a dozen sites. The best search engines, however, such as Google and AltaVista, list the most relevant sites first.

shopping and banking online

Nowadays, there are a great many Web sites where you can buy things. The most popular items are books, compact discs, videos, and airline tickets, because you don't need to see them before you buy. You can also buy all kinds of other goods online, and even do your weekly grocery shopping at various supermarkets on the Web.

The usual method of payment is by credit card, and people often worry about sending their credit card details over the Internet. They're quite right to be concerned, as there have been some high-profile cases of Web sites, including banks, not having in place the tight security they ought to.

You shouldn't send sensitive information such as credit card details over the Internet unless the site you're sending them to allows you to do so over a secure connection. Your information will then be **encrypted** (scrambled) before it is transmitted, so that, even if other people managed to intercept it, they wouldn't be able to read it.

As well as shopping online, you can also bank over the Internet, and in some countries this is very popular. It is certainly very convenient to be able to check your account balance from home or work, and to be able to pay bills online, transfer money from a current to a savings account, or look at your credit card statement. You can also download information from your bank account to a financial software package on your PC, such as Intuit Quicken or Microsoft Money.

sending e-mail

Despite the growth of the World Wide Web, sending e-mail is still the biggest use of the Internet. E-mail programs such as Microsoft Outlook Express, Netscape Messenger, Eudora, and Pegasus allow you to compose messages offline, and queue them up, before sending them to their respective destination e-mail addresses. When you send e-mail to private individuals, it only reaches their computers once these people have linked to their ISP's **mail server** and downloaded any messages waiting for them.

Because of the way messages are sent and retrieved, you need to spend very little time online, making e-mail an extremely cheap (and fast) method of sending information. As well as the actual message itself, you can send any sort of file as an attachment. Don't forget, though, that these files can take a long time to download at the other end.

While an e-mail message cannot contain a virus, an attachment can – although the virus will not have any effect unless the attachment file is opened or run. It is therefore important to treat attachments with great care, not opening any files you're not expecting. Some programs, such as Outlook Express, can be set to open attachments automatically, so make sure that this facility is switched off.

using online discussion groups

Usenet is a collection of over 25,000 online discussion groups, known as **newsgroups**, where you can post messages and get replies from people all over the world. The topics under discussion cover everything you might possibly wish for, and quite a few that you might not! Newsgroups usually contain a list of Frequently Asked Questions (FAQs), to avoid everyone new to the group taking up space and time by asking the same questions about the purpose of the group, and so on.

Newsgroups can be particularly useful if you're having a problem with a piece of software or hardware. Sometimes you won't even need to post a message, if you're lucky. You may find that the problem is quite common, and that there's already a discussion going on. Messages are held online for only a few days, but you can find an index to all previous Usenet postings at the Deja.com Web site (formerly known as Deja News). To access the newsgroups, you need a program such as Microsoft Outlook Express, Netscape Collabra, Agent, or Newswatcher (for the Macintosh).

chatting online

E-mail may be quick, but using it to have a conversation is still like sending letters backwards and forwards. For instant communication, you need Internet Relay Chat, using programs such as mIRC, or Homer (for the Macintosh), where your messages will be read and can be replied to immediately. You can use either public or private channels or **chatrooms**. Public discussion can be about specific topics, but a lot of it is just general talk. After all, this is chat!

You do have to be careful with IRC, however, as people are not necessarily who or what they say they are. So don't go arranging to meet anyone without observing the usual sensible dating precautions: don't give your full name, postal address, telephone number, or e-mail address to someone who is really a total stranger. If you do arrange to meet, do it in a public place, make sure someone knows where you're going, and make sure the person you're meeting is aware of that.

accessing the Internet without a computer

You can also access the Internet via a television set connected to a digital set-top box. Interactive television providers, as well as the Microsoft-owned WebTV, are providing Web access and e-mail, plus home shopping, banking, and travel services in competition with Web sites. Backers of television-based access are hopeful that they will be able to reach the same percentages of the population that terrestrial television does in the Western world (as high as 99% in the USA and Japan).

In addition, WAP-enabled mobile phones can access information on what is billed as the 'mobile Internet'. In reality, services are text-based and slow (9.6 Kbps) at present, and limited to data from a few WAP-enabled Web sites and some new location-based services. The number of services available will no doubt mushroom in the next few years, particularly with the arrival of WAP's Japanese competitor i-Mode (from NTT DoCoMo), and also new third-generation mobile phones with colour screens and small keyboards.

The Electronic Workplace

the changing workplace

Offices and factories have changed out of all recognition in the last few decades as workers have learned that technology makes a good servant but a bad master.

In 1971 the English scientist and novelist C P Snow wrote that 'Technology is a queer thing. It brings you great gifts with one hand, and it stabs you in the back with the other.' Snow knew nothing of the personal computer, the mobile phone, the Web site, or the other technological paraphernalia that have become such inescapable elements of working life in the ensuing three decades. Yet he was articulating one of the fundamental truths about new technology: that its effects are seldom entirely good or bad, and that, for every problem it solves, it has an uncanny knack of creating another.

The photocopier saved many laborious hours in the typing pool; but filing cabinets soon became stuffed with duplicate documents. The personal computer allowed people to create and keep information on disk; but once there, it became inaccessible to anybody else. So the computers were networked, and sharing was encouraged; but the networks proved time-consuming to manage and provided a back door for interlopers like viruses and hackers. Even an innovation so humble as direct dialling to office telephone extensions has helped to generate so much demand for numbers that in some parts of the country telephone numbers have changed three times in less than a decade.

the communications revolution

The two-edged nature of technology is particularly evident in communications. The personal computer is ceasing to be a storage and processing device and is becoming a communications tool, one among millions of tiny roadside halts on the global **Information Superhighway** (another term Snow never heard, since it was coined in 1993 by US vice president Al Gore). The upside is that we can communicate with all those other millions of roadside halts. The downside is that they can also communicate with us.

Examine the average business card and you will see why so many working people feel overwhelmed. It will feature several phone numbers - office, mobile, and possibly home - plus a fax number, e-mail address, Web site, possibly a pager, as well as a bricks-and-mortar address. With so many channels, no wonder we seem to have gone communications-mad. According to a study in 2000 by mail and messaging company Pitney Bowes, the average British worker sends and receives 191 messages every working day, including e-mails, faxes, phone calls, voice-mails, and old-fashioned letters. E-mail accounts for 39 of these, but the number is increasing rapidly - Pitney Bowes found that 42% of workers had only started using e-mail in the previous year.

Small wonder, then, that beleaguered workers retreat behind yet more technology to shield themselves from the deluge, switching their phones to voice-mail and using filtering software to try to weed out time-wasting e-mails. So, realizing that some of their communications may not get through, senders 'make sure' by sending a fax *and* an e-mail, *and* phoning both office and mobile to check that these have arrived.

information overload?

The sheer volume of data available today can easily result in information overload. Study Anglo-Saxon poetry, and you could learn the entire canon by heart, since only about 10,000 lines survive. Study the Internet and you could scarcely read the names of all the new Web sites, since thousands are launched every day. Yet, contrary to popular belief, the Internet contains less than 10% of the world's computerized information, according to a study by IBM, the largest manufacturer of computers in the world. The rest is stored on private systems.

It would be wrong, however, to suggest that the Internet and associated technologies are necessarily bad for knowledge workers. Used thoughtfully, e-mail can be very efficient. It is cheap, less intrusive than the telephone, and facilitates communication between people in different time-zones. With e-mail, Web-based information, and video-conferencing, teams of workers can be spread across the globe and seldom need to meet in person.

The Web has often become the first port of call when seeking information, from product specifications and government legislation to train times and telephone numbers. Specialized **portal** sites gather together information on particular subjects, and most companies of any size have their own **intranets**. Intranets are mini-Internets for use by staff only, giving access to everything from internal phone lists and job vacancies to stock information and customer databases, with online chat-rooms to help remote workers keep in touch, and sometimes separate areas for trading partners.

Having information at their fingertips can be very enabling for staff, especially those who deal with customer enquiries. Instead of an embarrassed 'I'll call you back' or frantic rifling through filing cabinets, the system can give the answer instantly. If the customer wants to do something the operator is not familiar with, the system can provide on-the-spot training or lead the operator through the necessary steps.

the changing nature of work

New technology is not restricted to white-collar staff; manual workers are being encouraged to use it to cut down on paperwork and to keep abreast of company news. Factory-floor machinery is increasingly controlled by personal computers, with which its operators must be familiar, and so-called **process intranets** can collect performance data from the machines and pass it to maintenance engineers and supervisors. Senior managers must also be computer- and Internet-literate, and the days when 'keyboards were only for secretaries' are long gone.

For that matter, many secretaries are long gone, too, replaced by a voice-mail system and a word-processing package on their former boss's personal computer. This is just one of the many changes in the workforce that technology has wrought. Automation in office and factory has led to swathes of redundancies. Some industries have suffered more than once, like the banks that shed back-office staff when they computerized in the 1960s and 1970s, and are now closing branches as more customers bank by telephone and Internet.

Telephone call centres have become the new sweatshops. If run badly, they can be like a battery hen house with a telephone in every cage, where operators are timed when they go to the lavatory and are made to pre-record their greeting message so they can answer more calls. But managerial grades are also suffering. The middle-manager, whose job was to summarize information and pass it up the chain, is disappearing because computers can do this automatically. And now that the office junior can e-mail the chairman directly with a bright idea, the traditional hierarchical structure of business is crumbling.

remote working is increasing

The days of the office itself may be numbered. Instead of wasting a couple of hours a day commuting, more people are **teleworking** (that is, working at home or on the road). The statistics vary, but it is estimated that 30% of the UK workforce could be teleworking by 2006. A much higher proportion of the workforce works away from the office some of the time.

The reasons are partly commercial - spending more time with customers, recruiting people with specialist skills who live far away, etc. - but technology is a major enabler. Portable computers are as powerful as desktop machines, and databases and diaries can be synchronized with the system back at the office so the mobile worker always has up-to-date information. The ubiquitous mobile phone means people are never out of touch, and **unified messaging systems** can forward all phone calls, voice-mails, e-mails, and faxes to a single electronic mailbox, accessible from anywhere.

Like all technology-induced changes, teleworking brings its own challenges. No longer restricted to office premises, workers are no longer restricted to office hours, and the dangers of stress and overwork are increased. Greater use of technology means an increased risk of repetitive strain injuries from keyboards and mice, eye-strain from displays, and the putative radiation risks from mobile phones. Loneliness can be a major problem, and work itself may need to be organized and managed differently - parcelled up into self-contained chunks and assessed by results, not by the number of hours the person sits at their desk.

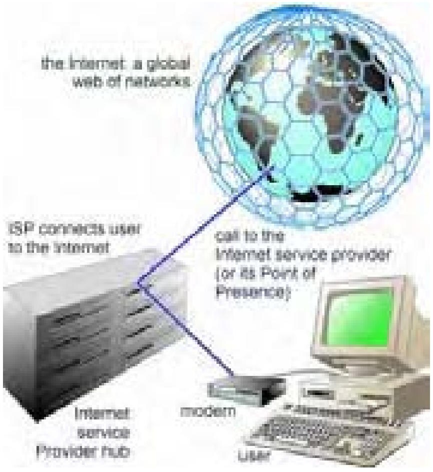
will the office survive?

As more and more staff telework, if only part-time, the nature of the workplace itself will change. Personal desks will be replaced by **hot desking**, with a smaller pool of desks that can be used by anybody when they are in the office, combined with open-plan 'café' areas where teleworkers can come into the office to socialize and exchange information.

Teleworkers are able to stay permanently connected to the Internet or their office networks, thanks to 'always-on' technologies like DSL (digital subscriber link) for fixed phones and GPRS (general packet radio services) for mobiles. Mobile phones and handheld computers will be able to access Web pages and corporate databases using WAP (wireless application protocol) technology, making it possible to look up key data in the middle of a meeting or to check a train timetable from the back of a taxi. And Bluetooth, a short-range wireless communications standard, will allow mobile phones to transmit data automatically to portable computers, or allow teleworkers to connect to data networks or printers as soon as they walk into a room.

As for the Internet, in evolutionary terms it is still in the Stone Age. In another generation, it will have become as essential and as commonplace as the telephone is today.

Internet


the Internet: a global web of networks
ISP connects user to the Internet
call to the Internet service provider (or its Point of Presence)
Internet service Provider hub
modem
user

(Image © Research Machines plc)

The Internet is accessed by users via a modem to the service provider's hub, which handles all connection requests. Once connected, the user can access a whole range of information from many different sources, including the World Wide Web.

Webby Awards

The Webby Awards have been presented annually in May since 1997 by the International Academy of Digital Arts to recognize some of the very best among the Internet's Web sites. The public can also vote for their favourite Web sites. The table below represents a selected list of winners.

2005		
Category	**Webby Award**	**People's Voice Award**
Activism	World Citizen's Guide http://www.worldcitizenguide.com/	IFAW http://www.ifaw.org/
Best Practises	Google http://www.google.com/	Google http://www.google.com/
Broadband	Elevator Moods http://www.elevatormoods.com/	Headline History http://www.headlinehistory.co.uk/
Community	Dogster http://www.dogster.com/	BookCrossing - Read and Release http://www.bookcrossing.com/
Education	Knowing Poe http://knowingpoe.thinkport.org/	Monterey Bay Aquarium http://www.montereybayaquarium.org/
Fashion	Alexander McQueen website http://www.alexandermcqueen.com/	Vogue.com UK http://www.vogue.co.uk/
Finance	Fortune http://www.fortune.com/	PayPal http://www.paypal.com/
Games	Metaphorical.net http://www.metaphorical.net/	Miniclip http://www.miniclip.com/
Government	National Cancer Institute Website http://www.cancer.gov/	Connexions Direct Website http://www.connexions-direct.com/
Health	The Merck Manual http://www.merckhomeedition.com/	HIV STOPS WITH ME http://www.hivstopswithme.org/

Humour	RatherGood http://www.rathergood.com/	Eddie Izzard http://www.eddieizzard.com/
Lifestyle	Epicurious.com http://www.epicurious.com/	Home & Garden Television Online http://www.hgtv.com/
Movie and Film	The Uninvited http://www.postvisual.com/theuninvited/	Garden State Movie Website and Blog http://www.gardenstatemovie.com/
Music	BBC OneMusic http://www.bbc.co.uk/radio1/onemusic/	BBC OneMusic http://www.bbc.co.uk/radio1/onemusic/
News	BBC News http://news.bbc.co.uk/	BBC News http://www.news.bbc.co.uk/
Personal Site	Rtm86.com http://www.rtm86.com/	101 Cookbooks http://www.101cookbooks.com/
Politics	Weapons of Misdirection http://www.weaponsofmisdirection.com/	Mother Jones http://www.motherjones.com/
Radio	Virgin Radio http://www.virginradio.co.uk/	Virgin Radio http://www.virginradio.co.uk/
Religion and Spirituality	Speaking of Faith http://speakingoffaith/publicradio.org/	Spirituality & Health http://www.spiritualityhealth.com/
Science	Hand on CERN http://hands-on-cern.physto.se/	National Geographic Forces of Nature http://wwww.nationalgeographic.com/forcesofnature/
Services	Singingfish.com http://www.singingfish.com/	Singingfish.com http://www.singingfish.com/
Sports	WhatIfSports http://www.whatifsports.com/	ESPN http://www.espn.com/
Travel	Flightmaker http://www.flightmaker.com/	Lonely Planet Online http://www.lonelyplanet.com/
TV	Comedy Central's Indecision 2004 http://www.comedycentral.com/tv_shows/indecision2004/	Comedy Central's Indecision 2004 http://www.comedycentral.com/tv_shows/indecision2004/
Weird	rathergood.com http://www.rathergood.com/	BrandonBird.com http://www.brandonbird.com/
Youth	ChannelOne.com http://www.channelone.com/	ChannelOne.com http://www.channelone.com/

Basic Guide to the Internet

Go to site

Well-organized introduction for beginners to the Internet. The page is divided into sections dealing with the 'Components of the Internet', such as the World Wide Web (WWW), e-mail, telnet, File Transfer Protocol (FTP), and discussion groups. It also contains a number of relevant links to other introductory sites.

CNet

Go to site

Source of up-to-date information about the Internet. This is not so much an introduction to the workings of the Internet, but a rich source of current news and issues facing users. There is also a lot of other computing news here, including new programs and games to download, as well as hints for maximizing the use of some common software packages.

Conducting Research on the Internet

Go to site

Guide that helps users to conduct research on the Internet. The topics covered include joining a discussion group or newsgroup and information on how to 'browse'. There is also a comprehensive section on search engines, plus a section on 'The invisible Web' - databases of information stored on the World Wide Web that are not accessible through search engines.

Digital Librarian

Go to site

A professional librarian from New York has plundered the World Wide Web for her choice of the best sites, then presented them in this immaculately classified Web site. Start from an A-Z list of first-level categories, then click on a subcategory to access a list of sites selected by the author. Easy-to-use and impeccably logical, this mine of information will be an asset to subject-oriented surfers.

Dr Know

Go to site

Well-designed online trivia quiz. Here you can pit your knowledge against other players, and win prizes. A useful feature is the ability to chat with your opponents.

Global Internet Liberty Campaign

Go to site

Umbrella group campaigning to promote freedom of speech and protection of privacy on the Internet. Its members include the Internet Society. GILC concerns about censorship, cryptography, and privacy are set out. There is news of lobbying and campaigning activities and GILC press releases.

How Can I Send a Fax From the Internet?

Go to site

As its title suggests, this is a tutorial for sending faxes from the Internet. It clearly explains the requirements for sending faxes, and points you to Web sites that allow you to fax over the Internet for free.

Internet 101

Go to site

Internet 101 takes you through the basics of what the Internet is and how it works. It introduces the Web, how to surf safely, and the avoidance of viruses. It also covers e-mail, news groups, e-commerce, and more. The text is well presented and concepts are simply explained. Each topic also contains links to other relevant Web sites.

Internet for Beginners

Go to site

Includes links for exploring the World Wide Web, information on creating your own Web pages, time-saving tips and tricks, and a weekly newsletter to help you get the most out of the Internet.

Internet ScamBusters

Go to site

Valuable advice on the perils of Internet scams, misinformation, and hype. This is a free and informative e-zine which might help to save a lot of puzzled newcomers from the small number of people trying to dupe others on the Net.

Parents' Guide to the Internet

Go to site

Useful electronic booklet aiming to bridge the gap between children's and parents' knowledge of the Internet. The site introduces the main features of the 'information superhighway' and argues for the benefits of getting connected to the Internet at home. Several sections provide navigation to assist parents' first steps on the Net and give them tips on safe travelling, and advice on how to encourage children's activities at home and at school.

Promoting Your Web Site

Go to site

Detailed guide that covers the dangers and benefits of Web site promotion. The guide shows you the pitfalls of site-promotion services, and explains clearly how to attract more visitors through links and search engines.

Web Building

Go to site

Guide to HTML, the programming language used to write Web sites. Topics covered here range from the basic - planning your Web site, graphics, and publishing - to more advanced topics, such as JavaScript, commerce over the Internet, and animated graphics. There are also reviews of the other sites, as well as numerous articles relating to Web design.

What Is..

Go to site

Useful site for anyone struggling to interpret computer jargon. The site is a fully searchable Internet dictionary including explanations of terms from 'Accelerated graphics port' to 'Zip drive'. The definitions are cross-referenced and can be searched alphabetically or by topic.

What Is a Browser?

Go to site

Introduces the user to the key points of Web browsers in around 15 minutes. The pages are very clearly and simply laid out, covering the basics of Web browsers and the ways they work.

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interplanetary matter

gas, dust, and charged particles from a variety of sources that occupies the space between the planets. Dust left over from the formation of the Solar System, or from disintegrating comets, orbits the Sun in or near the ecliptic plane and is responsible for scattering sunlight to cause the zodiacal light (mainly the smaller particles) and for meteor showers in the Earth's atmosphere (larger particles). The charged particles mostly originate in the solar wind, but some are cosmic rays from deep space.

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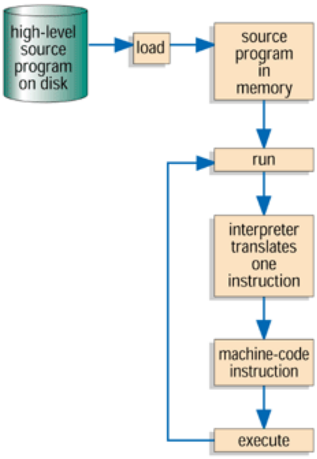
interpreter

in computing, a program that translates and executes a program written in a high-level language. Unlike a compiler, which produces a complete machine-code translation of the high-level program in one operation, an interpreter translates the source program, instruction by instruction, each time that program is run.

interpreter


high-level source program on disk
load
source program in memory
run
interpreter translates one instruction
machine-code instruction
execute

(Image © Research Machines plc)

The sequence of events when running an interpreter on a high-level language program. Instructions are translated one at a time, making the process a slow one; however, interpreted programs do not need to be compiled and may be executed immediately.

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intersex

individual that is intermediate between a normal male and a normal female in its appearance (for example, a genetic male that lacks external genitalia and so resembles a female).

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interstellar cirrus

in astronomy, wispy cloud-like structures discovered in the mid-1980s by the Infrared Astronomy Satellite and believed to be the remains of dust shells blown into space from cool giant or supergiant stars.

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interstitial

in biology, undifferentiated tissue that is interspersed with the characteristic tissue of an organ. It is often formed of fibrous tissue and supports the organ. Interstitial fluid refers to the fluid present in small amounts in the tissues of an organ.

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intertropical convergence zone

ITCZ

area of heavy rainfall found in the tropics and formed as the trade winds converge and rise to form cloud and rain. It moves a few degrees northwards during the northern summer and a few degrees southwards during the southern summer, following the apparent movement of the Sun. The ITCZ is responsible for most of the rain that falls in Africa. The doldrums are also associated with this zone.

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intestine

in vertebrates, the digestive tract from the stomach outlet to the anus. The human **small intestine** is 6 m/20 ft long, 4 cm/1.5 in in diameter, and consists of the duodenum, jejunum, and ileum; the **large intestine** is 1.5 m/5 ft long, 6 cm/2.5 in in diameter, and includes the caecum, colon, and rectum. The contents of the intestine are passed along slowly by peristalsis (waves of involuntary muscular action). The term intestine is also applied to the lower digestive tract of invertebrates.

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intracytoplasmic sperm injection

ICSI

in medicine, the injection of a single sperm into an egg. It is used to treat couples where infertility is caused by low sperm count, or misshapen or immobile sperm. During the period 1992–99 more than 20,000 children had been conceived by ICSI worldwide.

The technique has provoked some controversy following a 1997 study suggesting that it doubles the risk of birth defects and a 1998 study that concluded children conceived through the technique experienced some mild delays in their cognitive development at age one (these delays were no longer apparent by age two).

US researchers proved in 1999 that boys conceived through the technique were likely to inherit their fathers' low sperm counts if they are genetic in origin.

---

intrauterine device

IUD; or coil

a contraceptive device that is inserted into the womb (uterus). It is a tiny plastic object, sometimes containing copper. By causing a mild inflammation of the lining of the uterus it prevents fertilized eggs from becoming implanted.

IUDs are not usually given to women who have not had children. They are generally very reliable, as long as they stay in place, with a success rate of about 98%. Some women experience heavier and more painful periods, and there is a very slight risk of a pelvic infection leading to infertility.

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intravenous

method of delivery of a substance directly into a vein.

---

intravenous nutrition

or parenteral nutrition

in medicine, the provision of all essential nutrients in adequate amounts administered into the vein. It is used in patients with severe illnesses who are unable to take food by mouth, such as those who have undergone major surgery, have serious burns, or are suffering from renal failure. The risk of infection and the occurrence of biochemical abnormalities related to the compositions of the fluids infused are such that intravenous nutrition is reserved only for those who are severely ill.

---

introversion

in psychology, preoccupation with the self, generally coupled with a lack of sociability. The opposite of introversion is extroversion.

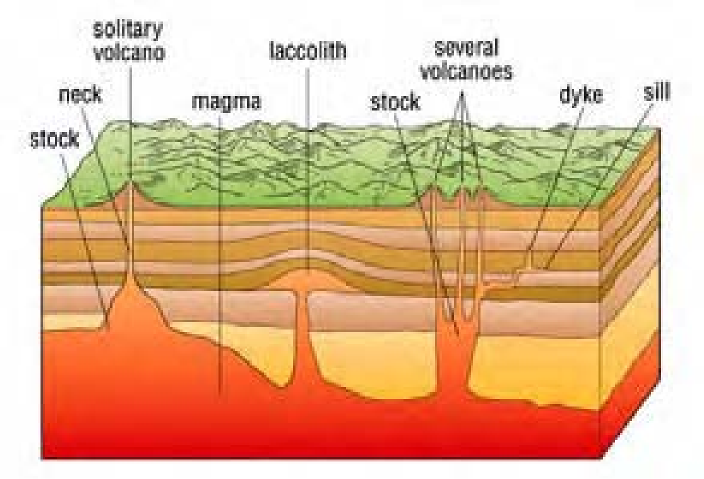
The term was introduced by the Swiss psychiatrist Carl Jung in 1924 in his description of schizophrenia, where he noted that 'interest does not move towards the object but recedes towards the subject'. The term is also used within psychoanalysis to refer to the turning of the instinctual drives towards objects of fantasy rather than the pursuit of real objects. Another term for this sense is fantasy cathexis.

---

intrusion

mass of igneous rock that has formed by 'injection' of molten rock, or magma, into existing cracks beneath the surface of the Earth, as distinct from a volcanic rock mass which has erupted from the surface. Intrusion features include vertical cylindrical structures such as stocks, pipes, and necks; sheet structures such as dykes that cut across the strata and sills that push between them; laccoliths, which are blisters that push up the overlying rock; and batholiths, which represent chambers of solidified magma and contain vast volumes of rock.

intrusion



(Image © Research Machines plc)

Igneous intrusions can be a variety of shapes and sizes. Laccoliths are domed circular shapes, and can be many miles across. Sills are intrusions that flow between rock layers. Pipes or necks connect the underlying magma chamber to surface volcanoes.

---

intrusive rock

or plutonic rock

igneous rock formed beneath the Earth's surface. Magma, or molten rock, cools slowly at these depths to form coarse-grained rocks, such as granite, with large crystals. (Extrusive rocks, which are formed on the surface, are generally fine-grained.) A mass of intrusive rock is called an intrusion.

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intubation

in medicine, operation that involves the introduction of a tube through the mouth and into the larynx to keep the air passage open.

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intuitionism

in mathematics, the theory that propositions can be built up only from intuitive concepts that we all recognize easily, such as unity or plurality. The concept of infinity, of which we have no intuitive experience, is thus not allowed.

---

inverse square law

when the strength or intensity of some quantity depends inversely on the square of the distance from the source or origin of that quantity, it is said to obey an inverse square law. For example, the strength of gravitational attraction of a body is inversely proportional to the square of the distance from that body; the intensity of a sound is inversely proportional to the distance from the source of the sound.

Light and electrostatic force (Coulomb's law), are among the other phenomena that obey the inverse square law.

---

invertebrate

animal without a backbone. The invertebrates form all of the major divisions of the animal kingdom called phyla, with the exception of vertebrates. Invertebrates include the sponges, coelenterates, flatworms, nematodes, annelids, arthropods, molluscs, and echinoderms.

invertebrate

Every year, at least two species of British invertebrates become extinct.

---

in vitro fertilization

IVF

('fertilization in glass')

allowing eggs and sperm to unite in a laboratory to form embryos. The embryos (properly called pre-embryos in their two- to eight-celled state) are stored by cooling to the temperature of liquid air (cryopreservation) until they are implanted into the womb of the otherwise infertile mother (an extension of artificial insemination). The first baby to be produced by this method was Louise Joy Brown, born in 1978 at Oldham General Hospital, Lancashire, UK. In cases where the Fallopian tubes are blocked, fertilization may be carried out by **intra-vaginal culture**, in which egg and sperm are incubated (in a plastic tube) in the mother's vagina, then transferred surgically into the uterus.

in vitro process

biological experiment or technique carried out in a laboratory, outside the body of a living organism (literally 'in glass', for example in a test tube). By contrast, an in vivo process takes place within the body of an organism.

in vivo process

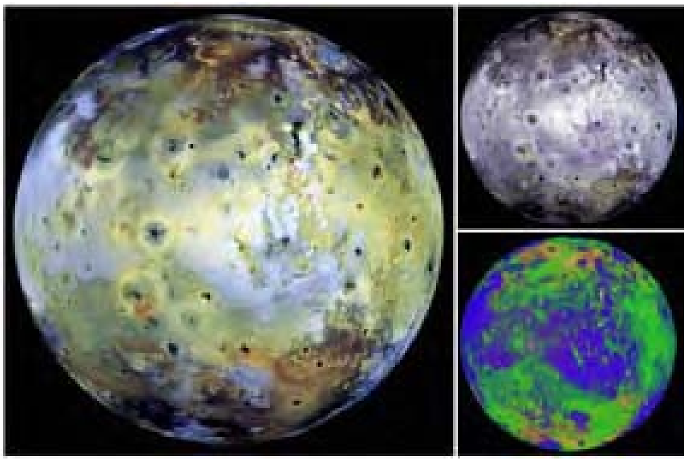
biological experiment or technique carried out within a living organism; by contrast, an in vitro process takes place outside the organism, in an artificial environment such as a laboratory.

Io

in astronomy, third-largest moon of the planet Jupiter, 3,630 km/2,260 mi in diameter, orbiting in 1.77 days at a distance of 422,000 km/262,000 mi. It is the most volcanically active body in the Solar System, covered by hundreds of vents that erupt sulphur (rather than lava), giving Io an orange-coloured surface. Io and Earth are the only two planetary bodies that are undergoing known high-temperature volcanism. Io's internal heating is caused by the continual stressing of its interior as the satellite travels through changing strengths of the gravitational fields of Jupiter and other Jovian satellites.

Data gathered by the spacecraft Galileo in 1996 indicated that Io has a large metallic core. The Galileo probe also detected a 10-megawatt beam of electrons flowing between Jupiter and Io.

Io



(Image © NASA)

The Galileo spacecraft captured these views of Jupiter's moon Io. The large frame to the left is an enhanced colour composite, made to boost natural hues. The composites on the right were made using different combinations of image filters: the upper right in order to study the type of volcanism across Io and the lower right to enhance very subtle colour variations.

iodide

compound formed between iodine and another element in which the iodine is the more electronegative element (see electronegativity, halide).

iodine

chemical symbol I

(Greek iodes 'violet')

greyish-black non-metallic element, atomic number 53, relative atomic mass 126.9044. It is a member of the halogen group (Group 7 of the periodic table). Its crystals sublime, giving off, when heated, a violet vapour with an irritating odour resembling that of chlorine. It occurs only in combination with other elements. Its salts are known as **iodides** and are found in sea water. As a mineral nutrient it is vital to the proper functioning of the thyroid gland, where it occurs in trace amounts as part of the hormone thyroxine. Absence of iodine from the diet leads to goitre. Iodine is used in photography, in medicine as an antiseptic, and in making dyes.

Its radioactive isotope iodine-131 (half-life of eight days) is a dangerous fission product from nuclear explosions and from the nuclear reactors in power plants, since, if ingested, it can be taken up by the thyroid and damage it. It was discovered in 1811 by French chemist B Courtois (1777-1838).

iodoform

or triiodomethane; CHI_3

antiseptic that crystallizes into yellow hexagonal plates. It is soluble in ether, alcohol, and chloroform, but not in water.

ion

atom, or group of atoms, that is either positively charged (cation) or negatively charged (anion), as a result of the loss or gain of electrons during chemical reactions or exposure to certain forms of radiation. In solution or in the molten state, ionic compounds such as salts, acids, alkalis, and metal oxides conduct electricity. These compounds are known as electrolytes.

Ions are produced during electrolysis, for example the salt zinc chloride ($ZnCl_2$) dissociates into the positively-charged Zn^{2+} and negatively-charged Cl^- when electrolysed.

ion engine

or ion drive or ion thruster

rocket engine that uses ions (charged particles) rather than hot gas for propulsion. Ion engines have been successfully tested in space, where they will eventually be used for gradual rather than sudden velocity changes. In an ion engine, atoms of mercury, for example, are ionized (given an electric charge by an electric field) and then accelerated to high speed by a more powerful electric field.

ion exchange

process whereby an ion in one compound is replaced by a different ion, of the same charge, from another compound. Ion exchange is used in commercial water softeners to exchange the dissolved ions responsible for the water's hardness with others that do not have this effect. For example, when hard water is passed over an ion-exchange resin, the dissolved calcium and magnesium ions are replaced by either sodium or hydrogen ions, so the hardness is removed. The addition of washing soda to hard water is also an example of ion exchange:

$Na_2CO_{3(aq)} + CaSO_{4(aq)} \rightarrow CaCO_{3(s)} + Na_2SO_{4(aq)}$

Ion exchange is the basis of a type of chromatography in which the components of a mixture of ions in solution are separated according to the ease with which they will replace the ions on the polymer matrix through which they flow. The exchange of positively charged ions is called cation exchange; that of negatively charged ions is called anion exchange.

ion half equation

equation that describes the reactions occurring at the electrodes of a chemical cell or in electrolysis. It indicates which ion is losing electrons (oxidation) or gaining electrons (reduction).

Examples are given from the electrolysis of dilute hydrochloric acid (HCl):

$2Cl^- - 2e^- \rightarrow Cl_2$ (positive electrode)

$2H^+ + 2e^- \rightarrow H_2$ (negative electrode)

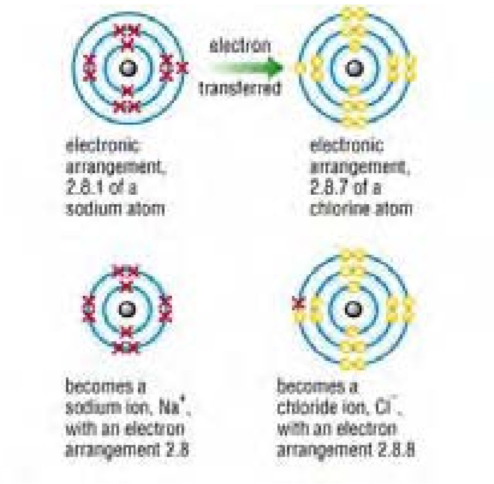
ionic bond

or electrovalent bond

bond produced when atoms of one element donate electrons to atoms of another element, forming positively and negatively charged ions respectively. The attraction between the oppositely charged ions constitutes the bond. Sodium chloride (Na^+Cl^-) is a typical ionic compound.

Each ion has the electronic structure of a noble gas (rare gas; see noble gas structure). The maximum number of electrons that can be gained is usually two.

ionic bond


electron
transferred
electronic arrangement, 2.8.1 of a sodium atom
electronic arrangement, 2.8.7 of a chlorine atom
becomes a sodium ion, Na^+, with an electron arrangement 2.8
becomes a chloride ion, Cl^-, with an electron arrangement 2.8.8

(Image © Research Machines plc)

The formation of an ionic bond between a sodium atom and a chlorine atom to form a molecule of sodium chloride. The sodium atom transfers an electron from its outer electron shell (becoming the positive ion Na^+) to the chlorine atom (which becomes the negative chloride ion Cl^-). The opposite charges mean that the ions are strongly attracted to each other. The formation of the bond means that each atom becomes more stable, having a full quota of electrons in its outer shell.

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ionic compound

substance composed of oppositely charged ions. All salts, most bases, and some acids are examples of ionic compounds. They possess the following general properties: they are crystalline solids with a high melting point; are soluble in water and insoluble in organic solvents; and always conduct electricity when molten or in aqueous solution. A typical ionic compound is sodium chloride (Na^+Cl^-).

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ionic equation

equation showing only those ions in a chemical reaction that actually undergo a change, either by combining together to form an insoluble salt or by combining together to form one or more molecular compounds. Examples are the precipitation of insoluble barium sulphate when barium and sulphate ions are combined in solution, and the production of ammonia and water from ammonium hydroxide.

$Ba^{2+}{}_{(aq)} + SO_4{}^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$

$NH_4{}^{+}{}_{(aq)} + OH^-{}_{(aq)} \rightarrow NH_{3(g)} + H_2O_{(l)}$

The other ions in the mixtures do not take part and are called spectator ions.

---

ionization

process of ion formation. It can be achieved in two ways. The first way is by the loss or gain of electrons by atoms to form positive or negative ions.

$Na - e^- \rightarrow Na^+$

$1/2Cl_2 + e^- \rightarrow Cl^-$

In the second mechanism, ions are formed when a covalent bond breaks, as when hydrogen chloride gas is dissolved in water. One portion of the molecule retains both electrons, forming a negative ion, and the other portion becomes positively charged. This bond-fission process is sometimes called dissociation.

$HCl_{(g)} + aq \leftrightarrow H^+{}_{(aq)} + Cl^-{}_{(aq)}$

---

ionization chamber

device for measuring ionizing radiation. The radiation ionizes the gas in the chamber and the ions formed are collected and measured as an electric charge. Ionization chambers are used for determining the intensity of X-rays or the disintegration rate of radioactive materials.

ionization potential

measure of the energy required to remove an electron from an atom. Elements with a low ionization potential readily lose electrons to form cations.

---

ionization therapy

enhancement of the atmosphere of an environment by instrumentally boosting the negative ion content of the air.

Fumes, dust, cigarette smoke, and central heating cause negative ion deficiency, which particularly affects sufferers from respiratory disorders such as bronchitis, asthma, and sinusitis. Symptoms are alleviated by the use of ionizers in the home or workplace. In severe cases, ionization therapy is used as an adjunct to conventional treatment.

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ionizing radiation

radiation that removes electrons from atoms during its passage, thereby leaving ions in its path. Alpha and beta particles are far more ionizing in their effect than are neutrons or gamma radiation.

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ionosphere

ionized layer of Earth's outer atmosphere (60-1,000 km/38-620 mi) that contains sufficient free electrons to modify the way in which radio waves are propagated, for instance by reflecting them back to Earth. The ionosphere is thought to be produced by absorption of the Sun's ultraviolet radiation. The British Antarctic Survey estimates that the ionosphere is decreasing at a rate of 1 km/0.6 mi every five years, based on an analysis of data from 1960 to 1998. Global warming is the probable cause.

---

ion plating

method of applying corrosion-resistant metal coatings. The article is placed in argon gas, together with some coating metal, which vaporizes on heating and becomes ionized (acquires charged atoms) as it diffuses through the gas to form the coating. It has important applications in the aerospace industry.

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ipecacuanha

or ipecac

South American plant belonging to the madder family, the dried roots of which are used in medicine as an emetic (to cause vomiting) and to treat amoebic dysentery (infection of the intestine with amoebae). (*Psychotria ipecacuanha*, family Rubiaceae.)

---

iPod

handheld MP3 music player. Launched by Apple Computer in October 2001, it was initially capable of storing 1,000 music tracks on its built-in hard disk drive; by 2004 a 40 gigabyte version was available capable of storing up to 10,000 tracks. The iPod was an instant success, and from 2004 it accounted for 90% of the hard-drive MP3 player market and 70% of the overall MP3 player market. Apple launched a number of variant models, including the Mini in 2004 and the Nano and Shuffle in 2005. Apple claim to have sold 50 million iPods up to mid-2006.

The iPod's distinctive design was developed by English designer Jonathan Ive, Apple's vice-president of industrial design (whose team was also responsible for designing the iMac, iBook, and PowerBook), who won the first UK Designer of the Year award in 2003.

IR

or ir

in physics, abbreviation for **infrared**.

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iridium

chemical symbol Ir

(Latin iridis 'rainbow')

hard, brittle, silver-white, metallic element, atomic number 77, relative atomic mass 192.2. It is resistant to tarnish and corrosion. Together with the elements ruthenium, rhodium, palladium, osmium, and platinum, it forms the group of platinum metals which have similar physical and chemical properties. It occurs in platinum ores and as a free metal (native metal) with osmium in osmiridium, a natural alloy that includes traces of the other platinum metals.

It is alloyed with platinum for jewellery and used for watch bearings and in scientific instruments. It was named in 1804 by English chemist Smithson Tennant (1761-1815) for the iridescence of its salts in solution.

iridium anomaly

unusually high concentrations of the element iridium found worldwide in sediments that were deposited at the Cretaceous-Tertiary boundary (K-T boundary) 65 million years ago. Since iridium is more abundant in extraterrestrial material, its presence is thought to be evidence for a large meteorite impact that may have caused the extinction of the dinosaurs and other life at the end of the Cretaceous.

iridology

diagnostic technique based on correspondences between specific areas of the iris and bodily functions and organs.

It was discovered in the 19th century independently by a Hungarian and a Swedish physician, and later refined and developed in the USA by Bernard Jensen. Iridology is of proven effectiveness in monitoring general well-being and indicating the presence of organic disorders, but cannot be as specific about the nature and extent of these as orthodox diagnostic techniques.

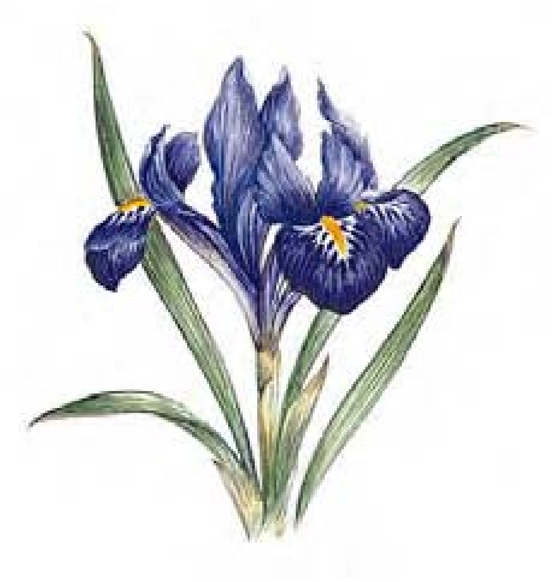
iris

in anatomy, the coloured muscular diaphragm that controls the size of the pupil in the vertebrate eye. It contains radial muscle that increases the pupil diameter and circular muscle that constricts the pupil diameter. Both types of muscle respond involuntarily to light intensity.

iris

in botany, any of a group of perennial northern temperate flowering plants belonging to the iris family. The leaves are usually sword-shaped; the purple, white, or yellow flowers have three upright inner petals and three outward- and downward-curving sepals. The wild yellow iris is called a flag. (Genus *Iris*, family Iridaceae.)

iris



(Image © Research Machines plc)

The iris is a plant of northern temperate regions. Most have flattened leaves with large and showy flowers with an equal number of upright and pendulous petals, called standards and falls.

iron

chemical symbol Fe

(Germanic eis 'strong')

hard, malleable and ductile, silver-grey, metallic element, atomic number 26, relative atomic mass 55.847. It chemical symbol comes from the Latin *ferrum*. It is the fourth most abundant element in the Earth's crust. Iron occurs in concentrated deposits as the ores haematite (Fe_2O_3), spathic ore ($FeCO_3$), and magnetite (Fe_3O_4). It sometimes occurs as a free metal, occasionally as fragments of iron or iron-nickel meteorites.

Iron is extracted from iron ore in a blast furnace. The chemical reactions of iron with oxygen, water, acids, and other substances, can be explained by its position in the middle of the reactivity series of metals. Iron is the most useful of all metals; it is strongly magnetic and is the basis for steel (an alloy with carbon and other elements) and cast iron. Steel is used for buildings, bridges, ships, car bodies, and tools. Stainless steel is used for car parts, kitchen sinks, and cutlery. In electrical equipment iron is used in permanent magnets and electromagnets, and forms the cores of transformers and magnetic amplifiers. The corrosion of iron is called rusting and is an example of an oxidation reaction. In the human body, iron is an essential component of haemoglobin, the molecule in red blood cells that transports oxygen to all parts of the body. A deficiency in the diet causes a form of anaemia.

Iron Age

developmental stage of human technology when weapons and tools were made from iron. Preceded by the Stone and Bronze ages, it is the last technological stage in the Three Age System framework for prehistory. Iron was produced in Thailand *c.* 1600 BC, but was considered inferior in strength to bronze until *c.* 1000 BC, when metallurgical techniques improved, and the alloy steel was produced by adding carbon during the smelting process.

Ironworking was introduced into different regions over a wide time span, appearing in Thailand *c.* 1600 BC, Asia Minor *c.* 1200 BC, central Europe *c.* 900 BC, China *c.* 600 BC, and in remoter areas during exploration and colonization by the Old World. It reached the Fiji Islands with an expedition in the late 19th century. Iron Age cultures include Hallstatt (named after a site in Austria) and La Tène (named after a site in Switzerland).

---

iron ore

any mineral from which iron is extracted. The chief iron ores are magnetite, a black oxide; **haematite**, or kidney ore, a reddish oxide; limonite, brown, impure oxyhydroxides of iron; and siderite, a brownish carbonate.

Iron ores are found in a number of different forms, including distinct layers in igneous intrusions, as components of contact metamorphic rocks, and as sedimentary beds. Much of the world's iron is extracted in Russia, Kazakhstan, and the Ukraine. Other important producers are the USA, Australia, France, Brazil, and Canada; over 40 countries produce significant quantities of ore.

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iron pyrites

or pyrite; FeS_2

common iron ore. Brassy yellow, and occurring in cubic crystals, it is often called 'fool's gold', since only those who have never seen gold would mistake it.

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irradiation

subjecting anything to radiation, including cancer tumours (when it is a type of radiotherapy). See also food irradiation.

---

irrational number

number that cannot be expressed as an exact fraction. Irrational numbers include some square roots (for example, $\sqrt{2}$, $\sqrt{3}$, and $\sqrt{5}$ are irrational); numbers such as π (for circles), which is approximately equal to the decimal 3.14159; and e (the base of natural logarithms, approximately 2.71828). If an irrational number is expressed as a decimal it would go on for ever without repeating. An irrational number multiplied by itself gives a rational number.

Maths Lessons

Go to site

General GCSE maths site. To get to the section on irrational numbers, click on 'number' on the left-hand menu, then 'irrationals' on the top menu. The page offers two resources, 'Lesson' and 'Test', covering all aspects of the topic. In 'Lesson', navigate by clicking on the page number from the menu on the left-hand side. This is a helpful site explaining the difference between irrational and rational numbers through decimals.

---

irregular galaxy

class of galaxy with little structure, which does not conform to any of the standard shapes in the Hubble classification. The two satellite galaxies of the Milky Way, the Magellanic Clouds, are both irregulars. Some galaxies previously classified as irregulars are now known to be normal galaxies distorted by tidal effects or undergoing bursts of star formation (see starburst galaxy).

---

irrigation

artificial water supply for dry agricultural areas by means of dams and channels. Drawbacks are that it tends to concentrate salts at the surface, ultimately causing soil infertility, and that rich river silt is retained at dams, to the impoverishment of the land and fisheries below them.

Irrigation has been practised for thousands of years, in Eurasia as well as the Americas. An example is the channelling of the annual Nile flood in Egypt, which has been done from earliest times to its present control by the Aswan High Dam.

ISBN

abbreviation for international standard book number

code number used for ordering or classifying book titles. Every book printed now has a number on its back cover or jacket, preceded by the letters ISBN. It is a code to the country of origin and the publisher. The number is unique to the book, and will identify it anywhere in the world.

The final digit in each ISBN number is a check digit, which can be used by a computer program to validate the number each time it is input (see validation).

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ischaemic heart disease

IHD

disorder caused by reduced perfusion of the coronary arteries due to atherosclerosis. It is the commonest cause of death in the Western world, leading to more than a million deaths each year in the USA and about 160,000 in the UK. See also coronary artery disease.

Early symptoms of IHD include angina or palpitations, but sometimes a heart attack is the first indication that a person is affected.

ischaemic heart disease

(Image © Research Machines plc)

A patient with ischaemic heart disease is having the blocked coronary artery bypassed using a section of vein taken from her leg. During the procedure, the circulation of oxygenated blood to the body and brain has been taken over by a heart-lung machine.

ISDN

abbreviation for Integrated Services Digital Network, a telecommunications system.

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island

area of land surrounded entirely by water. Australia is classed as a continent rather than an island, because of its size.

Islands can be formed in many ways.
Continental islands were once part of the mainland, but became isolated (by tectonic movement, erosion, or a rise in sea level, for example).
Volcanic islands, such as Japan, were formed by the explosion of underwater volcanoes.
Coral islands consist mainly of coral, built up over many years. An **atoll** is a circular coral reef surrounding a lagoon; atolls were formed when a coral reef grew up around a volcanic island that subsequently sank or was submerged by a rise in sea level.
Barrier islands are found by the shore in shallow water, and are formed by the deposition of sediment eroded from the shoreline.

Largest islands in the world

Island	Location	Area	
		sq km	sq mi
Greenland	northern Atlantic	2,175,600	840,000
New Guinea	southwestern Pacific	800,000	309,000
Borneo	southwestern Pacific	744,100	287,300
Madagascar	Indian Ocean	587,041	226,657
Baffin	Canadian Arctic	507,450	195,875
Sumatra	Indian Ocean	424,760	164,000
Honshu	northwestern Pacific	230,966	89,176
Great Britain	northern Atlantic	218,078	84,200
Victoria	Canadian Arctic	217,206	83,896
Ellesmere	Canadian Arctic	196,160	75,767
Sulawesi	Indian Ocean	189,216	73,057
South Island, New Zealand	southwestern Pacific	149,883	57,870
Java	Indian Ocean	126,602	48,900
North Island, New Zealand	southwestern Pacific	114,669	44,274
Cuba	Caribbean Sea	110,860	42,803
Newfoundland	northwestern Atlantic	108,860	42,030
Luzon	western Pacific	104,688	40,420
Iceland	northern Atlantic	103,000	39,768
Mindanao	western Pacific	94,630	36,537
Ireland (Northern Ireland and the Republic of Ireland)	northern Atlantic	84,406	32,590
Hokkaido	northwestern Pacific	83,515	32,245
Sakhalin	northwestern Pacific	76,400	29,500
Hispaniola (Dominican Republic and Haiti)	Caribbean Sea	76,192	29,418
Banks	Canadian Arctic	70,028	27,038
Tasmania	southwestern Pacific	67,800	26,171
Sri Lanka	Indian Ocean	65,610	25,332
Devon	Canadian Arctic	55,247	21,331

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island arc

curved chain of volcanic islands. Island arcs are common in the Pacific where they ring the ocean on both sides; the Aleutian Islands off Alaska are an example. The volcanism that forms island arcs is a result of subduction of an oceanic plate beneath another plate, as evidenced by the presence of ocean trenches on the convex side of the arc, and the Benioff zone of high seismic activity beneath.

Such island arcs are often later incorporated into continental margins during mountain-building episodes.

---

islets of Langerhans

groups of cells within the pancreas responsible for the secretion of the hormone insulin. They are sensitive to blood sugar levels, producing more hormone when glucose levels rise.

ISO

in photography, a numbering system for rating the speed of films, devised by the International Standards Organization.

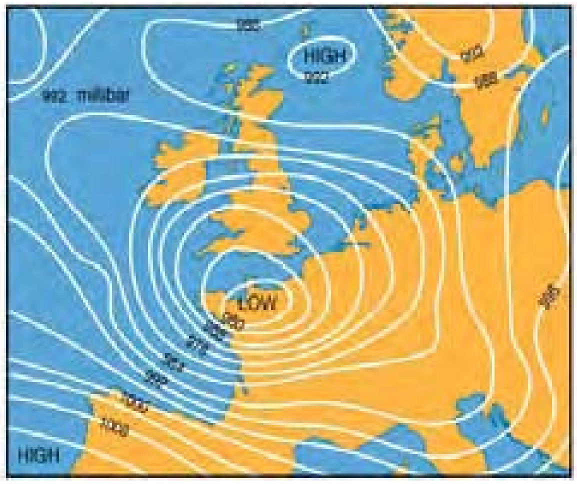
---

isobar

line drawn on maps and weather charts linking all places with the same atmospheric pressure (usually measured in millibars). When used in weather forecasting, the distance between the isobars is an indication of the barometric gradient (the rate of change in pressure).

Where the isobars are close together, cyclonic weather is indicated, bringing strong winds and a depression, and where far apart anticyclonic, bringing calmer, settled conditions.

isobar



(Image © Research Machines plc)

The isobars around a low-pressure area or depression. In the northern hemisphere, winds blow anticlockwise around lows, approximately parallel to the isobars, and clockwise around highs. In the southern hemisphere, the winds blow in the opposite directions.

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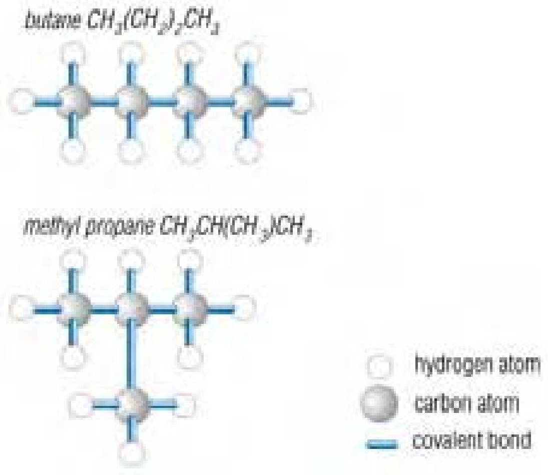
isomer

chemical compound having the same molecular formula but with different molecular structure. For example, the organic compounds butane ($CH_3(CH_2)_2CH_3$) and methyl propane ($CH_3CH(CH_3)CH_3$) are isomers, each possessing four carbon atoms and ten hydrogen atoms but differing in the way that these are arranged with respect to each other.

Structural isomers have obviously different constructions, but **geometrical** and **optical isomers** must be drawn or modelled in order to appreciate the difference in their three-dimensional arrangement. Geometrical isomers have a plane of symmetry and arise because of the restricted rotation of atoms around a bond; optical isomers are mirror images of each other. For instance, 1,1-dichloroethene ($CH_2{=}CCl_2$) and 1,2-dichloroethene ($CHCl{=}CHCl$) are structural isomers, but there are two possible geometric isomers of the latter (depending on whether the chlorine atoms are on the same side or on opposite sides of the plane of the carbon-carbon double bond).

isomer



(Image © Research Machines plc)

The chemicals butane and methyl propane are isomers. Each has the molecular formula C_4H_{10}, but with different spatial arrangements of atoms in their molecules.

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isomorphism

existence of substances of different chemical composition but with similar crystalline form.

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isoprene

technical name methylbutadiene; $CH_2CHC(CH_3)CH_2$

colourless, volatile liquid obtained from petroleum and coal, used to make synthetic rubber.

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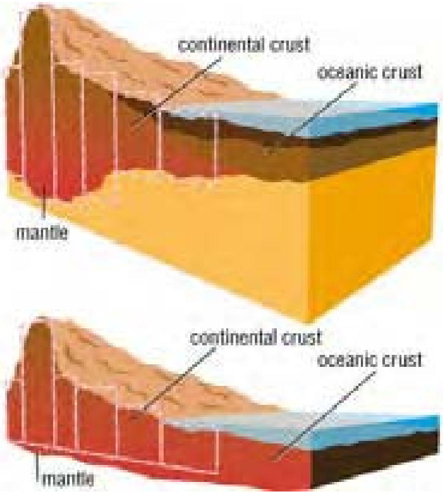
isostasy

condition of gravitational equilibrium of all parts of the Earth's crust. The crust is in isostatic equilibrium if, below a certain depth, the weight and thus pressure of rocks above is the same everywhere. The idea is that the lithosphere floats on the asthenosphere as a piece of wood floats on water. A thick piece of wood floats lower than a thin piece, and a denser piece of wood floats lower than a less dense piece. There are two theories of the mechanism of isostasy, the Airy hypothesis and the Pratt hypothesis, both of which have validity. In the **Airy hypothesis** crustal blocks have the same density but different thicknesses: like ice cubes floating in water, higher mountains have deeper roots. In the **Pratt hypothesis**, crustal blocks have different densities allowing the depth of crustal material to be the same. In practice, both mechanisms are at work.

isostasy



(Image © Research Machines plc)

Isostasy explains the vertical distribution of Earth's crust. George Bedell Airy proposed that the density of the crust is everywhere the same and the thickness of crustal material varies. Higher mountains are compensated by deeper roots. This explains the high elevations of most major mountain chains, such as the Himalayas. G H Pratt hypothesized that the density of the crust varies, allowing the base of the crust to be the same everywhere. Sections of crust with high mountains, therefore, would be less dense than sections of crust where there are lowlands. This applies to instances where density varies, such as the difference between continental and oceanic crust.

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isotonic solution

in medicine, a solution that can be mixed with body fluids without affecting their constituents. Solutions which are isotonic with blood, such as sodium chloride 0.9%, have the same osmotic pressure as serum and they do not affect the membranes of the red blood cells.

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isotope

one of two or more atoms that have the same atomic number (same number of protons), but which contain a different number of neutrons, thus differing in their relative atomic mass. They may be stable or radioactive (as a radioisotope), naturally occurring, or synthesized. For example, hydrogen has the isotopes ^{2}H (deuterium) and ^{3}H (tritium). The term was coined by English chemist Frederick Soddy, a pioneer researcher in atomic disintegration.

Elements at the lower end of the periodic table have atoms with roughly the same number of protons as neutrons. These elements are called **stable isotopes**. The stable isotopes of oxygen include ^{16}O, ^{17}O, and ^{18}O; those of carbon include ^{12}C and ^{14}C. Elements with high atomic mass numbers have many more neutrons than protons and are therefore less stable. It is these isotopes that are more prone to radioactive decay. Examples are ^{238}U (uranium-238) and ^{60}Co (cobalt-60).

ISS

abbreviation for *International Space Station*.

IT

abbreviation for information technology.

iteroparity

in biology, the repeated production of offspring at intervals throughout the life cycle. It is usually contrasted with semelparity, where each individual reproduces only once during its life.

ITU

abbreviation for **intensive therapy unit**, high-technology facility concerned with the care of patients with acute life-threatening conditions.

IUCN

abbreviation for International Union for the Conservation of Nature, an alternative name for the World Conservation Union.

IVF

abbreviation for in vitro fertilization.

ivory

hard white substance of which the teeth and tusks of certain mammals are made. Among the most valuable are elephants' tusks, which are of unusual hardness and density. Ivory is used in carving and other decorative work, and is so valuable that poachers continue to illegally destroy the remaining wild elephant herds in Africa to obtain it.

Poaching for ivory has led to the decline of the African elephant population from 2 million to approximately 600,000, with the species virtually extinct in some countries. Trade in ivory was halted by Kenya in 1989, but Zimbabwe continued its policy of controlled culling to enable the elephant population to thrive and to release ivory for export. China and Hong Kong have refused to obey an international ban on ivory trading. In 1997, the 138 member nations of the Convention on International Trade in Endangered Species (CITES) voted in Harare, amidst much controversy, to remove the ban on trade in ivory in Botswana, Namibia, and Zimbabwe. These three countries would be allowed to sell a limited amount of ivory to Japan, and the money must be channelled into elephant conservation projects. Trade is scheduled to resume in 1999 and would only be allowed from the existing stockpiles of ivory.

Vegetable ivory is used for buttons, toys, and cheap ivory goods. It consists of the hard albumen of the seeds of a tropical palm (*Phytelephas macrocarpa*), and is imported from Colombia.

ivy

any of an Old World group of woody climbing, trailing, or creeping evergreen plants. English or European ivy (*H. helix*) has shiny five-lobed leaves and clusters of small, yellowish-green flowers followed by black berries. It climbs by means of rootlike suckers put out from its stem, and causes damage to trees. (Genus *Hedera*, family Araliaceae.)

Ground ivy (*Glechoma hederacea*) is a small, originally European creeping plant belonging to the mint family; the North American poison ivy (*Rhus radicans*) belongs to the cashew family.

J

in physics, the symbol for **joule**, the SI unit of energy.

jaborandi

plant belonging to the rue family, native to South America. It is the source of **pilocarpine**, used in medicine to contract the pupil of the eye. (*Pilocarpus microphyllus*, family Rutaceae.)

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jacamar

insect-eating bird related to the woodpeckers, found in dense tropical forest in Central and South America. It has a long, straight, sharply-pointed bill, a long tail, and paired toes. The plumage is golden bronze with a steely lustre. Jacamars are usually seen sitting motionless on trees from which they fly out to catch insects on the wing, then return to crack them on a branch before eating them. The largest species is *Jacamerops aurea*, which is nearly 30 cm/12 in long. (Family Galbulidae, order Piciformes.)

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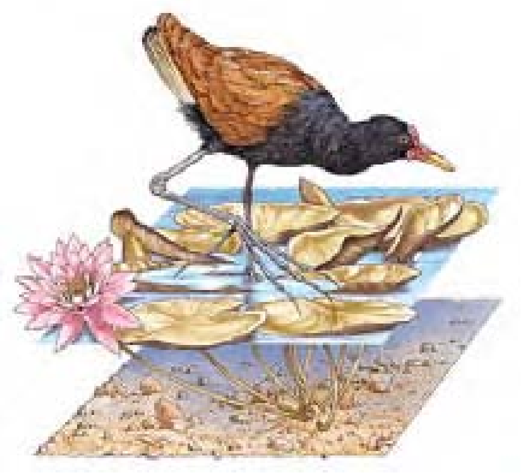
jacana

or lily-trotter

wading bird with very long toes and claws enabling it to walk on the floating leaves of water plants. There are seven species. Jacanas are found in Mexico, Central America, South America, Africa, South Asia, and Australia, usually in marshy areas. (Family Jacanidae, order Charadriiformes.)

The **Australian jacana** (*Irediparra gallinacea*) is so well adapted to life on water that the eggs are laid on floating vegetation and can themselves float.

jacana



(Image © Research Machines plc)

The American jacana, or lily trotter, is a common waterbird of lagoons and marshes in Mexico and Central America. Jacanas have extremely long toes and claws for walking on floating vegetation.

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jacaranda

any of a group of tropical American trees belonging to the bignonia family, with fragrant wood and showy blue or violet flowers, commonly cultivated in the southern USA. (Genus *Jacaranda*, family Bignoniaceae.)

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jack

tool or machine for lifting, hoisting, or moving heavy weights, such as motor vehicles. A **screw jack** uses the principle of the screw to magnify an applied effort; in a car jack, for example, turning the handle many times causes the lifting screw to rise slightly, and the effort is magnified to lift heavy weights. A **hydraulic jack** uses a succession of piston strokes to increase pressure in a liquid and force up a lifting ram.

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jackal

any of several wild dogs found in South Asia, southern Europe, and North Africa. Jackals can grow to 80 cm/2.7 ft long, and have greyish-brown fur and a bushy tail. (Genus *Canis*.)

The **golden jackal** (*C. aureus*) of South Asia, southern Europe, and North Africa is 45 cm/1.5 ft high and 60 cm/2 ft long. It is greyish-yellow, and darker on the back. A nocturnal animal, it preys on smaller mammals and poultry, although packs will attack larger animals; it will also scavenge. The **side-striped jackal** (*C. adustus*) is found over much of Africa; the **black-backed jackal** (*C. mesomelas*) occurs only in the south of Africa.

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jackdaw

bird belonging to the crow family, native to Europe and Asia. It is mainly black, but greyish on the sides and back of the head, and about 33 cm/1.1 ft long. It nests in tree holes or on buildings. Usually it lays five bluish-white eggs, mottled with tiny dark brown spots. Jackdaws feed on a wide range of insects, molluscs, spiders, worms, birds' eggs, fruit, and berries. (Species *Corvus monedula*, family Corvidae, order Passeriformes.)

Jackson, Daphne Frances (1936-1991)

English physicist who specialized in nuclear, medical, and radiation physics and was the first British female professor of physics.

Jackson, John Hughlings (1835-1911)

English neurologist and neurophysiologist. As a result of his studies of epilepsy, Jackson demonstrated that specific areas of the cerebral cortex (outer mantle of the brain) control the functioning of particular organs and limbs.

Jacob, François (1920-)

French biochemist who was awarded the Nobel Prize in Physiology or Medicine in 1965, with Jacques Monod and André Lwoff, for their work on the genetic control of enzyme and virus synthesis. They pioneered research into molecular genetics and showed how the production of proteins from DNA is controlled.

Jacquard, Joseph Marie (1752-1834)

French textile manufacturer. He invented a punched-card system for programming designs on a silk-weaving loom (the **Jacquard loom**). In 1801 he constructed looms that used a series of punched cards to control the pattern of longitudinal warp threads depressed before each sideways passage of the shuttle. On later machines the punched cards were joined to form an endless loop that represented the 'program' for the repeating pattern of a carpet.

Jacquard-style punched cards were used in the early computers of the 1940s-1960s.

Jacuzzi, Candido (1903-1986)

Italian-born US engineer who invented the Jacuzzi, a pump that produces a whirlpool effect in a bathtub. The Jacuzzi was commercially launched as a health and recreational product in the mid-1950s.

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jade

semi-precious stone consisting of either jadeite, $NaAlSi_2O_6$ (a pyroxene), or nephrite, $Ca_2(Mg,Fe)_5Si_8O_{22}(OH,F)_2$ (an amphibole), ranging from colourless through shades of green to black according to the iron content. Jade ranks 5.5-6.5 on the Mohs scale of hardness.

The early Chinese civilization discovered jade, bringing it from eastern Turkestan, and carried the art of jade-carving to its peak. The Olmecs, Aztecs, Maya, and the Maori have also used jade for ornaments, ceremony, and utensils.

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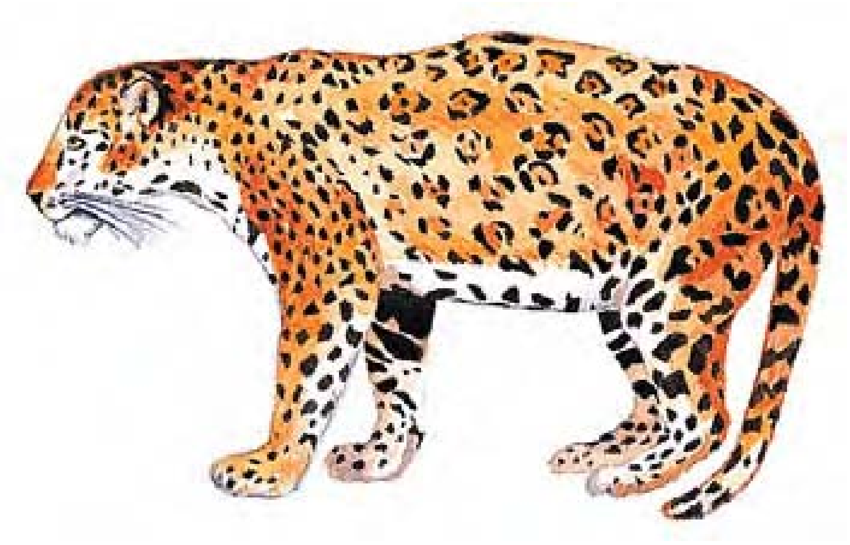
jaguar

largest species of cat in the Americas, formerly ranging from the southwestern USA to southern South America, but now extinct in most of North America. It can grow up to 2.5 m/8 ft long including the tail. Male jaguars weigh up to 150 kg/330 lb; females up to 90 kg/198 lb. The background colour of the fur varies from creamy white to brown or black, and is covered with black spots. The jaguar is usually solitary and lives approximately 11 years in the wild. (Species *Panthera onca*, family Felidae.)

The gestation period is 100 days and between one and four cubs are born. Jaguars are good swimmers and favour territory that is near water or flooded seasonally.

In 1999 there were 10,000-15,000 jaguars in the wild.

jaguar



(Image © Research Machines plc)

The jaguar has been hunted for its beautiful coat. This is commonly a rich yellow or tawny colour, marked with dark spots and rosettes running along the back and sides. The jaguar is an agile hunter, often climbing trees to wait for prey, and is an excellent swimmer.

Jaguar

Go to site

Details about the largest species of cat in the Americas, the jaguar. The page contains information about the appearance, breeding habits, and typical height and weight of the animal.

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jaguarundi

wild cat found in forests in Central and South America. Up to 1.1 m/3.5 ft long, it is very slim with rather short legs and short rounded ears. It is uniformly coloured dark brown or chestnut. A good climber, it feeds on birds and small mammals and, unusually for a cat, has been reported to eat fruit. (Species *Felis yaguoaroundi*, family Felidae.)

James, William (1842-1910)

US psychologist and philosopher. He was among the first to take an approach emphasizing the ends or purposes of behaviour and to advocate a scientific, experimental psychology. His *Varieties of Religious Experience* (1902) is one of the most important works on the psychology of religion.

In his classic *Principles of Psychology* (1890), James introduced the notion of the 'stream of consciousness' (thought, consciousness, or subjective life regarded as a flow rather than as separate bits), and propounded the theory of emotions now known as the James-Lange theory. James wrote extensively on abnormal psychology and had much to contribute to the study of the paranormal.

Classics in the History of Psychology - 'Stream of Consciousness'

Go to site

Transcript of James's 'Stream of Consciousness' theory as first published in *Psychology*, Chapter XI, (Cleveland & New York, World). The first sentence of the chapter sums up James's contribution to the science of psychology: 'The order of our study must be analytic.' James's belief in the value of scientific experimental method changed psychology forever.

Classics in the History of Psychology - The Principles of Psychology

Go to site

Text of William James's classic book.

Varieties of Religious Experience by William James

Go to site

Online version of James' seminal work on the psychology of religion. A series of well-arranged notes accompany the text and show the ongoing relevance of his analysis.

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jansky

unit of radiation received from outer space, used in radio astronomy. It is equal to 10^{-26} watts per square metre per hertz, and is named after US engineer Karl Jansky.

Jansky, Karl Guthe (1905-1950)

US radio engineer who in 1932 discovered that the Milky Way galaxy emanates radio waves; he did not follow up his discovery, but it marked the birth of radioastronomy.

Japan Current

or Kuroshio

warm ocean current flowing from Japan to North America.

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jarrah

type of eucalyptus tree of western Australia, with durable timber.

Jarvik 7

the first successful artificial heart intended for permanent implantation in a human being. Made from polyurethane plastic and aluminium, it is powered by compressed air. Barney Clark became the first person to receive a Jarvik 7, in Salt Lake City, Utah, USA, in 1982; it kept him alive for 112 days.

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jasmine

any of a group of subtropical plants with white or yellow flowers. The common jasmine (*J. officinale*) has fragrant pure white flowers that yield jasmine oil, used in perfumes; the Chinese winter jasmine (*J. nudiflorum*) has bright yellow flowers that appear before the leaves. (Genus *Jasminum*, family Oleaceae.)

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jasper

hard, compact variety of chalcedony SiO_2, usually coloured red, brown, or yellow. Jasper can be used as a gem.

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jaundice

yellow discoloration of the skin and whites of the eyes caused by an excess of bile pigment in the bloodstream. Approximately 60% of newborn babies exhibit some degree of jaundice, which is treated by bathing in white, blue, or green light that converts the bile pigment bilirubin into a water-soluble compound that can be excreted in urine. A serious form of jaundice occurs in rhesus disease (see rhesus factor).

Bile pigment is normally produced by the liver from the breakdown of red blood cells, then excreted into the intestines. A build-up in the blood is due to abnormal destruction of red cells (as in some cases of anaemia), impaired liver function (as in hepatitis), or blockage in the excretory channels (as in gallstones or cirrhosis). The jaundice gradually recedes following treatment of the underlying cause.

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jaw

one of two bony structures that form the framework of the mouth in all vertebrates except lampreys and hagfishes (the agnathous or jawless vertebrates). They consist of the upper jawbone (maxilla), which is fused to the skull, and the lower jawbone (mandible), which is hinged at each side to the bones of the temple by ligaments.

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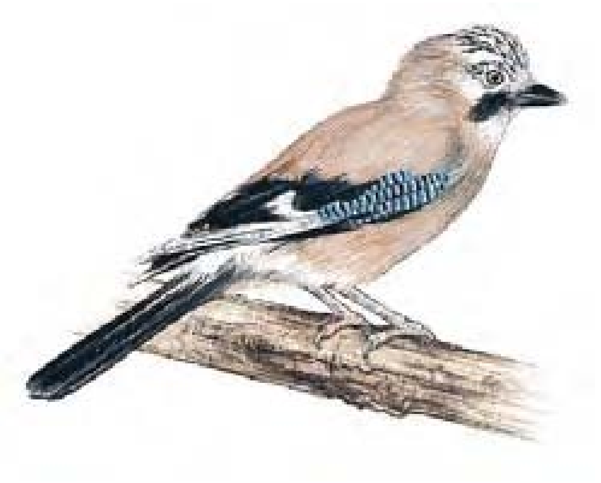
jay

any of several birds belonging to the crow family, generally brightly coloured and native to Europe, Asia, and the Americas. In the Eurasian **common jay** (*Garrulus glandarius*), the body is fawn with patches of white, blue, and black on the wings and tail. (Family Corvidae, order Passeriformes.)

Jays are shy and retiring in their habits, but have a screeching cry with the power to vary it by mimicking other birds. They feed chiefly on snails, insects, worms, and nuts, particularly acorns. They hide their nests in trees with thick foliage and lay about five or six eggs at a time.

The **blue jay** (*Cyanocitta cristata*), of the eastern and central USA, has a crest and is very noisy and bold.

jay



(Image © Research Machines plc)

The common jay ranges widely over Europe to North Africa, and Asia south to Myanmar, China, and Taiwan. Living alone in forests and woodlands, it feeds on insects, spiders, snails, slugs, and also on berries, acorns, and grain.

Jeans mass

in astronomy, mass that a cloud (or part of a cloud) of interstellar gas must have before it can contract under its own weight to form a protostar. The Jeans mass is an expression of the **Jeans criterion**, which says that a cloud will contract when the gravitational force tending to draw material towards its centre is greater than the opposing force due to gas pressure. It is named after English mathematician James Hopwood Jeans, whose work focused on the kinetic theory of gases and the origins of the cosmos.

Jeffreys, Alec John (1950-)

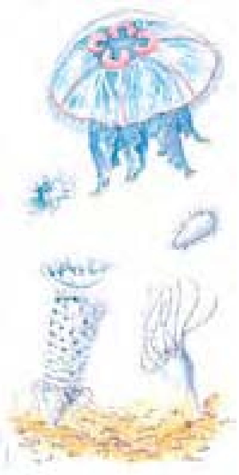
English geneticist who discovered the DNA probes necessary for accurate genetic fingerprinting so that a murderer or rapist could be identified by, for example, traces of blood, tissue, or semen.

jellyfish

marine invertebrate, belonging among the coelenterates (subphylum Cnidaria), with an umbrella-shaped body made of a semi-transparent jellylike substance, often tinted with blue, red, or orange colours, and having stinging tentacles that trail in the water. Most adult jellyfish move freely, but during parts of their life cycle many are polyp-like and attached to rocks, the seabed, or another underwater surface. They use the sense of smell in tracking prey, and feed on small animals that are paralysed by stinging cells in the jellyfish tentacles.

Most jellyfish cause no more discomfort to humans than a nettle sting, but contact with the tentacles of the subtropical Portuguese man-of-war (*Physalia physalis*) or the Australian box jellyfish (*Chironex fleckeri*) can be life-threatening.

jellyfish



(Image © Research Machines plc)

After fertilization, the gametes of a jellyfish may be released into the water as larvae (middle right) or retained in a brood pouch. After settling, the larvae change into a sedentary polyp stage (bottom right) similar to that of a coral. More polyps (bottom left) are produced by simple budding. These polyps may divide again to form the so-called ephyra larvae (middle left). These larvae eventually grow into the free-swimming medusa more familiarly known as a jellyfish (top).

Jenner, Edward (1749-1823)

English physician who pioneered vaccination. In Jenner's day, smallpox was a major killer. His discovery in 1796 that inoculation with cowpox gives immunity to smallpox was a great medical breakthrough.

Jenner observed that people who worked with cattle and contracted cowpox from them never subsequently caught smallpox. In 1798 he published his findings that a child inoculated with cowpox, then two months later with smallpox, did not get smallpox. He coined the word 'vaccination' from the Latin word for cowpox, *vaccinia*.

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jerboa

any of a group of small nocturnal rodents with long and powerful hind legs developed for leaping. There are about 25 species of jerboa, native to desert areas of North Africa and Southwest Asia. (Family Dipodidae.)

The common North African jerboa (*Jaculus orientalis*) is a typical species. Its body is about 15 cm/6 in long and the tail is 25 cm/10 in long with a tuft at the tip. At speed it moves in a series of long jumps with its forefeet held close to its body.

Jerusalem artichoke

a variety of artichoke.

JET

abbreviation for Joint European Torus

research facility at Culham, near Abingdon, Oxfordshire, England, that conducts experiments on nuclear fusion. Opened in 1984, it is the focus of the European effort to produce a safe and environmentally sound fusion-power reactor. On 9 November 1991, the JET tokamak, operating with a mixture of deuterium and tritium, produced a 1.7 megawatt pulse of power in an experiment that lasted two seconds. In 1997, isotopes of deuterium and tritium were fused to produce a record 21 megajoule of nuclear fusion power. JET has tested the first large-scale plant of the type needed to process and supply tritium in a future fusion power station.

On 1 January 2000, the European Fusion Development Agreement (EFDA) took over the operation of the JET machine. Future work at JET will pave the way for a new European fusion reactor to be built at Cadarache in southern France and expected to begin operation in 2016.

JET World Wide Web Page

Go to site

Web site of the Joint European Torus (JET) at Culham, UK, which includes an introduction to some aspects of nuclear fusion and an online tour of the project.

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jet

in astronomy, narrow luminous feature seen protruding from a star or galaxy and representing a rapid outflow of material. See active galaxy.

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jet

in earth science, hard, black variety of lignite, a type of coal. It is cut and polished for use in jewellery and ornaments. Articles made of jet have been found in Bronze Age tombs.

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jetfoil

advanced type of hydrofoil boat built by Boeing, propelled by water jets. It features horizontal, fully submerged hydrofoils fore and aft and has a sophisticated computerized control system to maintain its stability in all waters.

Jetfoils have been in service worldwide since 1975. A jetfoil service operates across the English Channel between Dover and Ostend, Belgium, with a passage time of about 1.5 hours. Cruising speed of the jetfoil is about 80 kph/50 mph.

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jet lag

the effect of a sudden switch of time zones in air travel, resulting in tiredness and feeling 'out of step' with day and night. Using the hormone melatonin at the desired bedtime may help to lessen the effect of jet lag by resetting the body clock. See also circadian rhythm.

Jet Lag

Go to site

Advice for travellers on how to adapt to changes in time zones. Calculations on how to adjust internal clocks are suited to the separate needs of 'night owls' and 'larks'. The physiological consequences of jet lag are also well explained.

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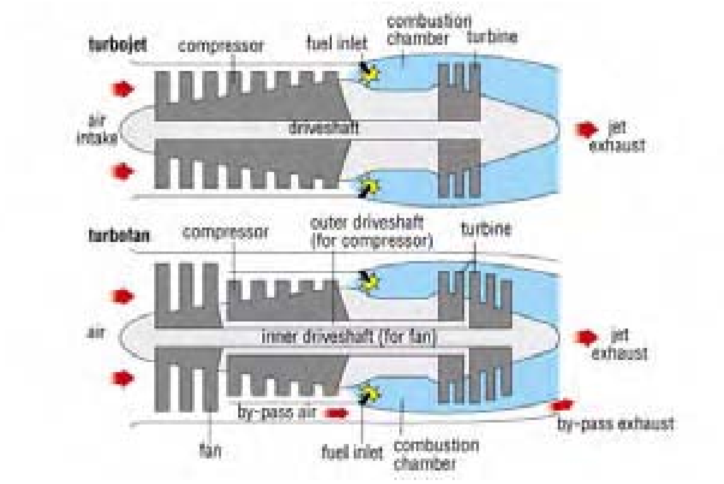
jet propulsion

method of propulsion in which an object is propelled in one direction by a jet, or stream of gases, moving in the other. This follows from Isaac Newton's third law of motion: 'To every action, there is an equal and opposite reaction.' The most widespread application of the jet principle is in the jet (gas turbine) engine, the most common kind of aircraft engine.

jet propulsion



(Image © Research Machines plc)

Two forms of jet engine. In the turbojet, air passing into the air intake is compressed by the compressor and fed into the combustion chamber where fuel burns. The hot gases formed are expelled at high speed from the rear of the engine, driving the engine forwards and turning a turbine which drives the compressor. In the turbofan, some air flows around the combustion chamber and mixes with the exhaust gases. This arrangement is more efficient and quieter than the turbojet.

Jet Propulsion Laboratory

JPL

NASA installation at Pasadena, California, operated by the California Institute of Technology. Established in 1944, it is the command centre for NASA's deep-space probes such as the Voyager, Magellan, and Galileo missions, with which it communicates via the deep-space network. It is the leading US centre for robotic exploration of the Solar System, with its spacecraft having visited all the planets except Pluto.

Jet Propulsion Laboratory

Go to site

Frequently updated site with news and articles on Solar System exploration. Pages describe new technologies and the laboratory's Earth-observation programme; there are activities for younger students, and the acclaimed Solar System Simulator. If you've ever wondered how Saturn would look from the vicinity of Titan, or Earth from Pluto, the Solar System Simulator is for you - you can quickly and easily generate your own views of the Solar System.

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jet stream

narrow band of very fast wind (velocities of over 150 kph/95 mph) found at altitudes of 10-16 km/6-10 mi in the upper troposphere or lower stratosphere. Jet streams usually occur about the latitudes of the Westerlies (35°-60°).

The jet stream may be used by high flying aircraft to speed their journeys. Their discovery of the existence of the jet stream allowed the Japanese to send gas-filled balloons carrying bombs to the northwestern USA during World War II.

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jigger

or sandflea

flea found in tropical and subtropical countries. The males of the species are free-living and measure about 1 mm/0.03 in in length. The females, which are slightly bigger, are parasites of humans and other animals.

Jiggers burrow into the skin, particularly the soft skin between the toes, and soon become enveloped within a skin fold. As they feed they become enlarged and distended and their legs degenerate; eventually a stage is reached when only the last two segments at the abdomen protrude from the skin fold. The eggs are then voided and fall on the soil or sand.

Apart from their presence within the host skin, which causes acute pain and the formation of ulcers, the fleas may be responsible for secondary infections. Preventive measures include ridding the host of the parasite, and destroying breeding places.

classification

The jigger *Tunga penetrans* is in order Siphonaptera, class Insecta, phylum Arthropoda.

Jodrell Bank

site in Cheshire, England, of the Nuffield Radio Astronomy Laboratories of the University of Manchester. Its largest instrument is the 76-m/250-ft radio dish (the Lovell Telescope), completed in 1957, modified in 1970, and upgraded in 2001 and 2002, given a new surface and drive system. A 38 × 25-m/125 × 82-ft elliptical radio dish was introduced in 1964, capable of working at shorter wavelengths.

These radio telescopes are used in conjunction with five smaller dishes up to 230 km/143 mi apart in an array called MERLIN (multi-element radio-linked interferometer network) to produce detailed maps of radio sources.

Jodrell Bank Observatory

Go to site

Comprehensive site describing the Nuffield Radio Astronomy Laboratories at Jodrell Bank, Cheshire, England. The radio telescope has been used for astronomy for many years. This site describes some of the important discoveries it has led to and also hints at future developments.

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joint

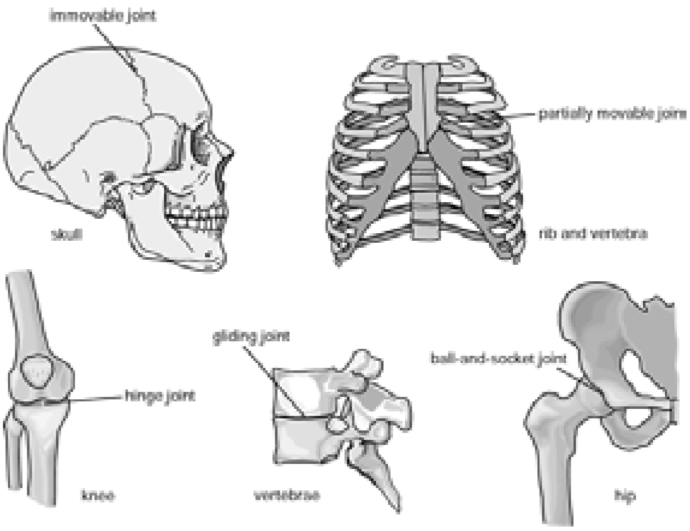
point of movement or articulation in any animal with a skeleton. In vertebrates, it is the point where two bones meet. Some joints allow no motion (the sutures between the bones of the skull), others allow a very small motion (the sacroiliac joints in the lower vertebral column), but most allow a relatively free motion. Of these, some allow a gliding motion (one vertebra of the spine on another), some have a hinge action (elbow and knee), and others allow motion in all directions (hip and shoulder joints) by means of a ball-and-socket arrangement.

Movement at a joint is usually produced by muscles, which are attached to the bones by tendons. The ends of the bones at a moving joint are covered with cartilage for greater elasticity and smoothness (to make movement easy), and enclosed in an envelope (capsule) of tough white fibrous tissue lined with a membrane which secretes a lubricating and cushioning synovial fluid. The joint is further strengthened by ligaments, which connect bone to bone. These joints are known as synovial joints. In invertebrates with an exoskeleton, the joints are places where the exoskeleton is replaced by a more flexible outer covering, the arthrodial membrane, which allows the limb (or other body part) to bend at that point.

joint

The sound of joints 'cracking' is caused by the nitrogen that is dissolved in the joint tissues, coming out of solution and entering the joint space with a popping noise.

joint



(Image © Research Machines plc)

The different types of joint allow varying degrees of movement, for example hinge joints allow movement in only one direction whereas ball-and-socket joints allow almost 360° of movement, and the sutures of the skull allow for no movement at all.

Major Joints

Go to site

This site covers the major joints in the body: ankle, elbow, foot, hand, hip, knee, shoulder, and back. These are listed on the first page, and clicking on a specific joint brings up a description and diagram of it, as well as information on ways to prevent and treat injuries.

Joint European Torus

experimental nuclear-fusion machine, known as JET.

Joliot-Curie, Frédéric (1900-1958)

born Frédéric Jean Joliot

French physicist. With his wife, Irène Joliot-Curie, he was awarded the Nobel Prize for Chemistry in 1935 for their discovery of artificial radioactivity.

Joliot was born in Paris, France, and graduated from the Ecole Supérieure de Physique et de Chimie Industrielle. He joined the Radium Institute in 1925. In 1937 he became professor of nuclear physics at the Collège de France. He succeeded his wife as director of the Radium Institute in 1956.

Joliot-Curie, Irène (1897-1956)

French physicist, daughter of Pierre and Marie Curie. She and her husband Frédéric Joliot were jointly awarded the Nobel Prize for Chemistry in 1935 for their discovery of artificial radioactivity. She was professor of physics at the Sorbonne from 1937, and director of the Radium Institute 1946-56.

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jonquil

species of small daffodil, with yellow flowers. It is native to Spain and Portugal, and is cultivated in other countries. (*Narcissus jonquilla*, family Amaryllidaceae.)

Josephson, Brian David (1940-)

Welsh physicist, a leading authority on superconductivity. He shared the Nobel Prize for Physics in 1973 for his theoretical predictions of the properties of a supercurrent through a tunnel barrier (the **Josephson effect**), which led to the development of the Josephson junction.

Josephson junction

device used in 'superchips' (large and complex integrated circuits) to speed the passage of signals by a phenomenon called 'electron tunnelling'. Although these superchips respond a thousand times faster than the silicon chip, they have the disadvantage that the components of the Josephson junctions operate only at temperatures close to absolute zero. They are named after English theoretical physicist Brian Josephson.

---

joule

symbol J

SI unit of work and energy (such as potential energy, kinetic energy, or electrical energy).

Joule, James Prescott (1818-1889)

English physicist. His work on the relations between electrical, mechanical, and chemical effects led to the discovery of the first law of thermodynamics.

He determined the mechanical equivalent of heat (**Joule's equivalent**) in 1843, and the SI unit of energy, the joule, is named after him. He also discovered **Joule's law**, which defines the relation between heat and electricity; and, with Irish physicist Lord Kelvin in 1852, the **Joule-Kelvin** (or **Joule-Thomson**) effect.

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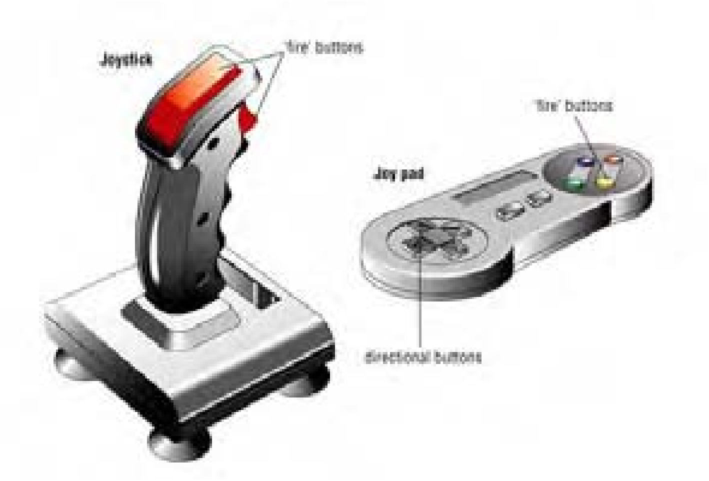
joystick

in computing, an input device that signals to a computer the direction and extent of displacement of a hand-held lever. It is similar to the joystick used to control the flight of an aircraft.

Joysticks are sometimes used to control the movement of a cursor (marker) across a display screen, but are much more frequently used to provide fast and direct input for moving the characters and symbols that feature in computer games. Unlike a mouse, which can move a pointer in any direction, simple games joysticks are often capable only of moving an object in one of eight different directions. Today, many joysticks and control pads feature some form of force feedback.

joystick



(Image © Research Machines plc)

The directional and other controls on a conventional joystick may be translated to a joy pad, which enables all controls to be activated by buttons.

JPL

abbreviation for Jet Propulsion Laboratory.

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jugular vein

one of two veins in the necks of vertebrates; they return blood from the head to the superior (or anterior) vena cava and thence to the heart.

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jujube

any of a group of trees belonging to the buckthorn family, with berrylike fruits. The common jujube (*Z.*

jujuba) of Asia, Africa, and Australia, cultivated in southern Europe and California, has fruit the size of small plums, known as Chinese dates when preserved in syrup. See also lotus. (Genus *Zizyphus*, family Thamnaceae.)

Julian date

in astronomy, measure of time used in which days are numbered consecutively from noon GMT on 1 January 4713 BC. It is useful where astronomers wish to compare observations made over long time intervals. The Julian date (JD) at noon on 1 January 2000 was 2451545.0. The **modified Julian date** (MJD), defined as MJD = JD -2400000.5, is more commonly used since the date starts at midnight GMT and the smaller numbers are more convenient.

---

jumbo jet

popular name for a generation of huge, wide-bodied airliners including the Boeing 747, which is 71 m/232 ft long, has a wingspan of 60 m/196 ft, a maximum takeoff weight of nearly 400 tonnes, and can carry more than 400 passengers.

Jung, Carl Gustav (1875-1961)

Swiss psychiatrist. He collaborated with Sigmund Freud from 1907 until their disagreement in 1914 over the importance of sexuality in causing psychological problems. Jung studied myth, religion, and dream symbolism, saw the unconscious as a source of spiritual insight, and distinguished between introversion and extroversion.

Jung devised the word-association test in the early 1900s as a technique for penetrating a subject's unconscious mind. He also developed his theory concerning emotional, partly repressed ideas which he termed 'complexes'. In place of Freud's emphasis on infantile sexuality, Jung introduced the idea of a 'collective unconscious' which is made up of many archetypes or 'congenital conditions of intuition'.

---

jungle

popular name for rainforest.

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juniper

any of a group of aromatic evergreen trees or shrubs of the cypress family, found throughout temperate regions. Junipers produce a valuable wood and their berries are used to flavour gin and in cooking. Some junipers are mistakenly called cedars. (Genus *Juniperus*, family Cupressaceae.)

Jupiter

fifth planet from the Sun and the largest in the Solar System, with a mass equal to 70% of all the other planets combined and 318 times as large as that of the Earth. A prominent feature is the Great Red Spot, a cloud of rising gases, 14,000 km/8,500 mi wide and 30,000 km/20,000 mi long, revolving anticlockwise.

mean distance from the Sun

778 million km/484 million mi

equatorial diameter

142,800 km/88,700 mi

rotation period

9 hours 51 minutes

year

11.86 Earth years

atmosphere

consists of clouds of white ammonia crystals, drawn out into belts by the planet's high speed of rotation (the fastest of any planet). Darker orange and brown clouds at lower levels may contain sulphur, as well as simple organic compounds. Temperatures range from -140°C/-220°F in the upper atmosphere to as much as 24,000°C/43,000°F near the core. This is the result of heat left over from Jupiter's formation, and it is this that drives the turbulent weather patterns of the planet. The Great Red Spot was first observed in 1664. Its top is higher than the surrounding clouds; its colour is thought to be due to red phosphorus. The Southern Equatorial Belt in which the Great Red Spot occurs is subject to unexplained fluctuation. In 1989 it sustained a dramatic and sudden fading. Jupiter's strong magnetic field gives rise to a large surrounding magnetic 'shell', or magnetosphere, from which bursts of radio waves are detected. Jupiter's faint rings are made up of dust from its moons, particularly the four inner moons

composition

largely hydrogen and helium, which under the high pressure and temperature of the interior behave not as a gas but as a supercritical fluid. Under even more extreme conditions, at a depth of 30,000 km/18,000 mi, hydrogen transforms into a metallic liquid. Jupiter probably has a molten rock core whose mass is 15 to 20 times greater than that of the Earth

In 1995, the Galileo probe revealed Jupiter's atmosphere to consist of 0.2% water, less than previously estimated.

satellites

Jupiter has 28 known moons. The four largest moons, Io, Europa (which is the size of the Moon), Ganymede, and Callisto, are the Galilean satellites, discovered in 1610 by Galileo Galilei (Ganymede, which is larger than Mercury, is the largest moon in the Solar System). Three small moons were discovered in 1979 by the US Voyager probes, as was a faint ring of dust around Jupiter's equator 55,000 km/34,000 mi above the cloud tops. One of Jupiter's small inner moons, Amalthea (diameter 250 km/155 mi), was shown by pictures from the Galileo probe in April 2000 to have a long, narrow, bright region, as yet unidentified. A new moon was first observed orbiting Jupiter in October 1999 by US researchers at the Kitt Peak Observatory, Arizona. It was thought to be an asteroid and named S/1999J1, but was confirmed to be a moon in July 2000. The moon is only 5 km/3 mi in diameter and orbits Jupiter once every two years at a distance of 24 million km/15 million mi. Ten previously unobserved moons were discovered orbiting Jupiter in November and December 2000. These moons are all believed to be less than 5 km/3.1 mi in diameter, and were observed by astronomers at the Mauna Kea observatory, Hawaii.

The comet Shoemaker-Levy 9 crashed into Jupiter in July 1994. Impact zones were visible for several months.

Jupiter's major satellites

Satellite	Year of discovery	Diameter		Mean distance from Jupiter	
		km	mi	km	mi
Callisto	1610	4,800	2,983	1,883,000	1,170,000
Europa	1610	3,138	1,950	671,000	417,000
Ganymede	1610	5,262	3,270	1,070,000	665,000
Io	1610	3,630	2,256	422,000	262,000
Amalthea	1892	shape irregular 270 × 170 × 150	shape irregular 168 × 106 × 93	181,000	112,000
Himalia	1904	180	112	11,480,000	7,133,000
Elara	1905	80	50	11,737,000	7,293,000
Pasiphae	1908	70	43	23,500,000	14,602,000
Sinope	1914	40	25	23,700,000	14,726,000
Carme	1938	44	27	22,600,000	14,043,000
Lysithea	1938	40	25	11,720,000	7,282,000
Ananke	1951	30	19	21,200,000	13,173,000
Leda	1974	16	10	11,094,000	6,893,000
Adrastea	1979	shape irregular 24 × 20 × 16	shape irregular 15 × 12 × 10	129,000	80,000
Metis	1979	40	25	128,000	80,000
Thebe	1979	100	62	222,000	138,000

Jupiter

Go to site

Full details of the planet and its moons, including a chronology of exploration, various views of the planet and its moons, and links to other planets.

Jurassic period

period of geological time 208-146 million years ago; the middle period of the Mesozoic era. Climates worldwide were equable, creating forests of conifers and ferns; dinosaurs were abundant, birds evolved, and limestones and iron ores were deposited.

The name comes from the Jura Mountains in France and Switzerland, where the rocks formed during this period were first studied.

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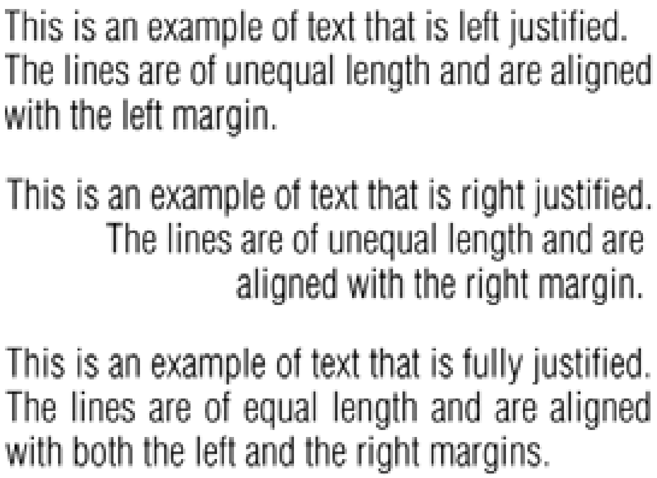
justification

in printing and word processing, the arrangement of text so that it is aligned with either the left or right margin, or both.

justification


This is an example of text that is left justified.
The lines are of unequal length and are aligned
with the left margin.

This is an example of text that is right justified.
The lines are of unequal length and are
aligned with the right margin.

This is an example of text that is fully justified.
The lines are of equal length and are aligned
with both the left and the right margins.

(Image © Research Machines plc)

An example of left, right, and fully justified text.

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jute

fibre obtained from two plants of the linden family: *C. capsularis* and *C. olitorius*. Jute is used for sacks and sacking, upholstery, webbing (woven strips used to support upholstery), string, and stage canvas. (Genus *Corchorus*, family Tiliaceae.)

In the production of bulk packaging and tufted carpet backing, jute is now often replaced by synthetic polypropylene. The world's largest producer of jute is Bangladesh.

---

k

symbol for **kilo-**, as in kg (kilogram) and km (kilometre).

K

abbreviation for thousand, as in a salary of $50K.

K

symbol for **kelvin**, a scale of temperature.

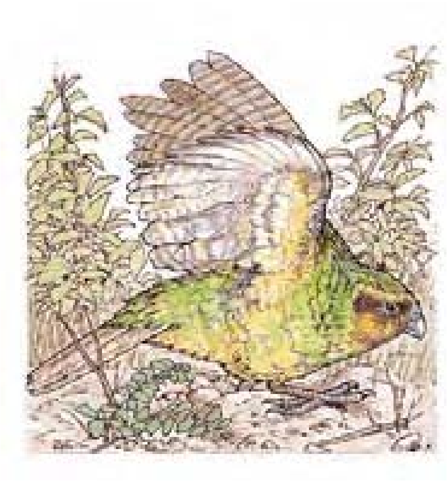
---

kakapo

nocturnal flightless parrot that lives in burrows in New Zealand. It is green, yellow, and brown with a disc of brown feathers round its eyes, like an owl. It weighs up to 3.5 kg/7.5 lb. When in danger, its main defence is to remain perfectly still. Because of the introduction of predators such as dogs, cats, rats, and ferrets, it is in danger of extinction. In 1998 there were only 56 birds left in the wild. (Species *Strigops habroptilus*, order Psittaciformes.)

Kakapos are the only parrots to have a lek mating system, where small territories are occupied by males during the mating season. The males excavate a hollow in the ground in a mating arena and then produce a low-frequency booming noise using an inflatable air sac in the thorax. Females can hear this noise from up to 5 km away. Females nest on the ground and can lay two to four eggs which they incubate without help from the male, for 30 days. Kakapos are very slow breeders and do not produce a clutch every year.

kakapo



(Image © Research Machines plc)

The kakapo, of New Zealand, is the only flightless parrot. As a flightless, ground-dwelling bird, it has fallen easy prey to introduced ground predators such as stoats and rats. Only two breeding populations on small, offshore islands survive in the wild.

Fabulous Kakapo

Go to site

Interesting profile of the solitary flightless parrot, which may live for 60 years, but is now on the verge of extinction. The reasons for the drastic decline in the bird's numbers are explained, together with information on conservation efforts on predator-free islands. The site is frequently updated with news of the fight for survival of this sturdy, but defenceless, bird.

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kale

type of cabbage.

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kame

geological feature, usually in the form of a mound or ridge, formed by the deposition of rocky material carried by a stream of glacial meltwater. Kames are commonly laid down in front of or at the edge of a glacier (kame terrace), and are associated with the disintegration of glaciers at the end of an ice age.

Kames are made of well-sorted rocky material, usually sands and gravels. The rock particles tend to be rounded (by attrition) because they have been transported by water.

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kangaroo

any of a group of marsupials (mammals that carry their young in pouches) found in Australia and Papua New Guinea. Kangaroos are plant-eaters and most live in groups. They are adapted to hopping, the vast majority of species having very large, powerful back legs and feet compared with the small forelimbs. The larger types can jump 9 m/30 ft in a single bound. Most are nocturnal. Species vary from small rat kangaroos, only 30 cm/1 ft long, through the medium-sized wallabies, to the large red and great grey kangaroos, which are the largest living marsupials. These may be 1.8 m/5.9 ft long with 1.1 m/3.5 ft tails. (Family Macropodidae.)

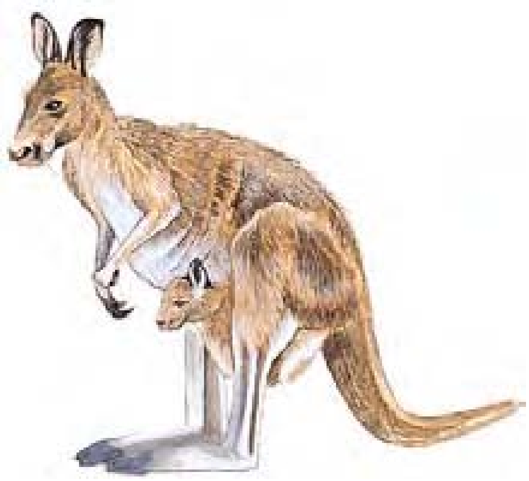
In Papua New Guinea and northern Queensland, tree kangaroos (genus *Dendrolagus*) occur. These have comparatively short hind limbs. The great grey kangaroo (*Macropus giganteus*) produces a single young ('joey') about 2 cm/1 in long after a very short gestation, usually in early summer. At birth the young kangaroo is too young even to suckle. It remains in its mother's pouch, attached to a nipple which squirts milk into its mouth at intervals. It stays in the pouch, with excursions as it matures, for about 280 days.

A new species of kangaroo was discovered 1994 in New Guinea. Local people know it as 'bondegezou'. It weighs 15 kg/33 lb and is 1.2 m/3.9 ft in height. As it shows traits of both arboreal and ground-dwelling species, it may be a 'missing link'.

kangaroo

A fully grown kangaroo can jump 13 m/14 yd. Mathematical calculations have shown that at speeds of over 29 kmph/18 mph, bouncing is a more energy-efficient way of moving for a kangaroo than running would be.

kangaroo



(Image © Research Machines plc)

The giant grey kangaroo may reach a weight of 90 kg/200 lb and a height of over 1.5 m/5 ft. Like the red kangaroo, the grey kangaroo lives in small herds, sheltering by rocky outcrops during the heat of the day and emerging during the night to feed and drink.

kaolin

or china clay

group of clay minerals, such as kaolinite, $Al_2Si_2O_5(OH)_4$, derived from the alteration of aluminium silicate minerals, such as feldspars and mica. It is used in medicine to treat digestive upsets, and in poultices.

Kaolinite is economically important in the ceramic and paper industries. It is mined in the UK, the USA, France, and the Czech Republic.

kaolinite

or kaolin

clay mineral, hydrous aluminum silicate, $Al_2Si_2O_5(OH)_4$, formed mainly by the chemical weathering of feldspar. It is made up of platelike crystals, the atoms of which are bonded together in two-dimensional sheets, between which the bonds are weak, so that they are able to slip over one another, a process made more easy by a layer of water. It is important in the manufacture of porcelain and other ceramics, paper, rubber, paint, textiles, and medicines. It is mined in France, the UK, Germany, China, and the USA.

kapok

silky hairs that surround the seeds of certain trees, particularly the **kapok tree** (*Bombax ceiba*) of India and Malaysia and the **silk-cotton tree** (*Ceiba pentandra*) of tropical America. Kapok is used for stuffing cushions and mattresses and for sound insulation; oil obtained from the seeds is used in food and soap.

karat

or carat

the unit of purity in gold in the USA. Pure gold is 24-karat; 22-karat (the purest used in jewelry) is 22 parts gold and two parts alloy (to give greater strength); 18-karat is 75% gold.

karst

landscape characterized by remarkable surface and underground forms, created as a result of the action of water on permeable limestone. The feature takes its name from the Karst (meaning **dry**) region on the Adriatic coast of Slovenia and Croatia, but the name is applied to landscapes throughout the world, the most dramatic of which is found near the city of Guilin in the Guangxi province of China. Karst landscapes are characterized by underground features such as caves, caverns, stalactites, and stalagmites. On the surface, clints, grikes, gorges, and swallow holes are common features.

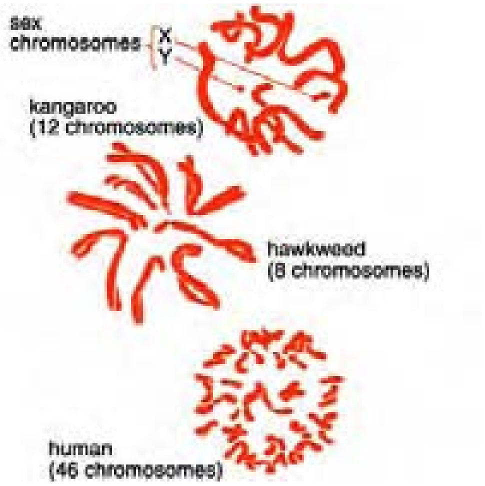
Limestone is soluble in the weak acid of rainwater. Erosion takes place most swiftly along cracks and joints in the limestone and these open up into gullies called grikes. The rounded blocks left upstanding between them are called clints.

karyotype

in biology, the set of chromosomes characteristic of a given species. It is described as the number, shape, and size of the chromosomes in a single cell of an organism. In humans, for example, the karyotype consists of 46 chromosomes, in mice 40, crayfish 200, and in fruit flies 8.

The diagrammatic representation of a complete chromosome set is called a **karyogram**.

karyotype



(Image © Research Machines plc)

The characteristics, or karyotype, of the chromosomes vary according to species. The kangaroo has 12 chromosomes, the hawkweed has 8, and a human being has 46.

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katydid

or bush cricket or longhorn grasshopper

one of over 4,000 insect species, most of which are tropical, related to grasshoppers.

Members of this family have very long antennae and they tend to be wingless. The tympanal organs ('ears') are on the forelegs. They may be either plant-eating or carnivorous.

Some species are winged and the left forewing generally overlaps the right one; stridulation is produced by rubbing the forewings together. The winged species are usually green and are found among herbage, bushes, and trees where they often simulate the colour and shape of a leaf. Wingless forms inhabit places at ground-level, such as in the soil or under stones.

classification

Katydids are in the family Tettigoniidae in order Orthoptera, class Insecta, phylum Arthropoda.

Katz, Bernard (1911-2003)

German-born British biophysicist who was awarded a Nobel Prize for Physiology or Medicine in 1970 for work on the storage, release, and inactivation of neurotransmitters, research vital in the search for remedies for nervous and mental disorders. He was knighted in 1969.

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kauri pine

New Zealand coniferous tree (see conifer). Its fossilized gum deposits are valued in varnishes; the wood is used for carving and handicrafts. (*Agathis australis*, family Araucariaceae.)

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kayser

unit of wave number (number of waves in a unit length), used in spectroscopy. It is expressed as waves per centimetre, and is the reciprocal of the wavelength. A wavelength of 0.1 cm has a wave number of 10 kaysers.

---

kcal

symbol for **kilocalorie** (see calorie).

---

kea

hawklike greenish parrot found in New Zealand. It eats insects, fruits, and discarded sheep offal. The Maori name imitates its cry. (Species *Nestor notabilis*, family Psittacidae, order Psittaciformes.) In 2000 there were only about 2,000 keas remaining.

Keck Telescope

world's largest optical telescope, situated on Mauna Kea, Hawaii. It has a primary mirror 10 m/33 ft in diameter, unique in that it consists of 36 hexagonal sections, each controlled and adjusted by a computer to generate single images of the objects observed; it weighs 331 tons and became fully operational in 1992. It received its first images in 1990.

An identical telescope next to it, named Keck II, became operational in 1996. Both telescopes are jointly owned by the California Institute of Technology, Pasadena, and the University of California's Lick Observatory, Mount Hamilton.

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keeshond

or Dutch barge dog

sturdily built dog with erect ears and curled tail. It has a long grey top-coat, forming a mane around the neck, and a short, very thick undercoat, with darker 'spectacles' around the eyes. The ideal height is 46 cm/18 in for dogs; 43 cm/17 in for bitches, and the ideal weight is 25-30 kg/55-66 lb.

Keeshond

Go to site

Profile of the keeshond dog. As well as information about the temperament, grooming, and origin of the breed, there are many photographs.

Kekulé von Stradonitz, Friedrich August (1829-1896)

German chemist whose theory in 1858 of molecular structure revolutionized organic chemistry. He proposed two resonant forms of the benzene ring.

In 1865 Kekulé announced his theory of the structure of benzene, which he envisaged as a hexagonal ring of six carbon atoms connected by alternate single and double bonds. In 1867 he proposed the tetrahedral carbon atom, which was to become the cornerstone of modern structural organic chemistry.

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keloid

in medicine, overgrowth of fibrous tissue, usually produced at the site of a scar. Surgical removal is often unsuccessful, because the keloid returns.

---

kelp

collective name for a group of large brown seaweeds. Kelp is also a term for the powdery ash of burned seaweeds, a source of iodine. (Typical families Fucaceae and Laminariaceae.)

The brown kelp (*Macrocystis pyrifera*), abundant in Antarctic and sub-Antarctic waters, is one of the fastest-growing living things, reaching lengths of up to 100 m/320 ft. It is farmed for the alginate industry, its rapid surface growth allowing cropping several times a year, but it is an unwanted pest in North Atlantic waters.

Kelvin, William Thomson (1824-1907)

1st Baron Kelvin

Irish physicist who introduced the **kelvin scale**, the absolute scale of temperature. His work on the conservation of energy in 1851 led to the second law of thermodynamics. He was knighted in 1866, and made a baron in 1892.

Kelvin's knowledge of electrical theory was largely responsible for the first successful transatlantic telegraph cable. In 1847 he concluded that electrical and magnetic fields are distributed in a manner analogous to the transfer of energy through an elastic solid. From 1849 to 1859 Kelvin also developed the work of English scientist Michael Faraday into a full theory of magnetism, arriving at an expression for the total energy of a system of magnets.

Kelvin, William Thomson

Go to site

Short biography of Irish physicist William Thomson (Lord Kelvin). The article, which quotes from contemporary sources and links to other important figures, is accompanied by quotes, references, and a list of accolades.

Kelvin scale

temperature scale used by scientists. It begins at absolute zero (-273.15°C) and increases in kelvins, the same degree intervals as the Celsius scale; that is, 0°C is the same as 273.15 K and 100°C is 373.15 K. It is named after the Irish physicist William Thomson, 1st Baron Kelvin.

Kendall, Edward Calvin (1886-1972)

US biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1950, with Philip Hench and Tadeus Reichstein, for their work on the structure and biological effects of hormones of the adrenal cortex. In 1914 Kendall isolated the hormone thyroxine, the active compound of the thyroid gland. He went on to work on secretions from the adrenal gland, among which he discovered the steroid cortisone.

Kennedy Space Center

KSC

NASA launch site on Merritt Island, near Cape Canaveral, Florida, used for *Apollo* project and space shuttle launches. It was established in 1962 and celebrated its 40th anniversary in 2002. The first *Apollo* flight to land on the Moon (1969) and *Skylab*, the first orbiting laboratory (1973), were launched from the site. In 2003, it launched the two spacecraft of the Mars Exploration Rover mission.

The centre, named after US president John F Kennedy, is dominated by the Vehicle Assembly Building, 160 m/525 ft tall, used for assembling Saturn rockets and space shuttles. The centre is in charge of the checkout, launch, and landing of shuttles. On 12 August 2003, the deputy director, James W Kennedy, succeeded Roy D Bridges, to become the eighth director of KSC.

Kennedy Space Center

Go to site

Latest news and information about space shuttle and rocket launches, progress on the *International Space Station*, development of spaceport technology, and other activities at the Kennedy Space Center. There are plentiful textual and multimedia resources, including a space flight archive profiling crewed space programmes and an excellent history of space flight.

Kennelly-Heaviside layer

former term for the E-layer of the ionosphere.

Kepler, Johannes (1571-1630)

German mathematician and astronomer. He formulated what are now called Kepler's laws of planetary motion. Kepler's laws are the basis of our understanding of the Solar System, and such scientists as Isaac Newton built on his ideas.

Kepler was one of the first advocates of Sun-centred cosmology, as put forward by Copernicus. Unlike Copernicus and Galileo, Kepler rejected the Greek and medieval belief that orbits must be circular in order to maintain the fabric of the cosmos in a state of perfection.

early work

Kepler also produced a calendar of predictions for the year 1595 which proved uncanny in its accuracy. In 1596, he published his *Prodromus dissertationum cosmographicarum seu mysterium cosmographicum* in which he demonstrated that the five Platonic solids (the only five regular polyhedrons) could be fitted alternately inside a series of spheres to form a 'nest'. The nest described quite accurately (within 5%) the distances of the planets from the Sun. Kepler regarded this discovery as a divine inspiration that revealed the secret of the Universe. Written in accordance with Copernican theories, it brought Kepler to the attention of all European astronomers.

In 1601 Kepler was bequeathed all of Tycho Brahe's data on planetary motion. He had already made a bet that, given Tycho's unfinished tables, he could find an accurate planetary orbit within a week. It was five years before Kepler obtained his first planetary orbit, that of Mars. His analysis of these data led to the discovery of his three laws. In 1604 his attention was diverted from the planets by his observation of the appearance of a new star, 'Kepler's nova'. Kepler had observed the first supernova visible since the one discovered by Brahe in 1572.

Kepler's laws

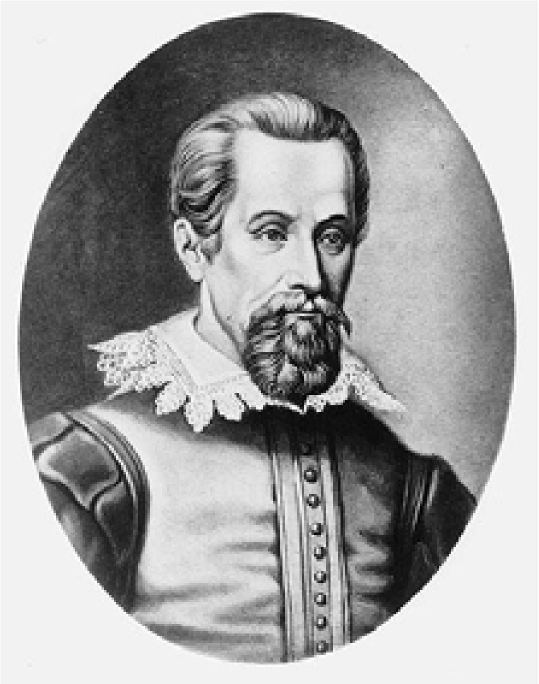
Kepler's first two laws of planetary motion were published in *Astronomia Nova* (1609). The first law stated that planets travel in elliptical rather than circular, or epicyclic, orbits and that the Sun occupies one of the two foci of the ellipses. The second law established the Sun as the main force governing the orbits of the planets. It stated that the line joining the Sun and a planet traverses equal areas of space in equal periods of time, so that the planets move more quickly when they are nearer the Sun. He also suggested that the Sun itself rotates, a theory that was confirmed using Galileo's observations of sunspots, and he postulated that this established some sort of 'magnetic' interaction between the planets and the Sun, driving them in orbit. This idea, although incorrect, was an important precursor of Newton's gravitational theory.

Kepler's third law was published in *De Harmonices Mundi*. It described in precise mathematical language the link between the distances of the planets from the Sun and their velocities – specifically, that the orbital velocity of a planet is inversely proportional to its distance from the Sun.

Rudolphine Tables and other work

Kepler finally completed and published the *Rudolphine Tables* (1627) based on Brahe's observations. These were the first modern astronomical tables, enabling astronomers to calculate the positions of the planets at any time in the past, present, or future. The publication also included other vital information, such as a map of the world, a catalogue of stars, and the latest aid to computation, logarithms.

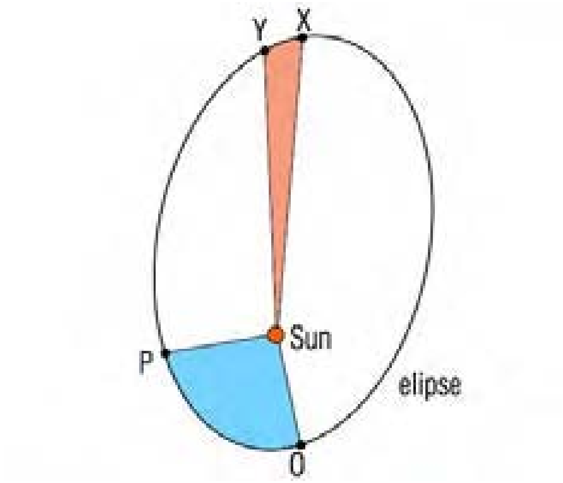
Kepler



(Image © Billie Love)

German mathematician Johannes Kepler, who was astronomer to the Holy Roman Emperor and formulated laws of planetary motion. An early advocate of the heliocentric theory of the solar system first developed by Nicolaus Copernicus, Kepler's observations that planetary orbits were elliptical and not circular foreshadowed the general application of scientific method to astronomy.

Kepler



(Image © Research Machines plc)

Kepler's second law states that the pink-shaded area equals the blue-shaded area if the planet moves from P to O in the same time that it moves from X to Y. The law says, in effect, that a planet moves fastest when it is closest to the Sun.

Kepler, Johannes

Go to site

Profile of the life and work of the German astronomer. Kepler's life is traced through his early conversion to Copernican theory, his work with Tycho Brahe, and the support he gave to Galileo. The traumas of his personal life, the accusations of witchcraft levelled against his mother, and the turmoil caused to his career by the Thirty Years' War, are all set out here. This account has pictures of Kepler and a high-resolution image of the model he used to demonstrate the relative distances of the planets from the Sun.

Kepler's laws

in astronomy, three laws of planetary motion formulated in 1609 and 1619 by German mathematician and astronomer Johannes Kepler: (1) the orbit of each planet is an ellipse with the Sun at one of the foci; (2) the radius vector of each planet sweeps out equal areas in equal times; (3) the squares of the periods of the planets are proportional to the cubes of their mean distances from the Sun.

Kepler derived the laws after exhaustive analysis of numerous observations of the planets, especially Mars, made by Danish astronomer Tycho Brahe without telescopic aid. British physicist and mathematician Isaac Newton later showed that Kepler's laws were a consequence of the theory of universal gravitation.

---

keratin

fibrous protein found in the skin of vertebrates and also in hair, nails, claws, hooves, feathers, and the outer coating of horns.

If pressure is put on some parts of the skin, more keratin is produced, forming thick calluses that protect the layers of skin beneath.

keratin

Sheep have more than 100 different genes for keratins.

---

keratitis

in medicine, eye disease characterized by inflammation of the cornea. This may be the result of mechanical trauma, for example being hit in the eye, contact with chemicals, or infection with bacteria or viruses. The affected eye is red and painful and those affected should avoid exposure to light due to sensitivity. Treatment varies depending on the cause of the disorder.

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kernel

the inner, softer part of a nut, or of a seed within a hard shell.

---

kerosene

thin oil obtained from the fractional distillation of crude oil (unrefined petroleum; a highly refined form is used in jet aircraft fuel. Kerosene is a mixture of hydrocarbons of the alkane series, consisting mainly of hydrocarbons with 11 or 12 carbon atoms. Boiling points range from 160°C/320°F to 250°C/480°F. Crude oil contains approximately 10–15% kerosene.

Kerry blue terrier

compact and sturdy dog, with a soft, full coat of bluish tone. It is 46 cm/18 in high and weighs 15–17 kg/33–37.4 lb. Its ears lie close to the head and it has a thin tail that is held erect.

Kertész, André (1894-1986)

Hungarian-born US photographer. His spontaneity had a great impact on photojournalism. A master of the 35-mm-format camera, he recorded his immediate environment (Paris, New York) with wit and style.

---

kestrel

either of two small species of falcon (genus *Falco*): the Eurasian kestrel *F. tinnunculus*, about 13.5 in/35 cm long, which occasionally visits eastern North America and the Aleutians; and the American kestrel or sparrowhawk *F. sparverius*, somewhat smaller, found throughout most of North America. Both species are russet, gray, and tan in color, with the male American kestrel having more gray on its wings. They hunt mainly by hovering in mid-air while watching for grasshoppers and small mammals.

---

ketone

member of the group of organic compounds containing the carbonyl group ($C{=}O$) bonded to two atoms of carbon (instead of one carbon and one hydrogen as in aldehydes). Ketones are liquids or low-melting-point solids, slightly soluble in water. An example is propanone (acetone, CH_3COCH_3), used as a solvent.

---

kettle

glacial geologic feature, formed when a block of stagnant ice from a receding glacier becomes isolated and buried in glacial outwash or drift before it finally melts. When the block disappears, it leaves a pit or depression called a kettle, in the drift. These depressions range from 15 ft/5 m to 8 mi/13 km in diameter, and some exceed 100 ft/33 m in depth.

As time passes, water sometimes fills the kettles to form lakes or swamps, features found throughout much of north North America. Lake Ronkonkoma, the largest lake on Long Island, New York, is an example.

Kew Gardens

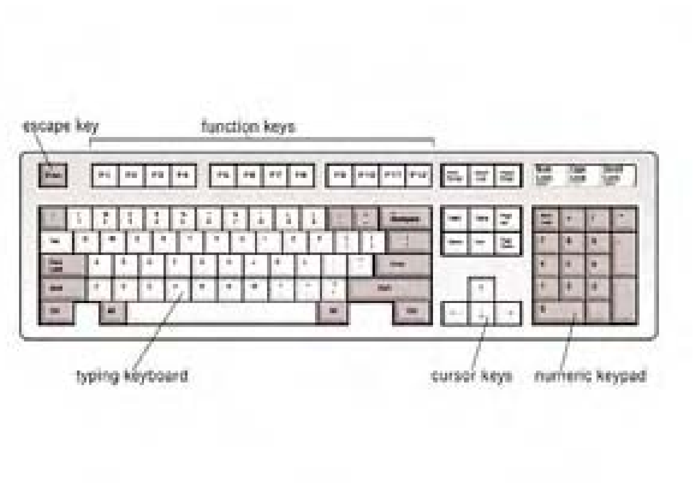
popular name for the Royal Botanic Gardens, Kew, Surrey, England. They were founded in 1759 by Augusta of Saxe-Coburg (1719–1772), the mother of King George III, as a small garden and were passed to the nation by Queen Victoria in 1840. By then they had expanded to almost their present size of 149 hectares/368 acres and since 1841 have been open daily to the public. They contain a collection of over 25,000 living plant species and many fine buildings. The gardens are also a centre for botanical research.

---

keyboard

in computing, an input device resembling a typewriter keyboard, used to enter instructions and data. There are many variations on the layout and labelling of keys. Extra numeric keys may be added, as may special-purpose function keys, whose effects can be defined by programs in the computer.

keyboard



(Image © Research Machines plc)

A standard 102-key keyboard. As well as providing a QWERTY typing keyboard, the function keys (labelled F1-F12) may be assigned tasks specific to a particular system.

---

kg

symbol for **kilogram**.

---

khamsin

hot southeasterly wind that blows from the Sahara desert over Egypt and parts of the Middle East from late March to May or June. It is called *sharav* in Israel.

Khorana, Har Gobind (1922-)

Indian-born US biochemist who was awarded the Nobel Prize for Physiology or Medicine in 1968 for his part in the interpretation of genetic code and its function in protein synthesis. In 1976 he led the team that first synthesized a biologically active gene. His work provides much of the basis for gene therapy and biotechnology.

Khwarizmi, al-, Muhammad ibn-Musa (c. 780-c. 850)

Persian mathematician. He wrote a book on algebra, from part of whose title (*al-jabr*) comes the word 'algebra', and a book in which he introduced to the West the Hindu-Arabic decimal number system. The word 'algorithm' is a corruption of his name.

He was born in Khwarizm (now Khiva, Uzbekistan), but lived and worked in Baghdad. He compiled astronomical tables and was responsible for introducing the concept of zero into Arab mathematics.

---

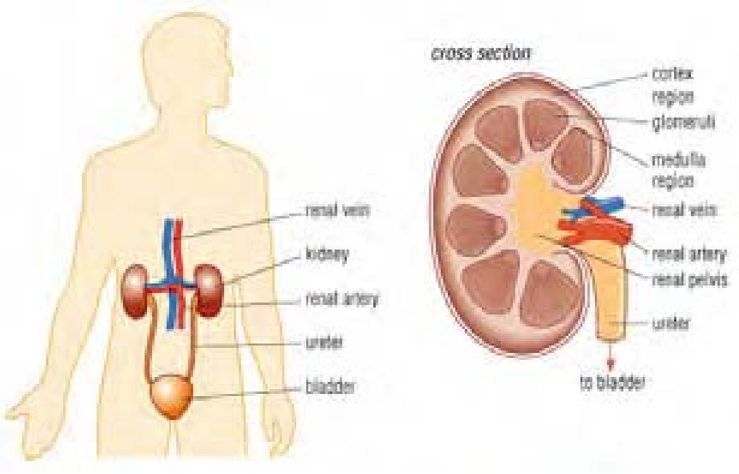
kidney

in vertebrates, one of a pair of organs responsible for fluid regulation, excretion of waste products, and maintaining the ionic composition of the blood - in other words the regulation of the concentrations of some chemicals in the blood. The kidneys are situated on the rear wall of the abdomen. Each one consists of a number of long tubules (see nephron) - the outer parts filter the aqueous components of blood, and the inner parts selectively reabsorb vital salts, leaving waste products in the remaining fluid (urine), which is passed through the ureter to the bladder.

The kidneys tasks can be broken down into a number of stages: filtering of the blood; re-absorbance of all sugar; re-absorbance of the dissolved ions needed by the body; re-absorbance of as much water as the body needs; and release of urea, excess ions, and excess water as urine.

The action of the kidneys is vital and so kidney failure is serious. However, if one kidney fails, the other enlarges to take over its function. A patient with two defective kidneys may still continue near-normal life with the aid of dialysis using a kidney machine or continuous ambulatory peritoneal dialysis (CAPD), or by a kidney transplant. Other diseases of the kidney can include the formation of kidney stones. These hard stones can build up as a result of high levels of blood calcium or high levels of uric acid, and can cause intense pain as they travel down the ureter, as well as causing bleeding in the tissues of the urinary tract.

kidney



(Image © Research Machines plc)

Blood enters the kidney through the renal artery. The blood is filtered through the glomeruli to extract the nitrogenous waste products and excess water that make up urine. The urine flows through the ureter to the bladder; the cleaned blood then leaves the kidney via the renal vein.

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kidney machine

medical equipment used in dialysis.

---

killer whale

or orca

toothed whale belonging to the dolphin family, found in all seas of the world. It is black on top, white below, and grows up to 9 m/30 ft long. It is the only whale that has been observed to prey on other whales, as well as on seals and seabirds. (Species *Orcinus orca*, family Delphinidae.)

killer whale

Killer whales deliberately strand themselves by hurtling out of the sea on to the beach to capture elephant seal pups. This dangerous hunting technique (with a success rate of only 35%) takes the killer whale calves more than two years to learn.

killer whale

(Image © Research Machines plc)

The killer whale or orca, a hunter of seals and penguins, is found in all the oceans of the world, and can grow to a length of 9 m/30 ft. Many are in captivity. This whale was photographed in the aquarium at Stanley Park, Vancouver, Canada.

Killer Whales

Go to site

Pictures and videos of this sea creature. There is also a lot of detailed biological information concerning, for example, the habitat, behaviour, and communication of killer whales. There are also plenty of activities and ideas to keep younger children entertained.

---

kiln

high-temperature furnace used for drying timber, roasting metal ores, or for making cement, bricks, and pottery. Ceramic kilns include early kilns, such as bonfire, sawdust, and wood-fired kilns, which have their roots in primitive cultures; and modern kilns, such as electric-, gas-, and oil-fired kilns, used in both the arts and industry. Oil- or gas-fired kilns can bake ceramics at up to 1,760°C/3,200°F; electric kilns do not generally reach such high temperatures. The type of kiln used to fire a ceramic will affect the qualities and appearance of the final creation.

---

kilo-

prefix denoting multiplication by 1,000, as in kilohertz, a unit of frequency equal to 1,000 hertz.

---

kilobyte

K or KB

in computing, a unit of memory equal to 1,024 bytes. It is sometimes used, less precisely, to mean 1,000 bytes.

In the metric system, the prefix 'kilo-' denotes multiplication by 1,000 (as in kilometre, a unit equal to 1,000 metres). However, computer memory size is based on the binary number system, and the most convenient binary equivalent of 1,000 is 2^{10}, or 1,024.

---

kilogram

symbol kg

SI unit of mass equal to 1,000 grams (2.24 lb). It is defined as a mass equal to that of the international prototype, a platinum-iridium cylinder held at the International Bureau of Weights and Measures in Sèvres, France.

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kilometre

symbol km

unit of length equal to 1,000 metres, equivalent to 3,280.89 ft or 0.6214 (about 5/8) of a mile.

---

kilowatt

symbol kW

unit of power equal to 1,000 watts or about 1.34 horsepower. If an electrical appliance has a power rating of 1 kW, it will change 1000 J of electrical energy into other forms of energy every second; for example, a 1 kW electric heater changes 1000 J of electrical energy into 1000 J of heat energy every second it is turned on.

---

kilowatt-hour

symbol kWh

commercial unit of electrical energy, defined as the work done by a power of 1,000 watts in one hour. It is used to calculate the cost of electrical energy taken from utility-company supplies.

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kimberlite

igneous rock that is ultramafic (containing very little silica); a type of alkaline peridotite with a porphyritic texture (larger crystals in a fine-grained matrix), containing mica in addition to olivine and other minerals. Kimberlite represents the world's principal source of diamonds.

Kimberlite is found in carrot-shaped pipelike intrusions called **diatremes**, where mobile material from very deep in the Earth's crust has forced itself upwards, expanding in its ascent. The material, brought upwards from near the boundary between crust and mantle, often altered and fragmented, includes diamonds. Diatremes are found principally near Kimberley, South Africa, from which the name of the rock is derived, and in the Yakut area of Siberia, Russia.

---

kinesis

(plural **kineses**) in biology, a nondirectional movement in response to a stimulus; for example, woodlice move faster in drier surroundings.
Taxis is a similar pattern of behaviour, but there the response is directional.

---

kinetic energy

the energy of a body resulting from motion.

A moving body has kinetic energy. This energy is equal to the work that would have to be done in bringing the body to rest, and is dependent on both the body's mass and speed. The kinetic energy in joules of a mass *m* kilograms travelling with speed *v* metres per second is given by the formula:

$KE = 1/2mv^2$

If a moving object collides with another object, then work is done. For example, if a moving car collides with a stationary car, it will cause the stationary car to move. The force from the moving object is used to move the stationary object by a certain distance.

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kinetics

branch of chemistry that investigates the rates of chemical reactions.

Chemical Kinetics: Terms and Concepts

Go to site

Introduction to chemical kinetics. This well-organized page defines the subject clearly, and considers topics such as reaction mechanisms and the factors that influence reaction rates.

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kinetics

alternative name for dynamics. It is distinguished from **kinematics**, which deals with motion without reference to force or mass.

---

kinetic theory

theory describing the physical properties of matter in terms of the behaviour - principally movement - of its component atoms or molecules. It states that all matter is made up of very small particles that are in constant motion, and can be used to explain the properties of solids, liquids, and gases, as well as changes of state. In a solid, the particles are arranged close together in a regular pattern and vibrate on the spot. In a liquid, the particles are still close together but in an irregular arrangement, and the particles are moving a little faster and are able to slide past one another. In a gas, the particles are far apart and moving rapidly, bouncing off the walls of their container. The temperature of a substance is dependent on the velocity of movement of its constituent particles, increased temperature being accompanied by increased movement.

A gas consists of rapidly moving atoms or molecules and, according to kinetic theory, it is their continual impact on the walls of the containing vessel that accounts for the pressure of the gas. The slowing of molecular motion as temperature falls, according to kinetic theory, accounts for the physical properties of liquids and solids, culminating in the concept of no molecular motion at absolute zero (0 K/-273.15°C).

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king crab

or Alaskan king crab

large, edible crab *Paralithodes camtschatica*, of the North Pacific. The term 'king crab' is sometimes used as another name for the horseshoe crab.

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kingdom

primary division in biological classification. At one time, only two kingdoms were recognized: animals and plants. Today most biologists prefer a five-kingdom system, even though it still involves grouping together organisms that are probably unrelated. One widely accepted scheme is as follows: **Kingdom Animalia** (all multicellular animals); **Kingdom Plantae** (all plants, including seaweeds and other algae, except blue-green); **Kingdom Fungi** (all fungi, including the unicellular yeasts, but not slime moulds); **Kingdom Protista** or **Protoctista** (protozoa, diatoms, dinoflagellates, slime moulds, and various other lower organisms with eukaryotic cells); and **Kingdom Monera** (all prokaryotes - the bacteria and cyanobacteria, or blue-green algae, and the archaea). The first four of these kingdoms make up the eukaryotes.

When only two kingdoms were recognized, any organism with a rigid cell wall was a plant, and so bacteria and fungi were considered plants, despite their many differences. Other organisms, such as the photosynthetic flagellates (euglenoids), were claimed by both kingdoms. The unsatisfactory nature of the two-kingdom system became evident during the 19th century, and the biologist Ernst Haeckel was among the first to try to reform it. High-power microscopes have revealed more about the structure of cells; it has become clear that there is a fundamental difference between cells without a nucleus (prokaryotes) and those with a nucleus (eukaryotes). However, these differences are larger than those between animals and higher plants, and are unsuitable for use as kingdoms. At present there is no agreement on how many kingdoms there are in the natural world.

Although the five-kingdom system is widely favoured, some schemes have as many as 20.

kingfisher

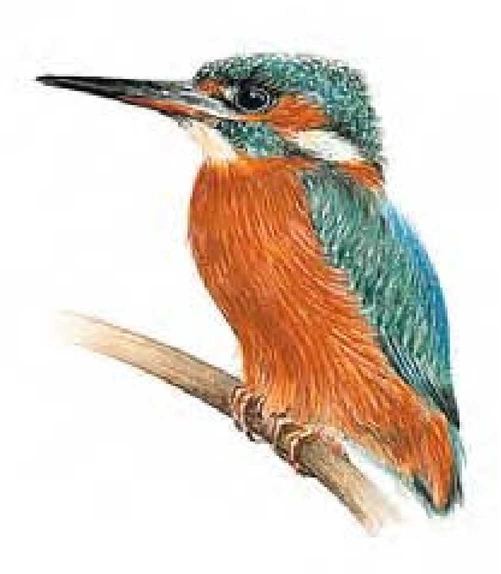
any of a group of heavy-billed birds found near streams, ponds, and coastal areas around the world. The head is exceptionally large, and the long, angular bill is keeled; the tail and wings are relatively short, and the legs very short, with short toes. Kingfishers plunge-dive for fish and aquatic insects. The nest is usually a burrow in a riverbank. (Family Alcedinidae, order Coraciiformes.)

There are 88 species of kingfisher, the largest being the Australian kookaburra. The Alcedinidae are sometimes divided into the subfamilies Daceloninae, Alcedininae, and Cerylinae.

kingfisher

Kingfishers have no blue pigment in their feathers. Their beautiful plumage appears to be blue as the upper feather layers scatter light and strongly reflect blue.

kingfisher



(Image © Research Machines plc)

The kingfisher, with its brilliantly coloured plumage and daggerlike beak, is unmistakeable. It is found in Europe, North Africa to Asia, New Guinea, and the Solomon Islands. When hunting, it perches on a branch overhanging a stream or lake, watching for prey, or it flies low over the water, perhaps hovering for a few seconds before diving.

kinkajou

Central and South American carnivorous mammal belonging to the raccoon family. Yellowish-brown, with a rounded face and slim body, the kinkajou grows to 55 cm/1.8 ft with a 50 cm/1.6 ft tail, and has short legs with sharp claws. It spends its time in trees and has a prehensile tail, which it uses as an extra limb when moving from branch to branch. It feeds largely on fruit. (Species *Potos flavus*, family Procyonidae.)

kin selection

in biology, the idea that altruism shown to genetic relatives can be worthwhile, because those relatives share some genes with the individual that is behaving altruistically, and may continue to reproduce. See inclusive fitness.

Alarm-calling in response to predators is an example of a behaviour that may have evolved through kin selection: relatives that are warned of danger can escape and continue to breed, even if the alarm caller is caught.

Kirchhoff, Gustav Robert (1824-1887)

German physicist who with R W von Bunsen developed spectroscopic analysis in the 1850s and showed that all elements, heated to incandescence, have their individual spectra.

Kirchhoff's laws

two laws governing electric circuits devised by the German physicist Gustav Kirchhoff.
Kirchhoff's first law states that the total current entering any junction in a circuit is the same as the total current leaving it. This is an expression of the conservation of electric charge.
Kirchhoff's second law states that the sum of the potential drops across each resistance in any closed loop in a circuit is equal to the total electromotive force acting in that loop. The laws are equally applicable to DC and AC circuits.

Kirkwood gaps

in astronomy, regions of the asteroid belt, between the planets Mars and Jupiter, where there are relatively few asteroids.

The orbital periods of particles in the gaps correspond to simple fractions, especially 1/3, 2/5, 3/7, and 1/2, of the orbital period of Jupiter, indicating that they are caused by the gravitational influence of the larger planet. The gaps are named after Daniel Kirkwood, the 19th-century US astronomer who first drew attention to them.

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kiss of life

or artificial ventilation

in first aid, another name for artificial respiration.

Kitasato, Shibasaburo (1852-1931)

Japanese bacteriologist who discovered the plague bacillus while investigating an outbreak of plague in Hong Kong. He was the first to grow the tetanus bacillus in pure culture. He and German bacteriologist Emil von Behring discovered that increasing nonlethal doses of tetanus toxin give immunity to the disease.

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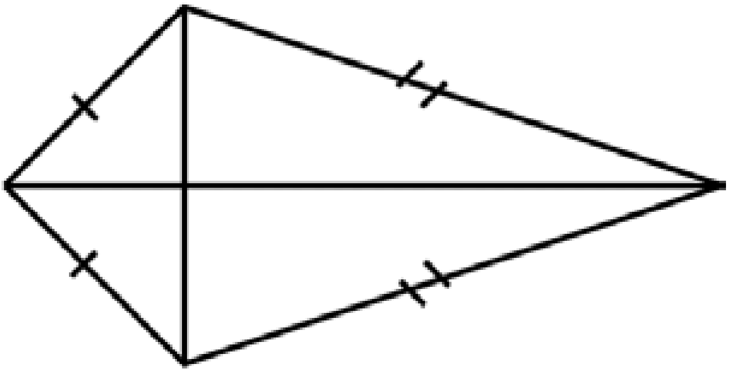
kite

quadrilateral with two pairs of adjacent equal sides. The geometry of this figure follows from the fact that it has one axis of symmetry.

kite



(Image © Research Machines plc)

Diagram of the geometric shape, demonstrating its properties: two pairs of adjacent equal sides and only one line of symmetry.

---

kite

any of a group of birds of prey found in all parts of the world. Kites have long, pointed wings and, usually, a forked tail. There are about 20 species. (Family Accipitridae, order Falconiformes.)

Kitt Peak National Observatory

KPNO

observatory in the Quinlan Mountains near Tucson, Arizona, operated by AURA (the Association of Universities for Research into Astronomy), by agreement with the National Science Foundation of the United States. It is a division of the National Optical Astronomy Observatories. Its main telescopes are the 4-m/158-in Mayall reflector (1973) and the McMath Solar Telescope (1962), the world's largest of its type.

Among numerous other telescopes on the site is a 2.3-m/90-in reflector owned by the Steward Observatory of the University of Arizona, and a 3.5-m/138-in reflecting telescope, opened in 1994, owned by the WIYN consortium, which comprises the University of Wisconsin, Indiana University, Yale University, and the National Optical Astronomy Observatories.

Kitt Peak National Observatory

Go to site

Comprehensive information on the range of research carried out at Kitt Peak, near Tucson, Arizona. In addition to scientific information of interest mainly to professional astronomers, there are details of current weather conditions at Kitt Peak, information for visitors, and links to other observatories in the southwestern USA. Visible and infrared images from satellites in geostationary orbits can also be accessed.

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kiwi

flightless bird found only in New Zealand. It has long hairlike brown plumage, minute wings and tail, and a very long beak with nostrils at the tip. It is nocturnal and insectivorous. It lays one or two white eggs per year, each weighing up to 450 g/15.75 oz. (Species *Apteryx australis*, family Apterygidae, order Apterygiformes.)

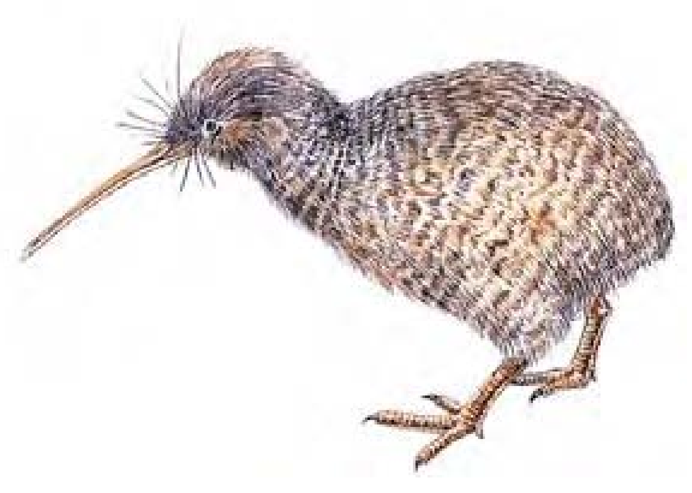
Kiwis live in burrows and a pair will share a territory of up to 40 hectares. The female is about a third bigger than the male and the egg she lays is up to a quarter of her own bodyweight. Incubation takes up to 80 days and the male may carry incubate the egg alone. By 2 weeks the chick is fully independent.

There are three main types of kiwi: brown, great spotted, and little spotted. All kiwi species have declined since European settlement of New Zealand, and the little spotted kiwi is most at risk. It survives only on one small island reservation, which was stocked with birds from the mainland. In 1999 there were fewer than 80,000 kiwis remaining in total.

kiwi

The kiwi produces the largest egg, proportionally to size, of any bird. The female lays one or two eggs, each weighing a quarter of her body weight.

kiwi



(Image © Research Machines plc)

The little spotted kiwi is one of three species of kiwi found in New Zealand. Kiwis have a good sense of smell – rare among birds – which is used to locate worms for food. The nostrils are at the tip of the pointed bill.

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kiwi fruit

or Chinese gooseberry

fruit of a vinelike plant grown commercially on a large scale in New Zealand. Kiwi fruits are egg-sized, oval, and similar in flavour to gooseberries, though much sweeter, with a fuzzy brown skin. (*Actinidithia chinensis*, family Actinidiaceae.)

Klaproth, Martin Heinrich (1743-1817)

German chemist who first identified the elements uranium and zirconium, in 1789, and was the second person to isolate titanium, chromium, and cerium. He was a pioneer of analytical chemistry.

Klein, Melanie (1882-1960)

born Melanie Reizes

Austrian child psychoanalyst. She pioneered child psychoanalysis and play studies, and was influenced by Sigmund Freud's theories. She published *The Psychoanalysis of Children* (1960).

Klein intended to follow a medical career. She gave this up when she married, but after the birth of her three children became interested in psychoanalysis. In 1919 she published her first paper on the psychoanalysis of young children. She moved to London 1926, where the main part of her work was done. In 1934 Klein extended her study to adult patients, and her conclusions, based on her observations of infant and childhood anxiety, were published in her book *Envy and Gratitude* (1957).

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kleptomania

(Greek kleptes 'thief')

behavioural disorder characterized by an overpowering desire to possess articles for which one has no need. In kleptomania, as opposed to ordinary theft, there is no obvious need or use for what is stolen and sometimes the sufferer has no memory of the theft.

---

klipspringer

small African antelope. It reaches about 60 cm at the shoulder and males weigh about 10 kg; females are heavier, weighing 13 kg. Klipspringers are browsers, feeding on leaves, berries, flowers, and seed pods and can survive for long periods without water. They are common in rocky or mountainous areas in the Ethiopian highlands, Namibia, and Angola.

Klipspringers pair monogamously, a rarity in mammals. They scent-mark their territory by rubbing secretions from glands just below the eyes onto twigs and rocks

klipspringer

The klipspringer antelope scent-marks its territory around 500 times a day.

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km

symbol for **kilometre**.

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knapweed

any of several weedy plants belonging to the daisy family. In the common knapweed (*C. nigra*), also known as a **hardhead**, the hard, dark buds break open at the top into pale purple composite flowers. It is native to Europe and has been introduced to North America. (Genus *Centaurea*, family Compositae.)

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knifefish

any of a group of fishes in which the body is deep at the front and drawn to a narrow or pointed tail at the rear, the main fin being the well-developed long ventral (stomach) fin that completes the knifelike shape. The ventral fin is rippled for forward or backward movement. Knifefishes produce electrical fields, which they use for navigation. (Genus *Gymnotus* and other allied genera, family Gymnotidae.)

Knight, Charles (1874-1953)

US palaeontological artist who was influential in bringing dinosaurs to life in the public imagination. His extensive knowledge of anatomy and his collaborations with palaeontologists, such as Edward Drinker Cope and Henry Fairfield Osborn, mean his paintings accurately reflect scientific thinking of the time.

Knight began painting dinosaurs in the late 1890s and was active into the 1940s. He painted murals for the American Museum of Natural History and the Field Museum of Natural History in the 1920s.

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knocking

in a spark-ignition petrol engine, a phenomenon that occurs when unburned fuel-air mixture explodes in the combustion chamber before being ignited by the spark. The resulting shock waves produce a metallic knocking sound. Loss of power occurs, which can be prevented by reducing the compression ratio, re-designing the geometry of the combustion chamber, or increasing the octane number of the petrol (formerly by the use of tetraethyl lead anti-knock additives, but now increasingly by MTBE – methyl tertiary butyl ether in unleaded petrol).

Knossos

Middle and Late Bronze Age settlement, 8 km/5 mi south of present-day Iraklion, Crete. Knossos is one of the main cities of what is known as the Minoan civilization (a modern name derived from the legend of King Minos). The archaeological site, excavated by Arthur Evans in 1899–1935, includes the palace throne room, the remains of frescoes, and construction on more than one level. The Greek myth of Theseus's encounter with the Minotaur in a labyrinth was possibly derived from the ritual 'bull-leaping' by young people depicted in the palace frescoes and from the mazelike layout of the palace.

storage jars, Knossos

(Image © Corel)

Giant clay storage jars ('pithoi') at the ruined Minoan palace of Knossos, Crete. Knossos was restored early in the 20th century by Arthur Evans, the archaeologist who first excavated the site.

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knot

wading bird belonging to the sandpiper family. It is about 25 cm/10 in long, with a short bill, neck, and legs. In the winter, it is grey above and white below, but in the breeding season, it is brick-red on the head and chest and black on the wings and back. It feeds on insects and molluscs. (Species *Calidris canutus*, family Scolopacidae, order Charadriiformes.)

Breeding in North American, European, and Asian arctic regions, knots travel widely in winter, to be found as far south as South Africa, Australasia, and southern parts of South America.

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knot

in navigation, unit by which a ship's speed is measured, equivalent to one nautical mile per hour (one knot equals about 1.15 miles per hour). It is also sometimes used in aviation.

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knotgrass

annual plant belonging to the dock family. The bases of the small lance-shaped leaves enclose the slender stems, giving a superficial resemblance to grass. Small pinkish flowers are followed by seeds that are eaten by birds. Knotgrass grows worldwide except in the polar regions. (*Polygonum aviculare*, family Polygonaceae.)

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knowledge-based system

KBS

computer program that uses an encoding of human knowledge to help solve problems. It was discovered during research into artificial intelligence that adding heuristics (rules of thumb) enabled programs to tackle problems that were otherwise difficult to solve by the usual techniques of computer science.

Chess-playing programs have been strengthened by including knowledge of what makes a good position, or of overall strategies, rather than relying solely on the computer's ability to calculate variations.

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knowledge management

process by which an organization gathers, organizes, shares, and analyses its knowledge. Data entered via a keyboard, a scanner, voice input, or other input device, can be catalogued, indexed, filtered, and linked. The information can then be refined, for example through data mining, in preparation for dissemination.

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koala

marsupial (mammal that carries its young in a pouch) found only in eastern Australia. It feeds almost entirely on eucalyptus shoots. It is about 60 cm/2 ft long, and resembles a bear (it is often incorrectly described as a 'koala bear'). The popularity of its greyish fur led to its almost complete extermination by hunters. Under protection since 1936, it rapidly increased in numbers, but recently numbers have fallen from 400,000 in 1985 to 40,000-80,000 in 1995. (Species *Phascolarctos cinereus*, family Phalangeridae.)

A three-year trial began in November 1996 in southern Australia, overpopulated by koalas, to bring their numbers under control by giving males vasectomies and females hormone implants preventing ovulation. In 1997, the programme of sterilization continued, and a relocation plan, following earlier trials, began.

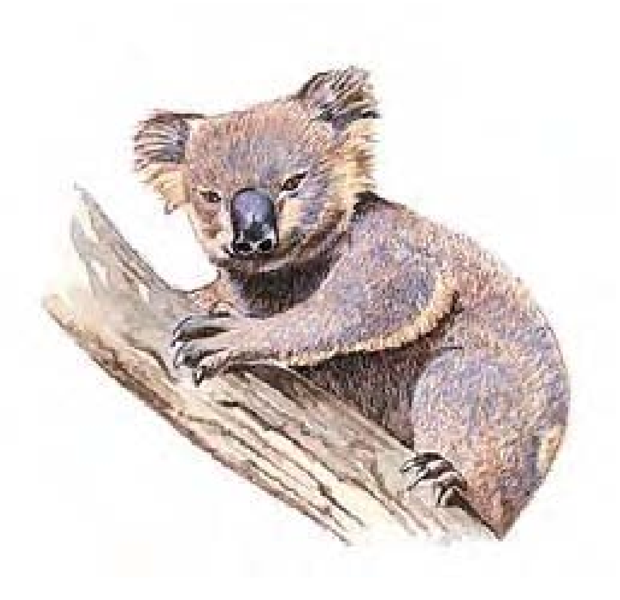
koala: fingerprints

The fingerprints of koala bears are very similar to those of humans, with similar whorls, loops, and arches. To avoid any confusion, Australian forensic scientists were warned, in 1996, to watch out for koalas at the scene of the crime.

koala: sleep

The koala sleeps on average 22 hours a day. It is the only animal more slothful than the sloth, which sleeps only 20 hours a day. Some say that the koala's diet of eucalyptus leaves means that it is in an almost permanently drugged sleep.

koala



(Image © Research Machines plc)

The koala lives in eucalyptus trees, and comes down only to pass from one tree to another. Its diet is limited to a few species of eucalyptus, of which it will eat over 1 kg/2 lb each day.

Australian Koala Foundation

Go to site

Large source of information on this reclusive marsupial. The behaviour of the animal, its unique physiology, and threats to its habitat are well described. There are also links to a number of koala conservation societies and news of latest koala research.

Koch, (Heinrich Hermann) Robert (1843-1910)

German bacteriologist who was awarded a Nobel Prize for Physiology or Medicine in 1905 for his investigations and discoveries in relation to tuberculosis. Koch and his assistants devised the techniques for culturing bacteria outside the body, and formulated the rules for showing whether or not a bacterium is the cause of a disease.

His techniques enabled him to identify the bacteria responsible for tuberculosis (1882), cholera (1883), and other diseases. He investigated anthrax bacteria in the 1870s and showed that they form spores which spread the infection.

Koch was a great teacher, and many of his pupils, such as Shibasaburo Kitasato, Paul Ehrlich, and Emil von Behring, became outstanding scientists.

Koh-i-noor

(Persian 'mountain of light')

diamond, originally part of the Aurangzeb treasure, seized in 1739 by the shah of Iran from the Moguls in India, taken back by Sikhs, and acquired by Britain in 1849 when the Punjab was annexed.

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kohlrabi

variety of kale, which is itself a variety of cabbage; it is used for food and resembles a turnip. The leaves of kohlrabi shoot from a round swelling on the main stem. (*Brassica oleracea caulorapa* or *B. oleracea gongylodes*, family Cruciferae.)

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kola

alternative spelling of cola, any of a group of tropical trees.

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kolkhoz

Russian term for a collective farm, as opposed to a sovkhoz or state-owned farm.

Königsberg bridge problem

long-standing puzzle that was solved by topology (the geometry of those properties of a figure which remain the same under distortion). In the city of Königsberg (now Kaliningrad in Russia), seven bridges connect the banks of the River Pregol'a and the islands in the river. For many years, people were challenged to cross each of the bridges in a single tour and return to their starting point. In 1736 Swiss mathematician Leonhard Euler converted the puzzle into a topological network, in which the islands and river banks were represented as nodes (junctions), and the connecting bridges as lines. By analysing this network he was able to show that it is not traversable – that is, it is impossible to cross each of the bridges once only and return to the point at which one started.

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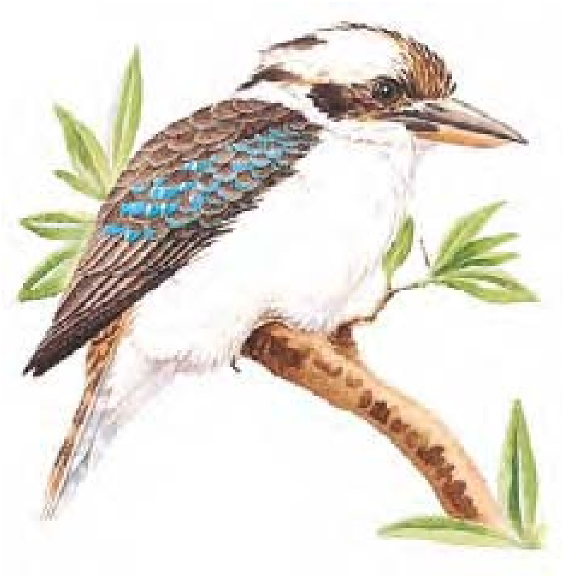
kookaburra

or laughing jackass

largest of the world's kingfishers, found in Australia, with an extraordinary laughing call. It feeds on insects and other small creatures. The body and tail measure 45 cm/18 in, the head is greyish with a dark eye stripe, and the back and wings are flecked brown with grey underparts. It nests in shady forest regions, but will also frequent the vicinity of houses, and its cry is one of the most familiar sounds of the bush in eastern Australia. (Species *Dacelo novaeguineae*, family Alcedinidae, order Coraciiformes.)

kookaburra



(Image © Research Machines plc)

Because of its loud laughing call, this bird is often called the laughing kookaburra or even laughing jackass. It is the largest member of the kingfisher family and is found in the lightly wooded or open country of Australia where it feeds largely on insects and other small creatures including rodents and reptiles.

Kornberg, Arthur (1918-)

US biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1959 for his discovery, in 1956, of enzymes that catalyse the formation of RNA (ribonucleic acid) and DNA (deoxyribonucleic acid). By 1967 he had synthesized a biologically active artificial viral DNA.

Korolev, Sergei Pavlovich (1906-1966)

Russian designer of the first Soviet intercontinental missile, used to launch the first Sputnik satellite in 1957, and of the *Vostok* spacecraft in which Yuri Gagarin made the world's first space flight in 1961.

Korolev and his research team built the first Soviet liquid-fuel rocket, launched in 1933. His innovations in rocket and space technology include ballistic missiles, rockets for geophysical research, launch vehicles, and crewed spacecraft. Korolev was also responsible for the *Voskhod* spaceship, from which the first space walks were made.

Korolev, Sergei P

Go to site

Biography of the Soviet rocket designer from NASA, the institution he spent his career attempting to outdo. There is a photograph of Korolev, an account of his technical achievements, and details of the imprisonment he suffered at the hands of Stalin.

Kourou

second-largest town of French Guiana, northwest of Cayenne, site of the Centre Spatial Guyanais (Guianese Space Centre) of the European Space Agency (ESA); population (2005 est) 27,000 (14% of the total population of French Guiana). ESA launches have included SMART-1 on 27 September 2003, a flight to orbit the Moon, and Rosetta on 2 March 2004, a mission to land on a comet.

Situated near the Equator, it is an ideal site for launches of satellites into geostationary orbit.

Kovalevskaia, Sofya Vasilevna (1850-1891)

born Sofya Vasilevna Krukovskya

Russian mathematician and novelist who worked on partial differential equations and Abelian integrals. In 1886 she won the Prix Bordin of the French Academy of Sciences for a paper on the rotation of a rigid body about a point, a problem the 18th-century mathematicians Euler and Lagrange had both failed to solve.

Kovalevskaya, Sofia Vasilyevna

Go to site

Extensive biography of the Russian mathematician. The site contains a description of her contribution to mathematics, and in particular to the theory of differential equations. Several literature references for further reading are also listed, and the Web site also features a photograph of Kovalevskaya.

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kph

or km/h

symbol for **kilometres per hour**.

Krafft-Ebing, Richard, Baron von (1840-1902)

German pioneer psychiatrist and neurologist. He published *Psychopathia Sexualis* (1886).

Krebs, Hans Adolf (1900-1981)

German-born British biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1953 for his discovery of the citric acid cycle, also known as the **Krebs cycle**, the final pathway by which food molecules are converted into energy in living tissues. He was knighted in 1958.

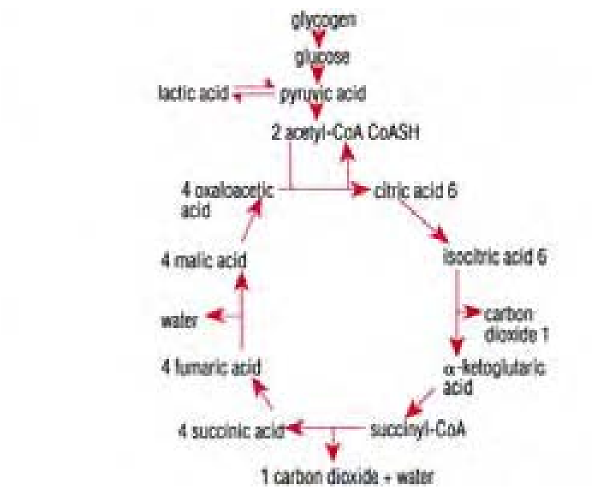
Krebs first became interested in the process by which the body degrades amino acids. He discovered that nitrogen atoms are the first to be removed (deamination) and are then excreted as urea in the urine. He then investigated the processes involved in the production of urea from the removed nitrogen atoms, and by 1932 he had worked out the basic steps in the urea cycle.

Krebs cycle

or citric acid cycle or tricarboxylic acid cycle

final part of the chain of biochemical reactions by which organisms break down food using oxygen to release energy (respiration). It takes place within structures called mitochondria in the body's cells, and breaks down food molecules in a series of small steps, producing energy-rich molecules of ATP.

Krebs cycle



(Image © Research Machines plc)

The purpose of the Krebs (or tricarboxylic acid) cycle is to complete the biochemical breakdown of food to produce energy-rich molecules, which the organism can use to fuel work. Acetyl coenzyme A (acetyl CoA) - produced by the breakdown of sugars, fatty acids, and some amino acids - reacts with oxaloacetic acid to produce citric acid, which is then converted in a series of enzyme-catalysed steps back to oxaloacetic acid. In the process, molecules of carbon dioxide and water are given off, and the precursors of the energy-rich molecules ATP are formed. (The numbers in the diagram indicate the number of carbon atoms in the principal compounds.)

Krebs cycle

To remember the Krebs cycle, also known as the TCA (tricarboxylic acid) cycle:

Actors **i**n **K**ansas **s**hould **s**ee **f**oreign **m**ovies, **o**f **c**ourse

Aconitate, **i**socitrate, α-**k**etoglutarate, **s**uccinyl-CoA, **s**uccinate, **f**umarate, **m**alate, **o**xaloacetate, **c**itrate

---

Kremer, Gerhard

Flemish mapmaker and mathematician, see Mercator, Gerardus.

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krill

any of several Antarctic crustaceans, the most common species being *Euphausia superba*. Similar to a shrimp, it is up to 5 cm/2 in long, with two antennae, five pairs of legs, seven pairs of light organs along the body, and is coloured orange above and green beneath. It is the most abundant animal, numbering perhaps 600 trillion (million million). (Order Euphausiacea.)

Moving in enormous swarms, krill constitute the chief food of the baleen whales, and have been used to produce a protein concentrate for human consumption, and meal for animal feed.

krill

Approximately 600 trillion krill thrive in the Southern Ocean. Together they weigh more than the world's entire human population. The schools of shrimplike krill (moving at a rapid 20 cm/7.9 in per sec) form the base of many food chains; whales alone consume 150 million tonnes a year.

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krypton

chemical symbol Kr

(Greek kryptos 'hidden')

colourless, odourless, gaseous, non-metallic element, atomic number 36, relative atomic mass 83.80. It is grouped with the noble gases (rare gases) in Group 0 of the periodic table, and was long believed not to enter into reactions, but it is now known to combine with fluorine under certain conditions; it remains inert to all other reagents. As with the other noble gases, krypton's lack of reactivity is due to its full outer shell of electrons. It is present in very small quantities in the air (about 114 parts per million). It is used chiefly in fluorescent lamps, lasers, and gas-filled electronic valves.

Krypton was discovered in 1898 in the residue from liquid air by British chemists William Ramsay and Morris Travers; the name refers to their difficulty in isolating it.

K-T boundary

geologists' shorthand for the boundary between the rocks of the Cretaceous and the Tertiary periods 65 million years ago. It coincides with the end of the extinction of the dinosaurs and in many places is marked by a layer of clay or rock enriched in the element iridium. Extinction of the dinosaurs at the K-T boundary and deposition of the iridium layer are thought to be the result of either impact of an asteroid or comet that crashed into the Yucatán Peninsula (forming the **Chicxulub crater**), perhaps combined with a period of intense volcanism on the continent of India.

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kudu

either of two species of African antelope. The **greater kudu** (*T. strepsiceros*) is fawn-coloured with thin white vertical stripes, and stands 1.3 m/4.2 ft at the shoulder, with head and body 2.4 m/8 ft long. Males have long spiral horns. The greater kudu is found in bush country from Angola to Ethiopia. The similar **lesser kudu** (*T. imberbis*) lives in East Africa and is 1 m/3 ft at the shoulder. (Genus *Tragelaphus*, family Bovidae.)

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kudzu

Japanese creeper belonging to the legume family, which helps fix nitrogen (see nitrogen cycle) and can be used as a feed crop for animals, but became a pest in the southern USA when introduced to check soil erosion. (*Pueraria lobata*, family Leguminosae.)

Kuiper, Gerard Peter (1905-1973)

Dutch-born US astronomer who made extensive studies of the Solar System. His discoveries included the atmosphere of the planet Mars and that of Titan, the largest moon of the planet Saturn. In 1951 he proposed the existence of the Kuiper belt, a ring of small bodies orbiting the Sun beyond the outermost planet.

Kuiper was adviser to many NASA exploratory missions, and pioneered the use of telescopes on high-flying aircraft. The Kuiper Airborne Observatory, one such telescope, is named after him; it was permanently grounded in October 1995.

Kuiper belt

ring of small, icy bodies orbiting the Sun beyond the outermost planet. The Kuiper belt, named after Dutch-born US astronomer Gerard Kuiper, who proposed its existence in 1951, is thought to be the source of comets that orbit the Sun with periods of less than 200 years. The first member of the Kuiper belt was seen in 1992. In 1995 the first comet-sized objects were discovered; previously the only objects found had diameters of at least 100 km/62 mi (comets generally have diameters of less than 10 km/6.2 mi). An object named Xena, discovered in 2003, is larger than Pluto.

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kumquat

small orange-yellow fruit of any of several evergreen trees native to East Asia and cultivated throughout the tropics. The trees grow 2.4-3.6 m/8-12 ft high and have dark green shiny leaves and white scented flowers. The fruit is eaten fresh (the skin is edible), preserved, or candied. The oval or Nagami kumquat is the most common variety. (Genus *Fortunella*, family Rutaceae.)

Kuroshio

or Japan Current

warm ocean current flowing from Japan to North America.

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kW

symbol for **kilowatt**.

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kwashiorkor

severe protein deficiency in children under five years, resulting in retarded growth, lethargy, oedema, diarrhoea, and a swollen abdomen. It is common in developing countries with a high incidence of malnutrition.

The term, derived from a Ghanaian word for a child who has been weaned due to the arrival of a new sibling, was introduced to medical literature by Dr Cicely Williams in the 1930s.

---

kyanite

aluminium silicate, Al_2SiO_5, a pale-blue mineral occurring as blade-shaped crystals. It is an indicator of high-pressure conditions in metamorphic rocks formed from clay sediments. Andalusite, kyanite, and sillimanite are all polymorphs (see polymorphism).

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labelled compound

or tagged compound

chemical compound in which a radioactive isotope is substituted for a stable one. The path taken by such a compound through a system can be followed, for example by measuring the radiation emitted.

This powerful and sensitive technique is used in medicine, chemistry, biochemistry, and industry.

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labellum

lower petal of an orchid flower; it is a different shape from the two lateral petals and gives the orchid its characteristic appearance. The labellum is more elaborate and usually larger than the other petals. It often has distinctive patterning to encourage pollination by insects; sometimes it is extended backwards to form a hollow spur containing nectar.

---

laburnum

any of a group of flowering trees or shrubs belonging to the pea family; the seeds develop in pealike pods but are poisonous. *L. anagyroides*, native to the mountainous parts of central Europe, is often grown as an ornamental tree. The flowers, in long drooping clusters, are bright yellow and appear in early spring; some varieties have purple or reddish flowers. (Genus *Laburnum*, family Leguminosae.)

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labyrinthitis

inflammation of the part of the inner ear responsible for the sense of balance (the labyrinth). It results in dizziness, which may then cause nausea and vomiting. It is usually caused by a viral infection of the ear (otitis), which resolves in a few weeks. The nausea and vomiting may respond to anti-emetic drugs.

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lac

resinous incrustation produced by the female of the lac insect (*Laccifer lacca*), which eventually covers the twigs of trees in India and the Far East. The gathered twigs are known as **stick lac**, and yield a useful crimson dye; **shellac**, which is used in varnishes, polishes, and leather dressings, is manufactured commercially by melting the separated resin and spreading it into thin layers or flakes.

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laccolith

intruded mass of igneous rock that forces apart two strata and forms a round lens-shaped mass many times wider than thick. The overlying layers are often pushed upward to form a dome. A classic development of laccoliths is illustrated in the Henry, La Sal, and Abajo mountains of southeastern Utah, found on the Colorado Plateau.

---

lacewing

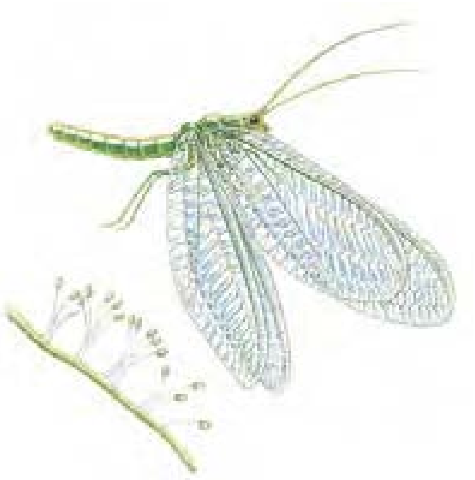
any of a group of insects found throughout the world. Lacewings take their name from the intricate veining of their two pairs of semitransparent wings. They have narrow bodies and long thin antennae. The larvae (called aphid lions) are predators, especially on aphids. (Families Hemerobiidae (brown lacewings) and Chrysopidae (green lacewings), order Neuroptera.)

The eggs of the golden-eye lacewing (*Chrysopa aculata*) are laid on the ends of plant stalks.

lacewing

Green lacewing larvae disguise themselves to find their food. They feed on woolly alder aphids, but the aphids are guarded by ants who milk them for their honeydew. The larvae trick the ants by plucking the white waxy fluff from the aphids and sticking it over themselves. With this disguise, they move among the aphids and eat them without the ants noticing.

lacewing



(Image © Research Machines plc)

Lacewing adults are slender-bodied flies with two pairs of wings covered with a network of veins - hence the name. They are often green in colour and have long antennae. Both adults and larvae feed voraciously on greenfly and other aphids so they are valuable to gardeners.

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lac insect

small plant-sucking insect related to scale insects and mealy bugs. The females of most species lack legs and have reduced antennae; their bodies are globular and enclosed within a dense resinous secretion called lac.

Lac insects are members of the family Lacciferidae, order Hemiptera (suborder Homoptera), class Insecta, phylum Arthropoda.

A number of species have two generations annually, in which two types of males occur: the first generation includes both winged and wingless males; the second generation is wingless.

Many species used to be of considerable commercial value, as they yield a dye. However, with the advent of synthetic dyes the demand for lac insects has decreased.

The Indian lac insect, *Laccifer lacca*, produces stick lac, a secretion from which shellac (used in varnishes and polishes) is prepared.

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lacrimation

in medicine, the production of tears by the lacrimal apparatus of the eye.

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lactation

secretion of milk in mammals, from the mammary glands. In late pregnancy, the cells lining the lobules inside the mammary glands begin extracting substances from the blood to produce milk. The supply of milk starts shortly after birth with the production of colostrum, a clear fluid consisting largely of water, protein, antibodies, and vitamins. The production of milk continues practically as long as the baby continues to suckle.

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lacteal

small vessel responsible for absorbing fat in the small intestine. Occurring in the fingerlike villi of the ileum, lacteals have a milky appearance and drain into the lymphatic system.

Before fat can pass into the lacteal, bile from the liver causes its emulsification into droplets small enough for attack by the enzyme lipase. The products of this digestion form into even smaller droplets, which diffuse into the villi. Large droplets re-form before entering the lacteal and this causes the milky appearance.

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lactic acid

or 2-hydroxypropanoic acid; $CH_3CHOHCOOH$

organic acid, a colourless, almost odourless liquid, produced by certain bacteria during fermentation and by active muscle cells when they are exercised hard and are experiencing oxygen debt. An accumulation of lactic acid in the muscles may cause cramp. It occurs in yogurt, buttermilk, sour cream, poor wine, and certain plant extracts, and is used in food preservation and in the preparation of pharmaceuticals.

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lactose

white sugar, found in solution in milk; it forms 5% of cow's milk. It is commercially prepared from the whey obtained in cheese-making. Like table sugar (sucrose), it is a disaccharide, consisting of two basic sugar units (monosaccharides), in this case, glucose and galactose. Unlike sucrose, it is tasteless.

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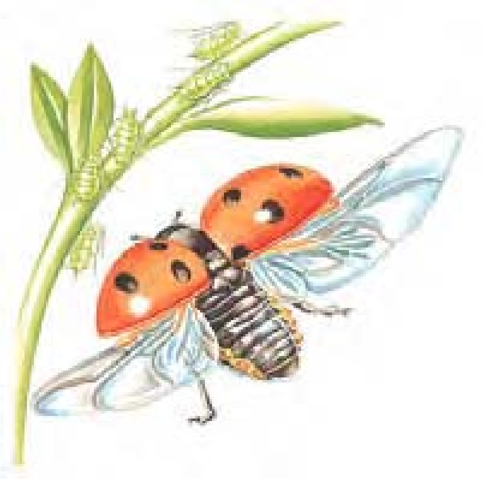
ladybird

or ladybug

any of various small beetles, generally red or yellow in colour, with black spots. There are more than 5,200 species worldwide. As larvae and adults, they feed on aphids and scale-insect pests. (Family Coccinellidae, order Coleoptera.)

Ladybirds have been used as a form of biological control since the 19th century and the US ladybird harvest was worth an annual $3-5 million by 1991.

ladybird



(Image © Research Machines plc)

Ladybirds' red colouration with black spots is a warning to potential predators, such as birds, that they are unpleasant to eat. When attacked by ants, ladybirds secrete a sticky fluid that entangles their antennae long enough to allow the beetle to escape. Ladybirds feed mainly on aphids.

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lady's smock

another name for the cuckoo flower.

Laënnec, René Théophile Hyacinthe (1781-1826)

French physician, inventor of the stethoscope in 1816. He advanced the diagnostic technique of auscultation (listening to the internal organs) with his book *Traité de l'auscultation médiaté* in 1819, which quickly became a medical classic.

Laënnec's special interest was in chest disease. Listening to the internal organs (auscultation) had been used diagnostically since the time of Hippocrates, but Laënnec introduced a wooden tube to transmit sound. He called it a stethoscope from the Greek *stethos* 'chest'.

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lagoon

coastal body of shallow salt water, usually with limited access to the sea. The term is normally used to describe the shallow sea area cut off by a coral reef or barrier islands.

Lagrange, Joseph Louis (1736-1813)

born Giuseppe Lodovico Lagrange

Italian-born French mathematician. His *Mécanique analytique* (1788) applied mathematical analysis, using principles established by Isaac Newton, to such problems as the movements of planets when affected by each other's gravitational force. He presided over the commission that introduced the metric system in 1793.

Lagrange, Joseph Louis

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of Joseph Louis Lagrange. In addition to biographical information, you will find a list of references about Lagrange and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Lagrange. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

Lagrangian points

five locations in space where the centrifugal and gravitational forces of two bodies neutralize each other; a third, less massive body located at any one of these points will be held in equilibrium with respect to the other two. Three of the points, L1-L3, lie on a line joining the two large bodies. The other two points, L4 and L5, which are the most stable, lie on either side of this line. Their existence was predicted in 1772 by French mathematician Joseph Louis Lagrange.

The **Trojan asteroids** lie at Lagrangian points L4 and L5 in Jupiter's orbit around the Sun. Clouds of dust and debris may lie at the Lagrangian points of the Moon's orbit around the Earth.

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lahar

mudflow formed of a fluid mixture of water and volcanic ash. During a volcanic eruption, melting ice may combine with ash to form a powerful flow capable of causing great destruction. The lahars created by the eruption of Nevado del Ruiz in Colombia, South America, in 1985 buried 22,000 people in 8 m/26 ft of mud.

Laing, R(onald) D(avid) (1927-1989)

Scottish psychoanalyst. He was the originator of the social theory of mental illness; for example, that schizophrenia is promoted by family pressure for its members to conform to standards alien to themselves. His books include *The Divided Self* (1960) and *The Politics of the Family* (1971).

Influenced by existentialist philosophy, Laing inspired the antipsychiatry movement. He observed interactions between people in an attempt to understand and describe their experience and thinking. In *The Divided Self* he criticized the psychiatrist's role as one that, with its objective scientific outlook, depersonalized the patient. By investigating the personal interactions within the families of diagnosed schizophrenics, he found that the seemingly bizarre behaviour normally regarded as indicating the illness began to make sense.

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lake

body of still water lying in depressed ground without direct communication with the sea. Lakes are common in formerly glaciated regions, along the courses of slow rivers, and in low land near the sea. The main classifications are by origin: **glacial lakes**, formed by glacial scouring; **barrier lakes**, formed by landslides and glacial moraines; **crater lakes**, found in volcanoes; and **tectonic lakes**, occurring in natural fissures.

Crater lakes form in the calderas of extinct volcanoes, for example Crater Lake, Oregon, USA. Subsidence of the roofs of limestone caves in karst landscape exposes the subterranean stream network and provides a cavity in which a lake can develop. Tectonic lakes form during tectonic movement, as when a rift valley is formed. Lake Tanganyika was created in conjunction with the East African Great Rift Valley. Glaciers produce several distinct types of lake, such as the lochs of Scotland and the Great Lakes of North America.

Lakes are mainly freshwater, but salt and bitter lakes are found in areas of low annual rainfall and little surface run-off, so that the rate of evaporation exceeds the rate of inflow, allowing mineral salts to accumulate. The Dead Sea has a salinity of about 250 parts per 1,000 and the Great Salt Lake, Utah, about 220 parts per 1,000. Salinity can also be caused by volcanic gases or fluids, for example Lake Natron, Tanzania.

In the 20th century large artificial lakes have been created in connection with hydroelectric and other works. Some lakes have become polluted as a result of human activity. Sometimes eutrophication (a state of overnourishment) occurs, when agricultural fertilizers leaching into lakes cause an explosion of aquatic life, which then depletes the lake's oxygen supply until it is no longer able to support life.

lake

(Image © Garret Nagle)

An aerial view of the lakes near Selfoss, a small town in southern Iceland. It is a centre for food processing and manufacture. Since the building of a bridge over the River Ölfusá, the town has evolved into the commercial centre of the region, providing a variety of financial, legal, and retail services.

Largest lakes in the world

Lake	Location	Area	
		sq km	sq mi
Caspian Sea	Azerbaijan/Russian Federation/Kazakhstan/Turkmenistan/Iran	370,990	143,239
Superior	USA/Canada	82,071	31,688
Victoria	Tanzania/Kenya/Uganda	69,463	26,820
Huron	USA/Canada	59,547	22,991
Michigan	USA	57,735	22,291
Aral Sea	Kazakhstan/Uzbekistan	33,800	13,000
Tanganyika	Tanzania/Democratic Republic of Congo/Zambia/Burundi	32,880	12,695
Baikal	Russian Federation	31,499	12,162
Great Bear	Canada	31,316	12,091
Malawi (or Nyasa)	Malawi/Tanzania/Mozambique	28,867	11,146
Great Slave	Canada	28,560	11,027
Erie	USA/Canada	25,657	9,906
Winnipeg	Canada	25,380	9,799
Ontario	USA/Canada	19,010	7,340
Balkhash	Kazakhstan	18,421	7,112
Ladoga	Russian Federation	17,695	6,832
Chad	Chad/Cameroon/Nigeria	16,310	6,297
Maracaibo	Venezuela	13,507	5,215

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lake dwelling

or pile dwelling

prehistoric habitation built on piles driven into the bottom of a lake or at the edge of a lake or river. Such villages are found throughout Europe, in West Africa, South America, Borneo, and New Guinea.

Objects recovered from lake dwellings are often unusually well preserved by the mud or peat in which they are buried. Wooden items, wickerwork, woven fabrics, fruit, and pollen grains have been retrieved.

Lakeland terrier

medium-sized wire-haired terrier weighing about 7-8 kg/15.5-17.5 lb with an ideal height of no more than 37 cm/14.5 in. Its skull is moderately broad, with small, V-shaped ears and dark eyes; the body is short and the tail traditionally docked.

Lamarck, Jean Baptiste Pierre Antoine de Monet (1744-1829)

Chevalier de Lamarck

French naturalist. His theory of evolution, known as **Lamarckism**, was based on the idea that acquired characteristics (changes acquired in an individual's lifetime) are inherited by the offspring, and that organisms have an intrinsic urge to evolve into better-adapted forms. *Philosophie zoologique/ Zoological Philosophy* (1809) outlined his 'transformist' (evolutionary) ideas.

Zoological Philosophy tried to show that various parts of the body developed because they were necessary, or disappeared because of disuse when variations in the environment caused a change in habit. If these body changes were inherited over many generations, new species would eventually be produced.

Lamarck was the first to distinguish vertebrate from invertebrate animals by the presence of a bony spinal column. He was also the first to establish the crustaceans, arachnids, and annelids among the invertebrates. It was Lamarck who coined the word 'biology'.

Lamarckism

theory of evolution, now discredited, advocated during the early 19th century by French naturalist Jean Baptiste Lamarck. Lamarckism is the theory that acquired characteristics, such as the increased body mass of an athlete, were inherited. It differs from the Darwinian theory of evolution.

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lambert

unit of luminance (the light shining from a surface), equal to one lumen per square centimetre. In scientific work the candela per square metre is preferred.

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lamina

in flowering plants (angiosperms), the blade of the leaf on either side of the midrib. The lamina is generally thin and flattened, and is usually the primary organ of photosynthesis. It has a network of veins through which water and nutrients are conducted. More generally, a lamina is any thin, flat plant structure, such as the thallus of many seaweeds.

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lammergeier

or bearded vulture

Old World vulture with a wingspan of 2.7 m/9 ft. It ranges over southern Europe, North Africa, and Asia, in wild mountainous areas. It feeds on offal and carrion and drops bones onto rocks to break them and so get at the marrow. (Species *Gypaetus barbatus*, family Accipitridae.)

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lamp, electric

device designed to convert electrical energy into light energy.

In a **filament lamp** such as a light bulb an electric current causes heating of a long thin coil of fine high-resistance wire enclosed at low pressure inside a glass bulb. In order to give out a good light the wire must glow white-hot and therefore must be made of a metal, such as tungsten, that has a high melting point. The efficiency of filament lamps is low because most of the electrical energy is converted to heat.

A **fluorescent lamp** uses an electrical discharge or spark inside a gas-filled tube to produce light. The inner surface of the tube is coated with a fluorescent material that converts the ultraviolet light generated by the discharge into visible light. Although a high voltage is needed to start the discharge, these lamps are far more efficient than filament lamps at producing light.

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lamprey

any of various eel-shaped jawless fishes. A lamprey feeds on other fish by fixing itself by its round mouth to its host and boring into the flesh with its toothed tongue. Lampreys breed in fresh water, and the young live as larvae for about five years before migrating to the sea. (Family Petromyzontidae.)

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lancelet

any of a variety of marine animals about 2.5 cm/1 in long. They have no skull, brain, eyes, heart, vertebral column, centralized brain, or paired limbs, but there is a notochord (a supportive rod) which runs from end to end of the body, a tail, and a number of gill slits. Found in all seas, lancelets burrow in the sand but when disturbed swim freely. (Genus *Amphioxus*, phylum Chordata, subphylum Cephalocordata.)

Taxonomically they are significant since the notochord may be regarded as the precursor of the backbone (spinal column).

Land, Edwin Herbert (1909-1991)

US inventor of the Polaroid Land camera in 1947. The camera developed the film in one minute inside the camera and produced an 'instant' photograph.

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land reclamation

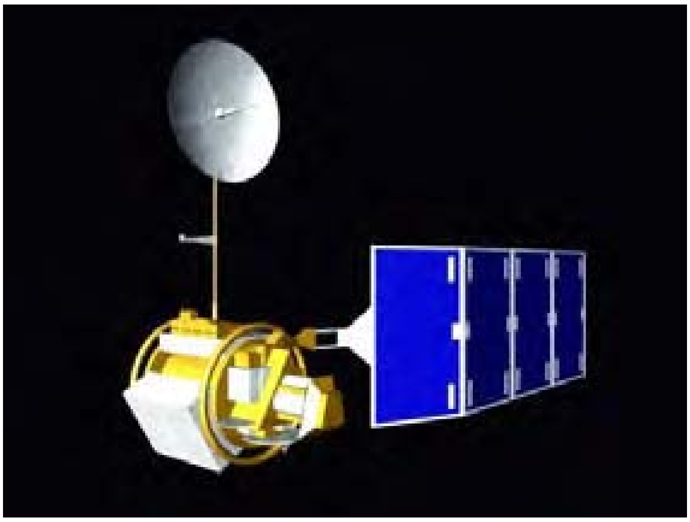
conversion of derelict or otherwise unusable areas into productive land. For example, where industrial or agricultural activities, such as sand and gravel extraction or open-cast mining, have created large areas of derelict or waste ground, the companies involved are usually required to improve the land so that it can be used.

Landsat

series of US satellites launched from 1972 that monitor the Earth's resources and the effects of pollution, deforestation, and desertification. The latest in the series, Landsat 7, was launched on 15 April 1999.

Landsat 1, originally called ERTS-A (Earth Resources Technology Satellite-A), orbited 1972-75, acquiring more than 300,000 images of the Earth's surface. Landsat 4, launched in June 1982, contained a new kind of technology, the thematic mapper (TM). The National Oceanic and Atmospheric Administration took over the running of the Landsat programme from NASA in 1983.

Landsat



(Image © Research Machines plc)

Landsat 4, launched on 16 July 1982, orbited the Earth 14 times a day (with repeat coverage of the Equator once every 16 days) until an on-board data transmitter failed in August 1993. The satellite carried the thematic mapper (TM), which detected reflected radiation from the Earth's surface in the visible and infrared wavelengths.

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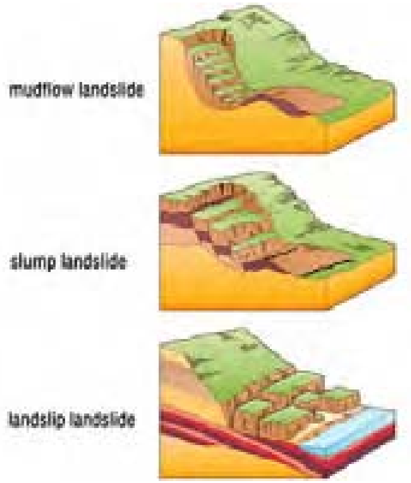
landslide

sudden downward movement of a mass of soil or rocks from a cliff or steep slope. Landslides happen when a slope becomes unstable, usually because the base has been undercut or because materials within the mass have become wet and slippery.

A **mudflow** happens when soil or loose material is soaked so that it no longer adheres to the slope; it forms a tongue of mud that reaches downhill from a semicircular hollow. A **slump** occurs when the material stays together as a large mass, or several smaller masses, and these may form a tilted steplike structure as they slide. A **landslip** is formed when beds of rock dipping towards a cliff slide along a lower bed. Earthquakes may precipitate landslides.

landslide



(Image © Research Machines plc)

Types of landslide. A mudflow is a tongue of mud that slides downhill. A slump is a fall of a large mass that stays together after the fall. A landslip occurs when beds of rock move along a lower bed.

Landsteiner, Karl (1868-1943)

Austrian-born US immunologist who was awarded a Nobel Prize for Physiology or Medicine in 1930 for his discovery of the ABO blood group system in the period 1900–02. He also aided in the discovery of the Rhesus blood factors in 1940, and discovered the polio virus.

In 1927 Landsteiner found that, in addition to antigens A and B, human blood cells contain one or other or both of two heritable antigens, M and N. These are of no importance in transfusions, because human serum does not contain the corresponding antibodies, but they are of value in resolving paternity disputes.

Lange, Dorothea (1895-1965)

born Dorothea Nutzhorn

US photographer. She was hired in 1935 by the federal Farm Security Administration to document the westward migration of farm families from the Dust Bowl of the southern central USA. Her photographs, characterized by a gritty realism, were widely exhibited and subsequently published as *An American Exodus: A Record of Human Erosion* (1939).

Women Come to the Front - Dorothea Lange

Go to site

Profile of the US realist photography. It traces her work chronicling the lives of displaced farm families during the Great Depression and the commission to photograph interned Japanese Americans which led to a clash with the US Government and the censoring of her work. A large number of her photographs are available.

Langmuir, Irving (1881-1957)

US scientist who invented the mercury vapour pump for producing a high vacuum, and the atomic hydrogen welding process; he was also a pioneer of the thermionic valve. He was awarded the Nobel Prize for Chemistry in 1932 for his work on surface chemistry.

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langur

any of various leaf-eating Old World monkeys that live in trees in South Asia. There are about 20 species. Langurs are related to the colobus monkey of Africa. (Genus *Presbytis* and other related genera.)

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lanolin

sticky, purified wax obtained from sheep's wool and used in cosmetics, soap, and leather preparation.

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lanternfish

any of about 300 species of small deep-sea bony fish. They are less than 15 cm/6 in long, with a large mouth, large eyes, and many luminous organs along the underside of the body, the function of which is not understood. They feed on plankton.

classification

Lanternfish are in the order Myctophiformes, class Osteichthyes.

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lanthanide

any of a series of 15 metallic elements (also known as rare earths) with atomic numbers 57 (lanthanum) to 71 (lutetium). One of its members, promethium, is radioactive. All occur in nature. Lanthanides are grouped because of their chemical similarities (most are trivalent, but some can be divalent or tetravalent), their properties differing only slightly with atomic number.

Lanthanides were called rare earths originally because they were not widespread and were difficult to identify and separate from their ores by their discoverers. The series is set out in a band in the periodic table of the elements, as are the actinides.

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lanthanum

chemical symbol La

(Greek lanthanein 'to be hidden')

soft, silvery, ductile and malleable, metallic element, atomic number 57, relative atomic mass 138.91, the first of the lanthanide series. It is used in making alloys. It was named in 1839 by Swedish chemist Carl Mosander (1797-1858).

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laparoscope

in medicine, another name for an endoscope.

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laparotomy

exploratory surgical procedure involving incision into the abdomen. The use of laparotomy, as of other exploratory surgery, has decreased sharply with advances in medical imaging and the direct-viewing technique known as endoscopy.

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lapis lazuli

rock containing the blue mineral lazurite in a matrix of white calcite with small amounts of other minerals. It occurs in silica-poor igneous rocks and metamorphic limestones found in Afghanistan, Siberia, Iran, and Chile. Lapis lazuli was a valuable pigment of the Middle Ages, also used as a gemstone and in inlaying and ornamental work.

Laplace, Pierre Simon (1749-1827)

Marquis de Laplace

French astronomer and mathematician. In 1796 he theorized that the Solar System originated from a cloud of gas (the nebular hypothesis). He studied the motion of the Moon and planets, and published a five-volume survey of celestial mechanics, *Traité de méchanique céleste* (1799-1825). Among his mathematical achievements was the development of probability theory.

Traité de mécanique céleste contained the law of universal attraction - the law of gravity as applied to the Earth - and explanations of such phenomena as the ebb and flow of tides and the precession of the equinoxes. He became Marquis in 1817.

Laplace, Pierre Simon

Go to site

Biographical details of French 18th-century mathematician Pierre Simon Laplace. The site has a picture of Laplace and describes how his work has influenced mathematicians and physicists from later centuries, including Einstein. Over 40 references to Laplace's work are available via a hypertext link.

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laptop computer

portable microcomputer, small enough to be used on the operator's lap. It consists of a single unit, incorporating a keyboard, hard disk drives, and a screen. The screen often forms a lid that folds back in use. It uses a liquid-crystal or gas-plasma display, rather than the bulkier and heavier cathode-ray tubes found in most display terminals. A typical laptop computer measures about 210 × 300 mm/8 × 12 in (about the size of an A4 sheet of paper), is 5 cm/2 in in depth, and weighs less than 3 kg/6 lb 9 oz. In the 1980s there were several types of laptop computer, but in the 1990s designs converged on systems known as notebook computers. The first of these, such as the Epson HX-20 and Tandy 100, became available in the early 1980s, with the first PC-compatible notebook, the Toshiba T1100, following in 1985. In the 1990s, the notebook format became the standard for portable PCs and Apple PowerBooks. Since then, the ability to make smaller and smaller chips and associated hardware has led to hand-held, palm-sized, and pocket PC models. At the end of 2002, manufacturers began to supply a new type of laptop, the tablet PC.

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lapwing

bird belonging to the plover family, also known as the **green plover** and, from its call, as the **peewit**. Bottle-green above and white below, with a long thin crest and rounded wings, it is about 30 cm/1 ft long. It inhabits moorland in Europe and Asia, making a nest scratched out of the ground, and is also often seen on farmland. (Species *Vanellus vanellus*, family Charadriidae.)

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larch

any of a group of trees belonging to the pine family. The common larch (*L. decidua*) grows to 40 m/130 ft. It is one of the few conifers to shed its leaves annually. The small needlelike leaves are replaced every year by new bright-green foliage, which later darkens. (Genus *Larix*, family Pinaceae.)

Closely resembling it is the North American tamarack (*L. laricina*), and both are timber trees. The golden larch (*Pseudolarix amabilis*), a native of China, turns golden in autumn.

Large Electron Positron Collider

LEP

formerly the world's largest particle accelerator, in operation 1989-2000 at the CERN laboratories near Geneva in Switzerland. It occupied a tunnel 3.8 m/12.5 ft wide and 27 km/16.7 mi long, which is buried 180 m/590 ft underground and forms a ring consisting of eight curved and eight straight sections. In June 1996, LEP resumed operation after a £210 million upgrade. The upgraded machine, known as LEP2, generated collision energies of 161 gigaelectron volts.

Electrons and positrons entered the ring after passing through the Super Proton Synchrotron accelerator. They travelled in opposite directions around the ring, guided by 3,328 bending magnets and kept within tight beams by 1,272 focusing magnets. As they passed through the straight sections, the particles were accelerated by a pulse of radio energy. Once sufficient energy had been accumulated, the beams were allowed to collide. Four giant detectors were used to study the resulting shower of particles. In 1989 the LEP was used to measure the masses and lifetimes of the W and Z bosons, carriers of the weak nuclear force. The LEP has now been removed from its tunnel to make way for another particle accelerator, the Large Hadron Collider (LHC).

ALEPH Experiment

Go to site

Home page of one of the four high-energy particle physics experiments, which used the Large Electron Positron Collider at the European Laboratory for Particle Physics. This Web site displays images of the components used in this experiment, including a cutaway schematic diagram of the huge detector assembly. The site also allows the visitor to discover more about the physics the collider and associated instruments are used to observe.

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lark

any of a group of songbirds found mainly in the Old World, but also in North America. Larks are brownish-tan in colour and usually about 18 cm/7 in long; they nest on the ground in the open. The **skylark** (*Alauda arvensis*) sings as it rises almost vertically in the air. It is light brown and 18 cm/7 in long. (Family Alaudidae, order Passeriformes.)

Lartigue, Jacques-Henri Charles Auguste (1894-1986)

French photographer. He began taking photographs of his family at the age of seven, and went on to make autochrome colour prints of women. During his lifetime he took over 40,000 photographs, documenting everyday people and situations.

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larva

stage between hatching and adulthood in those species in which the young have a different appearance and way of life from the adults. Examples include tadpoles (frogs) and caterpillars (butterflies and moths). Larvae are typical of the invertebrates, some of which (for example, shrimps) have two or more distinct larval stages. Among vertebrates, it is only the amphibians and some fishes that have a larval stage.

The process whereby the larva changes into another stage, such as a pupa (chrysalis) or adult, is known as metamorphosis.

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laryngitis

inflammation of the larynx, causing soreness of the throat, a dry cough, and hoarseness. The acute form is due to a virus or other infection, excessive use of the voice, or inhalation of irritating smoke, and may cause the voice to be completely lost. With rest, the inflammation usually subsides in a few days.

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larynx

in mammals, a cavity at the upper end of the trachea (windpipe) containing the vocal cords. It is stiffened with cartilage and lined with mucous membrane. Amphibians and reptiles have much simpler larynxes, with no vocal cords. Birds have a similar cavity, called the **syrinx**, found lower down the trachea, where it branches to form the bronchi. It is very complex, with well-developed vocal cords.

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laser

acronym for light amplification by stimulated emission of radiation

device for producing a narrow beam of light, capable of travelling over vast distances without dispersion, and of being focused to give enormous power densities (10^8 watts per cm^2 for high-energy lasers). The laser operates on a principle similar to that of the maser (a high-frequency microwave amplifier or oscillator). The uses of lasers include communications (a laser beam can carry much more information than can radio waves), cutting, drilling, welding, satellite tracking, medical and biological research, and surgery. Sound wave vibrations from the window glass of a room can be picked up by a reflected laser beam. Lasers are also used as entertainment in theatres, concerts, and light shows.

laser material

Any substance in which the majority of atoms or molecules can be put into an excited energy state can be used as laser material. Many solid, liquid, and gaseous substances have been used, including synthetic ruby crystal (used for the first extraction of laser light in 1960, and giving a high-power pulsed output) and a helium-neon gas mixture, capable of continuous operation, but at a lower power. A silicon-based laser was created in 2004, using the natural atomic vibrations of silicon nanocrystals to generate the light.

applications

Carbon dioxide gas lasers (CO_2 lasers) can produce a beam of 100 watts or more power in the infrared (wavelength 10.6 µm) and this has led to an important commercial application, the cutting of material for suits and dresses in hundreds of thicknesses at a time. Dye lasers, in which complex organic dyes in solution are the lasing material, can be tuned to produce light of any chosen wavelength over a range of a sizeable fraction of the visible spectrum.

laser

The Petawatt, the world's most powerful laser, generates 1,200 times as much power as the entire electrical grid of the USA. When focused on platinum, it turns it into gold.

Laser: Different Types

lasers and chips

Imagine lasers so small that a million could be packed into an area of 0.5 sq cm. This would have been a flight of fancy a few years ago, but no more. Laser science has made great strides recently, largely by adopting the technology used to make complex integrated circuits or chips.

familiar lasers

The most familiar laser is perhaps the helium-neon gas laser, the type used at supermarket check-outs to read bar codes. However, semiconductor lasers are much more widespread. They are used in compact-disc players, CD-ROMs or optical disks, fibre optic communications networks, and laser printers. Over 25 million semiconductor lasers were sold last year.

Simple semiconductor lasers are made from two layers of semiconductor material, gallium arsenide, formed into a small cube or chip. The layers are 'doped' with different kinds of impurities. In one layer, the impurities add extra electrons; in the other layer, they create electron vacancies or 'holes'. Applying a voltage across the junction between the layers causes electrons and holes to move towards the junction where they combine, releasing heat and light. If the edges of the chip are made to reflect some of the light back into the junction, the emission of more light is stimulated – this is the laser action which amplifies the intensity of the light. Eventually the light is intense enough to escape from one end of the chip, producing a narrow beam of laser light.

quantum well lasers

The key to improving semiconductor lasers is to confine the light to a small region around the junction; this produces more light and less heat. The development of molecular beam epitaxy, a technique which deposits atoms layer by layer, made possible the production of extremely thin layers to act as the laser, sandwiched between thicker barrier layers. The resulting devices, called quantum well lasers, are more efficient and are already used in some commercial semiconductor lasers.

Although the output of a quantum well laser is small, it is possible to pack an array of these lasers on to a chip. Although each laser emits only a small amount of light, the total output is sufficient for some applications.

strained layer lasers

The next step forward was the strained layer laser. These depend upon the fact that it is possible to vary the composition of the barrier layers either side of the thin laser layer. In the past few years this technique has been used to make lasers which produce light of various colours. The technique was used in the most dramatic breakthrough in semiconductor technology in 1991 – the first semiconductor laser emitting green light, with a wavelength of 525 nm, at room temperature. The shortest wavelengths previously reported were around 600 nm, a red-orange colour. Commercial lasers emit red of near infrared light with a wavelength of 635 nm or more.

vertical-cavity lasers

Another recent innovation has been to produce semiconductor lasers that shine their light upwards from the chip surface rather than from the chip edge. This can be done by incorporating sloping reflective mirrors into the chip, or by etching small grooves into the sides of the chip to diffract light sideways. A more sophisticated approach is to place reflective surfaces above and below the junction layer so that the laser beam is generated perpendicular to the junction layer. Such devices are called vertical-cavity lasers. The reflective layers can be made circular and packed closely together in an array on the chip. This is how the million lasers, roughly one-tenth the thickness of a human hair, were packed on to a single chip.

In some laser arrays, each laser can be turned off and on independently. This can be done up to 5 billion times a second in a two-by-eight array, to produce 800 billion pulses of light a second. Other arrays can combine the output of many laser elements to produce a single beam of higher power. It is possible for each laser element on a chip to produce a different wavelength of light because the distance between the reflective layers determines the wavelength of light produced.

the endless possibilities

Researchers have barely begun to explore the possibilities of these devices. One obvious application is in fibre optic communications; each laser element could be used to transmit a message using a different wavelength. The chips could be used in extremely fast, high-quality laser printers and in optical computers which process information coded as pulses of light instead of electric currents.

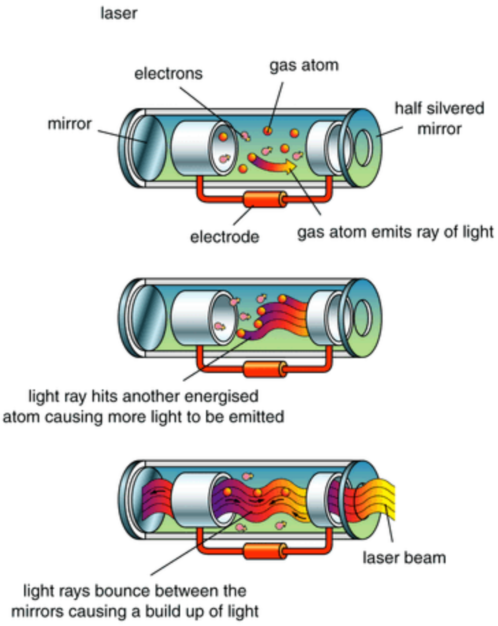
Laser: Fastest Pulses

fastest-ever laser pulses

Pulses of laser light lasting only 11 femtoseconds have been produced by US physicists: the shortest pulses of light ever generated by a laser. What is a femtosecond? It is a millionth of a billionth of a second. Still not clear? Then consider this: light takes 1.25 seconds to travel from the Earth to the Moon but, in one femtosecond, light travels only one hundredth of the width of a human hair. This means that the record-breaking pulses are just over one-tenth of the width of a hair in length.

Generating the pulses was difficult, because short light pulses are composed of a range of wavelengths and, with a range of wavelengths, the pulse spreads out as it travels. Researchers at Washington State University in Pullman used a new type of laser to produce the 11 fs pulses, based on a sapphire crystal doped with titanium. The laser emits a wider range of wavelengths than any other laser but allows the pulses to be compressed before they leave the laser. The pulses will be used to probe high-speed events, such as chemical reactions and electron movements.

laser


laser
electrons
gas atom
mirror
half silvered mirror
electrode
gas atom emits ray of light
light ray hits another energised atom causing more light to be emitted
laser beam
light rays bounce between the mirrors causing a build up of light

(Image © Research Machines plc)

In a gas laser, electrons moving between the electrodes pass energy to gas atoms. An energized atom emits a ray of light. The ray hits another energized atom causing it to emit a further light ray. The rays bounce between mirrors at each end causing a build-up of light. Eventually it becomes strong enough to pass through the half-silvered mirror at one end, producing a laser beam.

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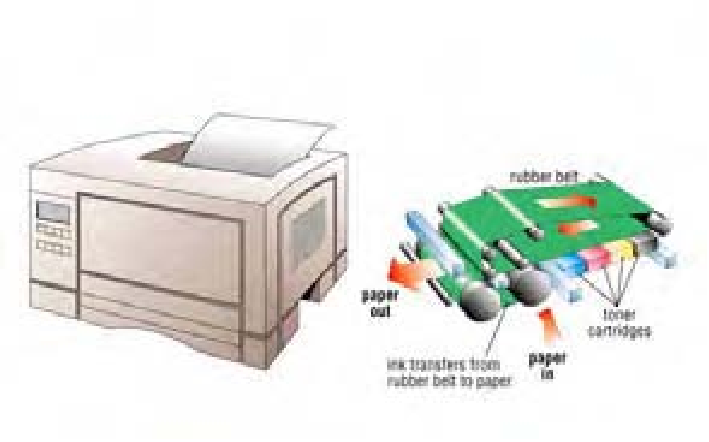
laser printer

computer printer in which the image to be printed is formed by the action of a laser on a light-sensitive drum, then transferred to paper by means of an electrostatic charge. Laser printers are page printers, printing a complete page at a time. The printed image, which can take the form of text or pictures, is made up of tiny dots, or ink particles. The quality of the image generated depends on the fineness of these dots - most laser printers can print up to 120 dots per cm/300 dots per in across the page.

A typical desktop laser printer can print about 4-40 pages per minute. The first low-cost laser printer suitable for office use appeared in 1984.

laser printer



(Image © Research Machines plc)

A laser printer works by transferring tiny ink particles contained in a toner cartridge to paper via a rubber belt. The image is produced by laser on a light-sensitive drum within the printer.

Laser Printers

Go to site

Explains the technology and principles behind laser printers and other PC hardware devices. The text is easy to follow and yet contains a satisfying level of detail. Thoughtfully constructed diagrams and annotated pictures illustrate the pages.

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laser surgery

use of intense light sources to cut, coagulate, or vaporize tissue. Less invasive than normal surgery, it destroys diseased tissue gently and allows quicker, more natural healing. It can be used by way of a flexible endoscope to enable the surgeon to view the diseased area at which the laser needs to be aimed.

Lassa fever

acute disease caused by an arenavirus, first detected in 1969, and spread by a species of rat found only in west Africa. It is classified as a haemorrhagic fever and characterized by high fever, headache, muscle pain, and internal bleeding. There is no known cure, the survival rate being less than 50%.

In west Africa 300,000 to 500,000 cases occur each year, causing approximately 5,000 deaths (as of 2006).

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lat.

abbreviation for latitude.

La Tène

prehistoric settlement at the east end of Lake Neuchâtel, Switzerland, which has given its name to a culture of the Iron Age dating from the 5th century BC to the Roman conquest.

The site was probably the crossing point of a river, no longer in existence, for most of the finds are associated with a wooden structure thought to be a bridge. The richness of metalwork found, in particular the swords and weapons, and a new style of decorative art recognized as the first Celtic art distinguish the culture, but little else changed from the preceding Hallstatt period.

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latent heat

in physics, the heat absorbed or released by a substance as it changes state (for example, from solid to liquid) at constant temperature and pressure.

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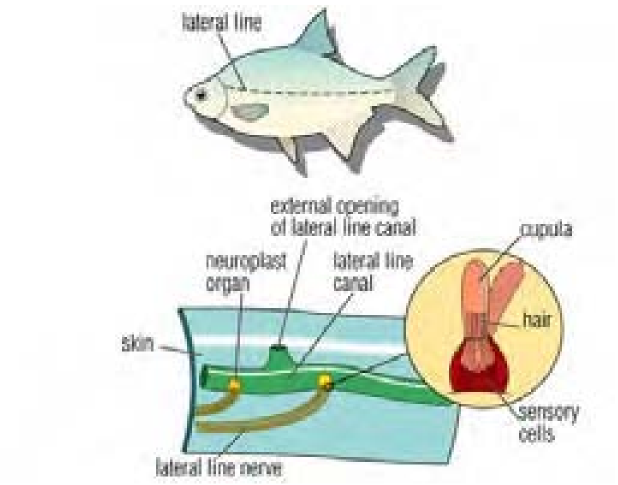
lateral line system

system of sense organs in fishes and larval amphibians (tadpoles) that detects water movement. It usually consists of a row of interconnected pores on either side of the body that divide into a system of canals across the head.

lateral line system



(Image © Research Machines plc)

In fishes, the lateral line system detects water movement. Arranged along a line down the length of the body are two water-filled canals, just under the skin. The canals are open to the outside, and water movements cause water to move in the canals. Nerve endings detect the movements.

lateral moraine

linear ridge of rocky debris deposited near the edge of a glacier. Much of the debris is material that has fallen from the valley side onto the glacier's edge, having been weathered by freeze-thaw (the alternate freezing and thawing of ice in cracks); it will, therefore, tend to be angular in nature. Where two glaciers merge, two lateral moraines may join together to form a **medial moraine** running along the centre of the merged glacier.

laterite

red residual soil characteristic of tropical rainforests. It is formed by the weathering of basalts, granites, and shales and contains a high percentage of aluminium and iron hydroxides. It may form an impermeable and infertile layer that hinders plant growth.

latex

(Latin 'liquid')

fluid of some plants (such as the rubber tree and poppy), an emulsion of resins, proteins, and other organic substances. It is used as the basis for making rubber. The name is also applied to a suspension in water of natural or synthetic rubber (or plastic) particles used in rubber goods, paints, and adhesives.

lathe

machine tool, used for turning. The workpiece to be machined, usually wood or metal, is held and rotated while cutting tools are moved against it. Modern lathes are driven by electric motors, which can drive the spindle carrying the workpiece at various speeds.

Computer Numerical Control (CNC) lathes include the hardware needed to interface with a computer system. These lathes can exactly reproduce items many times over, allowing automated mass-production where the only interaction from an operator is to supply the blanks (uncut material) and remove the finished pieces.

latifundium

(Latin for 'broad' and 'farm')

in ancient Rome, a large agricultural estate designed to make maximum use of cheap labour, whether free workers or slaves.

In present-day Italy, Spain, and South America, the term *latifondo* refers to a large agricultural estate worked by low-paid casual or semiservile labour in the interests of absentee landlords.

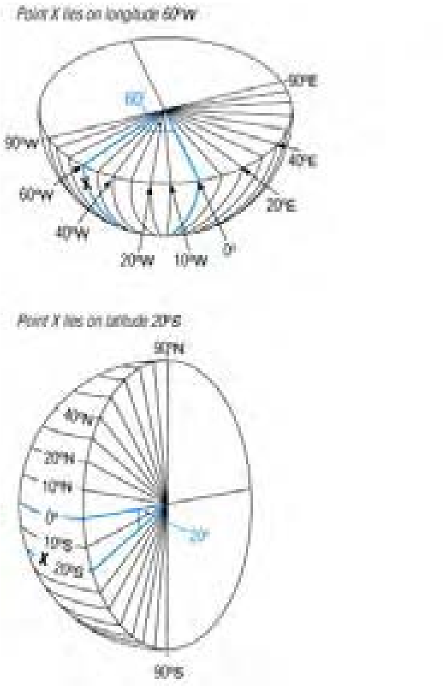
latitude and longitude

imaginary lines used to locate position on the globe. Lines of latitude are drawn parallel to the Equator, with 0° at the Equator and 90° at the north and south poles. Lines of longitude are drawn at right-angles to these, with 0° (the Prime Meridian) passing through Greenwich, England.

The 0-degree line of latitude is defined by Earth's Equator, a characteristic definable by astronomical observation. It was determined as early as AD 150 by Egyptian astronomer Ptolemy in his world atlas. The prime meridian, or 0-degree line of longitude, is a matter of convention rather than physics. Prior to the latter half of the 18th century, sailors navigated by referring to their position east or west of any arbitrary meridian. When Nevil Maskelyne (1732–1811), English astronomer and fifth Astronomer Royal, published the *Nautical Almanac* he referred all of his lunar–stellar distance tables to the Greenwich meridian. These tables were relied upon for computing longitudinal position and so the Greenwich meridian became widely accepted.

Chronometers, time-keeping devices with sufficient accuracy for longitude determination, invented by English instrument-maker John Harrison (1693–1776) and perfected in 1759, would gradually replace the lunar distance method for navigation, but reliance on the Greenwich meridian persisted because the *Nautical Almanac* was used by sailors to verify their position. The Greenwich meridian was officially adopted as the Prime Meridian by the International Meridian Conference held in Washington, DC, in 1884.

latitude and longitude



(Image © Research Machines plc)

Locating a point on a globe using latitude and longitude. Longitude is the angle between the terrestrial meridian through a place and the standard meridian 0° passing through Greenwich, England. Latitude is the angular distance of a place from the equator.

Latitude, longitude, and altitude of the world's major cities

City	Latitude		Longitude		Altitude	
	°	'	°	'	m	ft
Adelaide, Australia	34	55 S	138	36 E	43	140
Algiers, Algeria	36	50 N	03	00 E	59	194
Almaty, Kazakhstan	43	16 N	76	53 E	775	2,543
Amsterdam, Netherlands	52	22 N	04	53 E	3	10
Ankara, Turkey	39	55 N	32	55 E	862	2,825
Asunción, Paraguay	25	15 S	57	40 W	139	456
Athens, Greece	37	58 N	23	43 E	92	300
Bangkok, Thailand	13	45 N	100	31 E	0	0
Barcelona, Spain	41	23 N	02	09 E	93	305
Beijing, China	39	56 N	116	24 E	183	600
Belfast, Northern Ireland	54	37 N	05	56 W	67	217
Belgrade, Yugoslavia	44	52 N	20	32 E	132	433
Berlin, Germany	52	31 N	13	25 E	34	110
Bogotá, Colombia	04	32 N	74	05 W	2,640	8,660
Brussels, Belgium	50	52 N	04	22 E	100	328
Bucharest, Romania	44	25 N	26	07 E	92	302
Budapest, Hungary	47	30 N	19	05 E	139	456

Buenos Aires, Argentina	34	36 S	58	28 W	0	0
Cairo, Egypt	30	03 N	31	15 E	116	381
Cape Town, South Africa	33	55 S	18	22 E	17	56
Caracas, Venezuela	10	28 N	67	02 W	1,042	3,418
Copenhagen, Denmark	55	40 N	12	34 E	9	33
Dakar, Senegal	14	40 N	17	28 W	40	131
Delhi, India	28	35 N	77	12 E	218	714
Detroit (MI), USA	42	19 N	83	02 W	178	585
Djibouti, Djibouti	11	30 N	43	03 E	7	23
Dublin, Republic of Ireland	53	20 N	06	15 W	47	154
Edinburgh, Scotland	55	55 N	03	10 W	134	440
Frankfurt, Germany	50	07 N	08	41 E	103	338
Guatemala City, Guatemala	14	37 N	90	31 W	1,480	4,855
Havana, Cuba	23	08 N	82	23 W	24	80
Helsinki, Finland	60	10 N	25	00 E	46	151
Hong Kong, China	22	18 N	114	10 E	33	109
Istanbul, Turkey	41	06 N	29	03 E	114	374
Jakarta, Indonesia	06	10 S	106	48 E	8	26
Jerusalem, Israel	31	46 N	35	14 E	762	2,500
Johannesburg, South Africa	26	12 S	28	05 E	1,750	5,740
Kabul, Afghanistan	34	30 N	69	13 E	1,827	5,955
Karachi, Pakistan	24	48 N	66	59 E	4	13
Katmandu, Nepal	27	43 S	85	19 E	1,372	4,500
Kiev, Ukraine	50	26 N	30	31 E	179	587
Kinshasa, Democratic Republic of Congo	04	18 S	15	17 E	322	1,066
Lagos, Nigeria	06	27 N	03	24 E	3	10
La Paz, Bolivia	16	27 S	68	22 W	3,658	12,001
Lhasa, Tibet	29	40 N	91	07 E	3,685	12,090
Lima, Peru	12	00 S	77	02 W	120	394
Lisbon, Portugal	38	44 N	09	09 W	77	253
London, England	51	32 N	00	05 W	75	245
Los Angeles (CA), USA	34	03 N	118	14 W	104	340
Madrid, Spain	40	26 N	03	42 W	660	2,165
Manila, Philippines	14	35 N	120	57 E	14	47
Mecca, Saudi Arabia	21	27 S	39	49 E	2,000	6,562
Melbourne, Australia	37	47 N	144	58 E	35	115
Mexico City, Mexico	19	24 N	99	09 W	2,239	7,347
Milan, Italy	45	27 S	09	10 E	121	397
Montevideo, Uruguay	34	53 N	56	10 W	22	72
Moscow, Russian Federation	55	45 N	37	35 E	120	394
Mumbai (formerly Bombay), India	18	58 N	72	50 E	8	27
Nagasaki, Japan	32	48 S	129	57 E	133	436
Nairobi, Kenya	01	25 N	36	55 E	1,820	5,971
New Delhi, India	28	36 N	77	12 E	235	770
New York (NY), USA	40	45 N	73	59 W	17	55
Oslo, Norway	59	57 N	10	42 E	94	308
Ottawa, Canada	45	26 N	75	41 W	56	185
Panamá, Panama	08	58 N	79	32 W	0	0
Paris, France	48	52 N	02	20 E	92	300
Prague, Czech Republic	50	05 N	14	26 E	262	860
Quito, Ecuador	0	13 S	78	30 W	2,811	9,222
Reykjavik, Iceland	64	04 N	21	58 W	18	59
Rio de Janeiro, Brazil	22	43 S	43	13 W	9	30
Rome, Italy	41	53 N	12	30 E	29	95
St Petersburg, Russian Federation	59	56 N	30	18 E	4	13
Santiago, Chile	33	27 S	70	40 W	1,500	4,921
Seoul, South Korea	37	34 N	127	00 E	10	34
Shanghai, China	31	10 N	121	28 E	7	23
Singapore	01	14 N	103	55 E	10	33
Sofia, Bulgaria	42	40 N	23	20 E	550	1,805
Stockholm, Sweden	59	17 N	18	03 E	44	144
Sydney, Australia	33	53 S	151	12 E	8	25
Tehran, Iran	35	40 N	51	26 E	1,110	3,937
Tokyo, Japan	35	42 N	139	46 E	9	30
Toronto, Canada	43	39 N	79	23 W	91	300

Tripoli, Libya	32	54 N	13	11 E	0	0
Vancouver, Canada	49	18 N	123	04 W	43	141
Vienna, Austria	48	14 N	16	20 E	203	666
Warsaw, Poland	52	15 N	21	00 E	110	360
Washington, DC, USA	38	53 N	77	00 W	8	25
Wellington, New Zealand	41	18 S	174	47 E	0	0
Zurich, Switzerland	47	21 N	08	31 E	493	1,618

laudanum

alcoholic solution (tincture) of the drug opium. Used formerly as a narcotic and painkiller, it was available in the 19th century from pharmacists on demand in most of Europe and the USA.

laughing gas

popular name for nitrous oxide, an anaesthetic.

Laurasia

northern landmass formed 200 million years ago by the splitting of the single world continent Pangaea. (The southern landmass was Gondwanaland.) It consisted of what was to become North America, Greenland, Europe, and Asia, and is believed to have broken up about 100 million years ago with the separation of North America from Europe.

laurel

any of a group of European evergreen trees with glossy aromatic leaves, yellowish flowers, and black berries. The leaves of sweet bay or poet's laurel (*L. nobilis*) are used in cooking. Several species are cultivated worldwide. (Genus *Laurus*, family Lauraceae.)

laurustinus

evergreen shrub belonging to the honeysuckle family, of Mediterranean origin. It has clusters of white flowers in winter. (*Viburnum tinus*, family Caprifoliaceae.)

lava

molten magma that erupts from a volcano and cools to form extrusive igneous rock. Lava types differ in composition, temperature, gas content, and viscosity (resistance to flow).

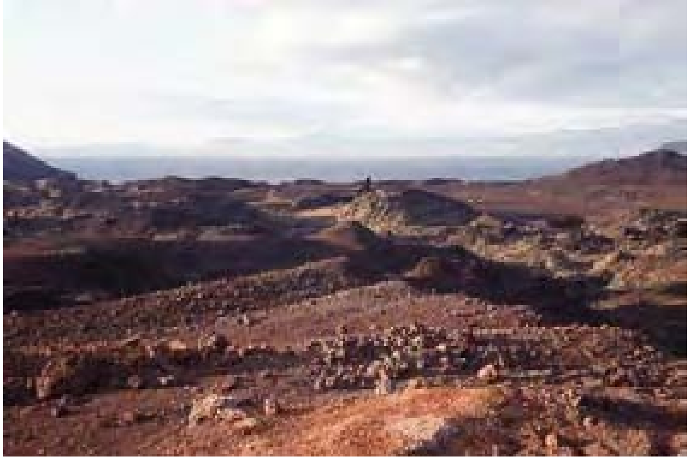
The three major lava types are basalt (dark, fluid, and relatively low silica content), rhyolite (light, viscous, high silica content), and andesite (an intermediate lava).

lava

(Image © Garret Nagle)

Cooled lava and boulders in Heimaey, in the Western Islands (Vestmannaeyjar), Iceland. The volcano last erupted in 1973, ejecting magma, rocks, ash, and soot. The slopes have since stabilized, allowing plants to grow there once again. Moss and lichen can be seen on the rocks in the foreground.

lava



(Image © Garret Nagle)

A landscape of cooled lava, created by the 1973 eruption of the Helgafell volcano, on the Icelandic island of Heimaey. The eruption created a new peak, Eldfell, and a 3 km/1.9 mi lava flow, *Eldfellshraun*. Magma, rocks, ash, and soot were ejected. Since the eruption, the volcano has stabilized, and vegetation has begun to colonize the slopes.

lava

(Image © Garret Nagle)

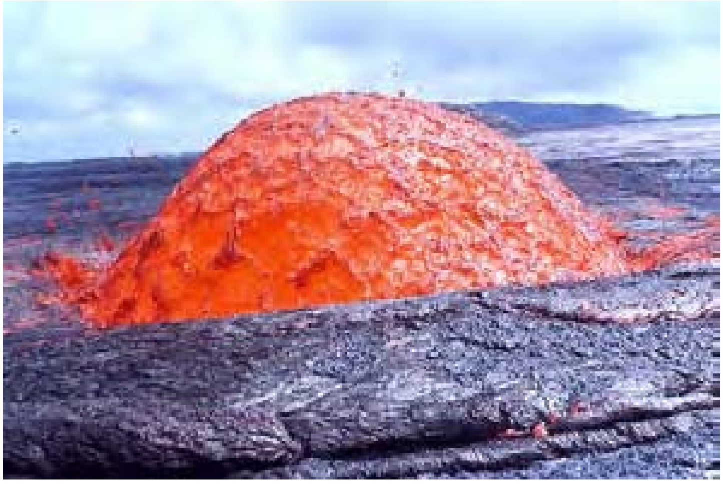
Vegetation has now begun to recolonize the lava slopes of the Helgafell volcano, on the Icelandic island of Heimaey, which last erupted in 1973.

lava

(Image © Garret Nagle)

A slope of cooled lava, showing evidence of the 1973 eruption of the Helgafell volcano, on the island of Heimaey, in the Icelandic Westman Islands. Since the eruption, vegetation has begun to grow once more on the areas affected by the volcano, although temperatures just below the topsoil remain high.

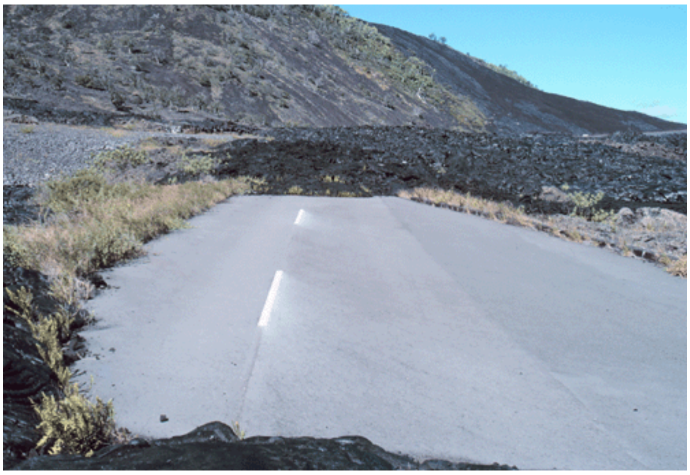
lava bubble



(Image © Corel)

A lava bubble in Mauna Ulu, Hawaii, USA.

lava



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

From Hawaiian shield volcanoes, lava may flow smoothly and consistently for long distances. The smoothness of flow is partly due to the chemical composition of the lava which has a comparatively low proportion of silica (silicon dioxide) and a comparatively high proportion of calcium (as feldspar) and magnesium (as pyroxene).

lava

(Image © Garret Nagle)

A plain in southern Iceland covered with the remains of former lava flows. The Reykjanes peninsula has many lava flows, as well as geothermal fields and crater lakes. Tectonically active, Iceland is located on a mid-ocean ridge where the North American and European plates move apart.

lava fountain

(Image © Corel)

A lava fountain on Kilauea Iki, Hawaii, USA. As magma reaches the earth's surface escaping gas sprays lava into the air.

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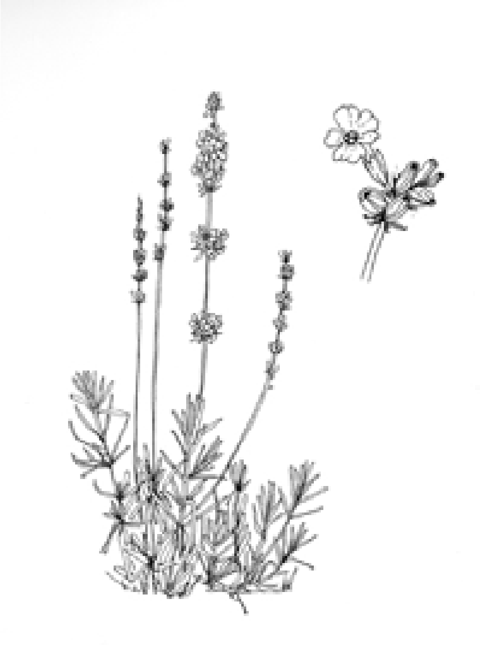
lavender

sweet-smelling purple-flowering herb belonging to the mint family, native to western Mediterranean countries. The bushy low-growing species *L. angustifolia* has long, narrow, upright leaves of a silver-green colour. The small flowers, borne on spikes, vary in colour from lilac to deep purple and are covered with small fragrant oil glands. Lavender oil is widely used in pharmacy and perfumes. (Genus *Lavandula*, family Labiatae.)

lavender



(Image © Research Machines plc)

English lavender (*Lavandula angustifolia*). Lavender is a small evergreen shrub with grey-green leaves and purple flowers in summer. Native to Europe, lavender is one of 3,500 species of the Lamiaceae family, which includes other aromatic plants such as catnip, basil, thyme, and mint. Lavender is cultivated for its essential oil, and for dried flowers.

lavender cultivation

(Image © Corel)

Commercial cultivation of lavender near Forcalquier, in Provence, France. The flowers are harvested for extraction of lavender oil, which is used in perfumes, aromatherapy, and medicinal products.

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laver

any of several edible purplish-red seaweeds, including purple laver (*P. umbilicalis*). Growing on the shore and in the sea, attached to rocks and stones, laver forms thin, roundish sheets of tissue up to 20 cm/8 in across. It becomes almost black when dry. (Genus *Porphyra*, family Rhodophyceae.)

Lavoisier, Antoine Laurent (1743-1794)

French chemist. He proved that combustion needs only a part of the air, which he called oxygen, thereby destroying the theory of phlogiston (an imaginary 'fire element' released during combustion). With astronomer and mathematician Pierre de Laplace, he showed in 1783 that water is a compound of oxygen and hydrogen. In this way he established the basic rules of chemical combination.

Lavoisier established that organic compounds contain carbon, hydrogen, and oxygen. From quantitative measurements of the changes during breathing, he showed that carbon dioxide and water are normal products of respiration.

Lavoisier, Antoine Laurent

Go to site

Account of the life and achievements of the French chemist, philosopher, and economist. It traces his education and growing disillusionment with the theory of phlogiston. There is an account of how in order to pay for his scientific experiments he was forced to enter into government service, a fateful move leading, despite his many successes, to his violent death.

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lawrencium

chemical symbol Lr

synthesized, radioactive, metallic element, the last of the actinide series, atomic number 103, relative atomic mass 262. Its only known isotope, Lr-257, has a half-life of 4.3 seconds and was originally synthesized at the University of California at Berkeley in 1961 by bombarding californium with boron nuclei. The original symbol, Lw, was officially changed in 1963.

The element was named after Ernest Lawrence (1901-1958), the US inventor of the cyclotron.

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laxative

substance used to relieve constipation (infrequent bowel movement). Current medical opinion discourages regular or prolonged use. Regular exercise and a diet high in vegetable fibre are believed to be the best means of preventing and treating constipation.

LCD

abbreviation for liquid-crystal display.

L-dopa

chemical, normally produced by the body, which is converted by an enzyme to dopamine in the brain. It is essential for integrated movement of individual muscle groups.

L-dopa is a left-handed isomer of an amino acid $C_9H_{11}NO_2$. As a treatment, it relieves the rigidity of Parkinson's disease in 60% of sufferers, but may have significant side effects, such as extreme mood changes, hallucinations, and uncontrolled writhing movements. It is often given in combination with other drugs to improve its effectiveness at lower doses.

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leaching

process by which substances are washed through or out of the soil. Fertilizers leached out of the soil drain into rivers, lakes, and ponds and cause water pollution. In tropical areas, leaching of the soil after the destruction of forests removes scarce nutrients and can lead to a dramatic loss of soil fertility. The leaching of soluble minerals in soils can lead to the formation of distinct soil horizons as different minerals are deposited at successively lower levels.

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lead

chemical symbol Pb

heavy, soft, malleable, grey, metallic element, atomic number 82, relative atomic mass 207.19. Its chemical symbol comes from the Latin *plumbum*. Usually found as an ore (most often as the sulphide galena), it occasionally occurs as a free metal (native metal), and is the final stable product of the decay of uranium. Lead is the softest and weakest of the commonly used metals, with a low melting point; it is a poor conductor of electricity and resists acid corrosion. As a cumulative poison, lead enters the body from lead water pipes, lead-based paints, and leaded petrol. (In humans, exposure to lead shortly after birth is associated with impaired mental health between the ages of two and four.) The metal is an effective shield against radiation and is used in batteries, glass, ceramics, and alloys such as pewter and solder.

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lead-acid cell

a type of battery.

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leaded gasoline

gasoline containing the lead compound tetraethyl lead, $(C_2H_5)_4Pb$, an anti-knock agent. It improves the combustion of gasoline and the performance of an automobile engine. The lead from the exhaust fumes enters the atmosphere, mostly as simple lead compounds, which are poisonous to the developing nervous systems of children.

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lead ore

any of several minerals from which lead is extracted. The primary ore is galena or lead sulphite PbS. This is unstable, and on prolonged exposure to the atmosphere it oxidizes into the minerals cerussite $PbCO_3$ and anglesite $PbSO_4$. Lead ores are usually associated with other metals, particularly silver – which can be mined at the same time – and zinc, which can cause problems during smelting.

Most commercial deposits of lead ore are in the form of veins, where hot fluids have leached the ore from cooling igneous masses and deposited it in cracks in the surrounding country rock, and in thermal metamorphic zones, where the heat of igneous intrusions has altered the minerals of surrounding rocks. Lead is mined in over 40 countries, but half of the world's output comes from the USA, Canada, Russia, Kazakhstan, Uzbekistan, Canada, and Australia.

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lead poisoning

in medicine, toxic condition due to the ingestion of lead. Symptoms include loss of appetite, nausea and vomiting, colic, anaemia, and nerve damage. It is treated by the removal of the source of lead and by chelating agents (see chelate) to remove the lead from the body. Most cases today are chronic and occur in workers at smelters or scrap yards, but lead poisoning used to occur more commonly because of the use of domestic lead-based paints and lead water pipes.

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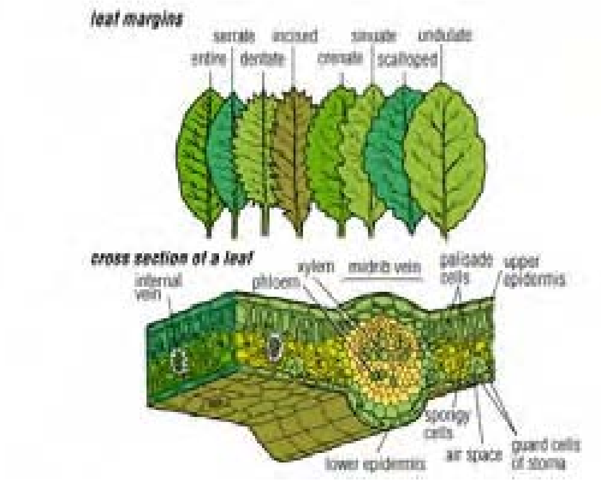
leaf

lateral outgrowth on the stem of a plant, and in most species is the primary organ of photosynthesis (the process in which the energy from absorbed sunlight is used to combine carbon dioxide and water to form sugars). The chief leaf types are cotyledons (seed leaves), scale leaves (on underground stems), foliage leaves, and bracts (in the axil of which a flower is produced).

Typically, leaves are composed of three parts: the sheath or leaf base, the petiole or stalk, and the lamina or blade. The lamina has a network of veins through which water and nutrients are conducted. A leaf contains several layers of tissue. Structurally the leaf is made up of inner tissues known as mesophyll cells, surrounded by the epidermis and usually an additional waxy layer, termed the cuticle, which prevents excessive evaporation of water from the leaf tissues by transpiration.

The epidermis is formed of a single layer of cells on the outside of the leaf. It is interrupted by small pores, or stomata, through which gas exchange between the plant and the atmosphere occurs for photosynthesis and respiration. Water is also lost through the stomata by transpiration. The mesophyll can be divided into two layers. The upper half of the mesophyll has elongated cells densely packed with chloroplasts that carry out photosynthesis – this is the palisade tissue. The lower half has more irregularly arranged cells with fewer chloroplasts – this is called spongy mesophyll. The mesophyll includes many air spaces, which allow carbon dioxide and oxygen to diffuse to and from the leaf cells (see diffusion). Outside the epidermis is a waxy layer, called the cuticle, which prevents evaporation of water directly from epidermal cells.

leaf



(Image © Research Machines plc)

Leaf shapes and arrangements on the stem are many and varied; in cross section, a leaf is a complex arrangement of cells surrounded by the epidermis. This is pierced by the stomata through which gases enter and leave.

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leaf-hopper

any of numerous species of plant-sucking insects. They feed on the sap of leaves. Each species feeds on a limited range of plants. (Family Cicadellidae, order Homoptera.)

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leaf insect

any of various insects about 10 cm/4 in long, with a green or brown, flattened body, remarkable for closely resembling the foliage on which they live. They are most common in Southeast Asia. (Genus *Phyllium*, order Phasmida.)

Leakey, Louis Seymour Bazett (1903-1972)

Kenyan archaeologist, anthropologist, and palaeontologist. With his wife Mary Leakey, he discovered fossils of extinct animals in the Olduvai Gorge in Tanzania, as well as many remains of an early human type. Leakey's conviction that human origins lie in Africa was opposed to contemporary opinion.

Leakey, Louis

Go to site

Account of the life and career of the missionary's son who did much to establish the African origins of human life. It traces his upbringing among the Kikuyu, his early interest in anthropology, his financial and academic struggles, and his work with his second wife, Mary, in Olduvai Gorge.

Leakey, Mary Douglas (1913-1996)

born Mary Douglas Nicol

English archaeologist and anthropologist. In 1948 she discovered, on Rusinga Island, Lake Victoria, East Africa, the prehistoric ape skull known as *Proconsul*, about 20 million years old; and human footprints at Laetoli, to the south, about 3.75 million years old.

Leakey, Richard Erskine Frere (1944-)

Kenyan palaeoanthropologist and politician. In 1972 he discovered at Lake Turkana, Kenya, an apelike skull estimated to be about 2.9 million years old; it had some human characteristics and a brain capacity of 800 cu cm/49 cu in. In 1984 his team found an almost complete skeleton of *Homo erectus* some 1.6 million years old. He is the son of Louis and Mary Leakey.

He was appointed director of the Kenyan Wildlife Service in 1988, waging a successful war against poachers and the ivory trade, but was forced to resign in 1994 in the face of political interference. He was reappointed to the post in 1998. In 1995 he co-founded the Kenyan political party Safina (Swahili for Noah's Ark), which aimed to clean up Kenya. The party was accused of racism and colonialism by President Daniel arap Moi. Nevertheless, in July 1999 the president appointed Leakey head of the civil service in the country. He resigned in March 2001, having completed the task, during which he had made enemies in the government. The office of President Moi agreed that he should stand down immediately.

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learning disability

limitation in the ability to learn. Learning disabilities vary in degree and arise from a variety of origins, including dysfunction of the brain and childhood behavioural problems. Learning disabilities are often associated with other disabilities.

The major causes of brain dysfunction are due to the presence of abnormal chromosomes, such as in Down's syndrome, and to other genetic disorders, or it can be due to head injuries. Intellectual and social impairment results in the individual requiring additional care and supervision to live as normal a life as possible.

Profound learning disabilities result in the person having multiple disabilities and being unable to walk or talk and being totally dependent upon others for care.

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learning theory

in psychology, any theory or body of theories about how behaviour in animals and human beings is acquired or modified by experience. Two main theories are classical and operant conditioning.

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least action, principle of

in physics, an alternative expression of Newton's laws of motion that states that a particle moving between two points under the influence of a force will follow the path along which its total action is least. Action is a quantity related to the average difference between the kinetic energy and the potential energy of the particle along its path. The principle is only true where no energy is lost from the system; for example an object moving in free fall in a gravitational field. It is closely related to Fermat's principle of least time which governs the path taken by a ray of light.

leather

material prepared from the hides and skins of animals, by tanning with vegetable tannins and chromium salts. Leather is a durable and water-resistant material, and is used for bags, shoes, clothing, and upholstery. There are three main stages in the process of converting animal skin into leather: cleaning, tanning, and dressing. Tanning is often a highly polluting process.

The skin, usually cattle hide, is dehydrated after removal to arrest decay. Soaking is necessary before tanning in order to replace the lost water with something that will bind the fibres together. The earliest practice, at least 7,000 years old, was to pound grease into the skin. In about 400 BC the Egyptians began to use vegetable extracts containing tannic acid, a method adopted in medieval Europe. Chemical tanning using mineral salts was introduced in the late 19th century.

Leavitt, Henrietta Swan (1868-1921)

US astronomer who in 1912 discovered the **period-luminosity law**, which links the brightness of a Cepheid variable star to its period of variation. This law allows astronomers to use Cepheid variables as 'standard candles' for measuring distances in space.

Leblanc, Nicolas (1742-1806)

French chemist who in the 1780s developed a process for making soda ash (sodium carbonate, Na_2CO_3) from common salt (sodium chloride, NaCl). Soda ash was widely used industrially in making glass, paper, soap, and various chemicals.

In the **Leblanc process**, salt was first converted into sodium sulphate by the action of sulphuric acid, which was then roasted with chalk or limestone (calcium carbonate) and coal to produce a mixture of sodium carbonate and sulphide. The carbonate was leached out with water and the solution crystallized. The process was adopted throughout Europe.

Le Chatelier's principle

or Le Chatelier-Braun principle

principle that if a change in conditions is imposed on a system in equilibrium, the system will react to counteract that change and restore the equilibrium.

First stated in 1884 by French chemist Henri le Chatelier (1850-1936), it has been found to apply widely outside the field of chemistry.

lecithin

(Greek lekithos 'egg yolk')

lipid (fat), containing nitrogen and phosphorus, that forms a vital part of the cell membranes of plant and animal cells. Eggs are a major source of lecithin.

LED

abbreviation for light-emitting diode.

Lederberg, Joshua (1925-)

US geneticist who was awarded the Nobel Prize for Physiology or Medicine in 1958 for work on genetic recombination and the organization of bacterial genetic material. He showed that bacteria can reproduce sexually, combining genetic material so that offspring possess characteristics of both parent organisms. He shared the prize with George Beadle and Edward Tatum.

Lederberg is a pioneer of genetic engineering, a science that relies on the possibility of artificially shuffling genes from cell to cell. He realized in 1952 that bacteriophages, viruses which invade bacteria, can transfer genes from one bacterium to another, a discovery that led to the deliberate insertion by scientists of foreign genes into bacterial cells.

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leech

any of a group of annelid worms. Leeches live in fresh water, and in tropical countries infest damp forests. As bloodsucking animals they are injurious to people and animals, to whom they attach themselves by means of a strong mouth adapted to sucking. (Class Hirudinea.)

Formerly, the **medicinal leech** (*Hirudo medicinalis*) was used extensively for 'bleeding' for a variety of ills. It is still cultivated as the source of the anticoagulant hirudin.

leech

In 1824, five million leeches were exported from France to England for therapeutic use. For centuries, it was believed that virtually all diseases could be at least partly relieved by leeching.

---

leek

onionlike plant belonging to the lily family. The cultivated leek is a variety of the wild species *A. ampeloprasum* of the Mediterranean area and Atlantic islands. The lower leaf parts and white bulb are eaten as a vegetable. (Genus *Allium*, family Liliaceae.)

Leeuwenhoek, Anton van (1632-1723)

Dutch pioneer of microscopic research. He ground his own lenses, some of which magnified up to 300 times. With these he was able to see individual red blood cells, sperm, and bacteria, achievements not repeated for more than a century.

Leeuwenhoek, Antony van

Go to site

Profile of the self-taught 'janitor of Delft'. It traces how his business success allowed him to pursue his scientific passions and win fame for his pioneering work in microscopy. There is a portrait of Leeuwenhoek and picture and a description of one of his best-known lenses.

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left-handedness

using the left hand more skilfully and in preference to the right hand for most actions. It occurs in about 9% of the population, predominantly males. It is caused by dominance of the right side of the brain.

Studies of twins suggest that there are genetic factors involved, but the precise causes for left-handedness (as for the predominant right-handedness) have remained elusive.

Famous Left-Handers

Go to site

Thorough listing of famous left-handers. Among this list are the last four US Presidents, Joan of Arc, Charlemagne and Queen Victoria. On a more serious note, there are accounts of ordinary people being stigmatized for left-handedness and a plea for greater understanding. There are links to many other left-handedness sites.

Primate Handedness and Brain Lateralization

Go to site

Rather scholarly title for what is a very readable account of left- and right-handedness in humans and other primates.

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legionnaires' disease

pneumonia-like disease, so called because it was first identified when it broke out at a convention of the American Legion in Philadelphia in 1976. Legionnaires' disease is caused by the bacterium *Legionella pneumophila*, which breeds in warm water (for example, in the cooling towers of air-conditioning systems). It is spread in minute water droplets, which may be inhaled. The disease can be treated successfully with antibiotics, though mortality can be high in elderly patients.

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legume

plant of the family Leguminosae, which has a pod containing dry seeds. The family includes peas, beans, lentils, clover, and alfalfa (lucerne). Legumes are important in agriculture because of their specialized roots, which have nodules containing bacteria capable of fixing nitrogen from the air (see nitrogen fixation) and increasing the fertility of the soil. The edible seeds of legumes are called **pulses**.

Leibniz, Gottfried Wilhelm (1646-1716)

German mathematician, philosopher, and diplomat. Independently of, but concurrently with, English scientist Isaac Newton, he developed the branch of mathematics known as calculus and was one of the founders of symbolic logic. Free from all concepts of space and number, his logic was the prototype of future abstract mathematics.

calculus and controversy

It was in London in 1673 that Leibniz became acquainted with the work of Newton and Isaac Barrow and began to work on problems that led him to his independent discovery of differential and integral calculus. Leibniz is due the credit for first using the **infinitesimals** (very small quantities that were precursors of the modern idea of limits) as differences. He devised a notation for integration and differentiation that was so much more convenient than Newton's **fluxions** that it remains in standard use today.

In 1699 the Swiss mathematician and Fellow of the Royal Society, Fatio de Duillier, accused Leibniz of stealing the idea from Newton, a charge which the Royal Society formally upheld in 1711. Leibniz himself never sought to conceal that it was after his 1673 visit to London, by which time Newton had worked out his calculus of fluxions, that he began his investigations into tangents and quadratures, the research that eventually led to his discovery of calculus. Newton's discovery, probably made in 1665, was not published for many years and there is no doubt that Leibniz arrived at his calculus independently. As he put it, he, Newton and Barrow were 'contemporaries in these discoveries'. Leibniz always communicated his findings to fellow mathematicians; most mathematicians of the time were working on the same problems and they all knew the work that had been done on infinitesimal quantities.

monads

In his metaphysical works, such as *The Monadology* (1714), he argued that everything consisted of innumerable units, **monads**, the individual properties of which determined each thing's past, present, and future. Monads, although independent of each other, interacted predictably; this meant that Christian faith and scientific reason need not be in conflict and that 'this is the best of all possible worlds'. Leibniz's optimism is satirized in French philosopher Voltaire's novel *Candide*.

Leibniz, Gottfried Wilhelm

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Maintained by the Metaphysics Research Lab at Stanford University, this page concerns the life and ideas of philosopher, logician, and mathematician Gottfried Leibniz. It features a time line of the major events in Leibniz's life, a list of his principle works, a brief examination of his philosophical contributions, and a list of sources for further reading.

Leibovitz, Annie (1949-)

born Anna-Lou Leibovitz

US photographer. Her elaborately staged portraits of US celebrities appeared first in *Rolling Stone* magazine and later in *Vanity Fair*. The odd poses in which her sitters allow themselves to be placed suggest an element of self-mockery.

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leishmaniasis

any of several parasitic diseases caused by microscopic protozoans of the genus *Leishmania* and transmitted by sandflies. It occurs in two main forms: **visceral** (also called kala-azar), in which various internal organs are affected, and **cutaneous**, where the disease is apparent mainly in the skin. Leishmaniasis occurs in the Mediterranean region, Africa, Asia, and Central and South America. There are 1.5-2 million new cases of leishmaniasis annually (as of 2006), with a total of 12 million people affected at any given time. The disease kills approximately 8,000 people a year in South America and results in hundreds of thousands more suffering permanent disfigurement and disability through skin lesions, joint pain, and swelling of the liver and spleen. The disease was identified by William Leishman (1865-1926).

In 1994 Indian researchers discovered a cheap and effective way of keeping sandfly populations under control, by plastering the walls of houses and outbuildings with mud and lime. The plaster deprives flies of the moist crevices in which they breed, and the lime kills any existing larvae. In trials, sandfly numbers dropped by 90%.

UK researchers determined the structure of the sex pheromone of the male sandfly, enabling Japanese researchers to synthesize the pheromone in 1999. This opened the way for possible control of sandfly numbers by attracting sandflies to areas of extermination rather than having to spray pesticides widely in urban areas, with all the concomitant risks.

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lek

in biology, a closely spaced set of very small territories each occupied by a single male during the mating season. Leks are found in the mating systems of several ground-dwelling birds (such as grouse) and a few antelopes, and in some insects.

The lek is a traditional site where both males and females congregate during the breeding season. The males display to passing females in the hope of attracting them to mate. Once mated, the females go elsewhere to lay their eggs or to complete gestation.

Lemaître, Georges Edouard (1894-1966)

Belgian cosmologist. He proposed the Big Bang theory of the origin of the universe in 1933. US astronomer Edwin Hubble had shown that the universe was expanding, but it was Lemaître who suggested that the expansion had been started by an initial explosion, the Big Bang, a theory that is now generally accepted.

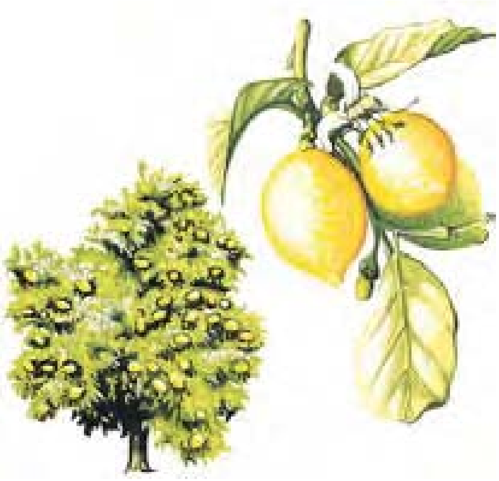
lemming

any of a group of small rodents distributed worldwide in northern latitudes. They are about 12 cm/5 in long, with thick brownish fur, a small head, and a short tail. Periodically, when their population exceeds the available food supply, lemmings undertake mass migrations. (Genus *Lemmus* and other related genera, family Cricetidae.)

lemon

sharp-tasting yellow citrus fruit of the small, evergreen, semitropical lemon tree. It may have originated in northwestern India, and was introduced into Europe by the Spanish Moors in the 12th or 13th century. It is now grown in Italy, Spain, California, Florida, South Africa, and Australia, and is widely used for flavouring and as a garnish. (*Citrus limon*, family Rutaceae.)

lemon



(Image © Research Machines plc)

The lemon tree and its fruit. The juice of the lemon fruit contains about four times as much citric acid as is found in the orange. It is a major commercial source of citric acid.

lemon balm

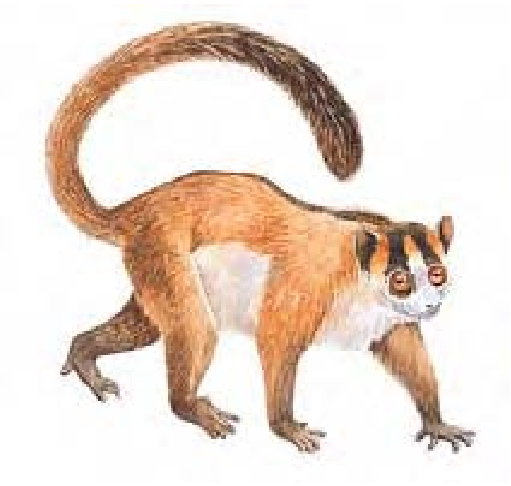
perennial herb belonging to the mint family, with lemon-scented leaves. It is widely used in teas, liqueurs, and medicines. (*Melissa officinalis*, family Labiatae.)

lemur

any of various prosimian primates of the Lemuridae family, found in Madagascar and the Comoros Islands. There are about 16 species, ranging from mouse-sized to dog-sized animals; the pygmy mouse lemur (*Microcebus myoxinus*), weighing 30 g/1 oz, is the smallest primate. The diademed sifaka, weighing 7 kg/15 lb, is the largest species of lemur. Lemurs are arboreal, and some species are nocturnal. They have long, bushy tails, and feed on fruit, insects, and small animals. Many are threatened with extinction owing to loss of their forest habitat and, in some cases, from hunting.

The fat-tailed dwarf lemur, *cheirogaleus medius*, is the first primate to be shown to hibernate through winter. Lemurs tagged with temperature transmitters demonstrated that, unlike other species that hibernate, dormant lemurs do not regulate their body temperature, which instead closely follows the ambient temperatures of their tree-hole homes. Lemurs hibernate to save energy through the hot, dry Madagascan winter period when their staple diet of fruit is scarce.

lemur



(Image © Research Machines plc)

The fork-marked lemur is tree-dwelling, with large eyes that look forwards over a small, pointed nose. The long, bushy tail is used for balance and, when held in different positions, as a signal to other lemurs.

Lemur

Go to site

Illustrated guide to the lemur including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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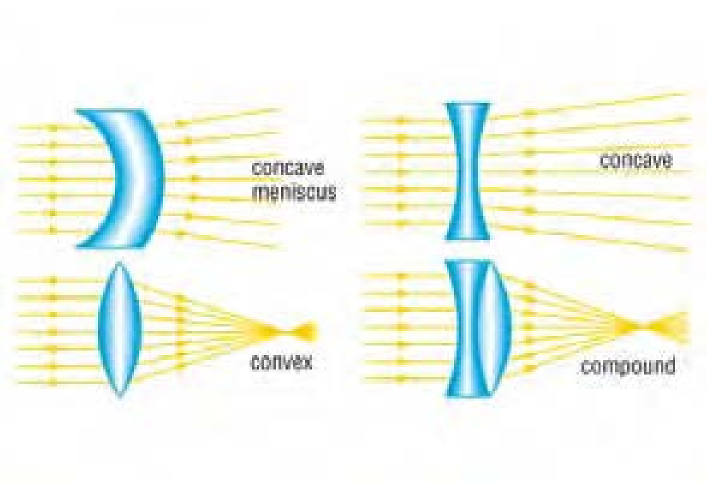
lens

in optics, a piece of a transparent material, such as glass, with two polished surfaces - one concave or convex, and the other plane, concave, or convex - that modifies rays of light. A convex lens brings rays of light together; a concave lens makes the rays diverge. Lenses are essential to spectacles, microscopes, telescopes, cameras, and almost all optical instruments.

The image formed by a single lens suffers from several defects or aberrations, notably **spherical aberration** in which an image becomes blurred, and **chromatic aberration** in which an image in white light tends to have coloured edges. Aberrations are corrected by the use of compound lenses, which are built up from two or more lenses of different refractive index.

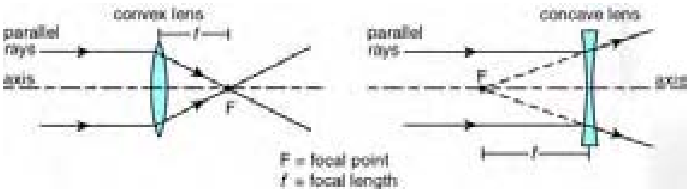
lens



(Image © Research Machines plc)

The passage of light through lenses. The concave lenses diverges a beam of light from a distant source. The convex and compound lenses focus light from a distant source to a point. The distance between the focus and the lens is called the focal length. The shorter the focus, the more powerful the lens.

lens



(Image © Research Machines plc)

A convex (or converging) lens causes light rays to refract inwards. A concave (or diverging lens) causes light rays to refract outwards. Convex lenses are used to correct long-sightedness and concave lenses to correct short-sightedness.

lens, gravitational

object in space which, by its gravitational field, bends light in a similar way to a spectacle lens. As a result of this, one object, such as a quasar, can appear as multiple images. A gravitational lens also produces a magnifying effect. Numerous examples are now known of such multiple imaging. Images of quasars and galaxies are also stretched into arcs by gravitational lenses.

See gravitational lensing.

lenticel

small pore on the stems of woody plants or the trunks of trees. Lenticels are a means of gas exchange between the stem interior and the atmosphere. They consist of loosely packed cells with many air spaces in between, and are easily seen on smooth-barked trees such as cherries, where they form horizontal lines on the trunk.

lenticular galaxy

lens-shaped galaxy with a large central bulge and flat disc but no discernible spiral arms.

lentil

annual Old World plant belonging to the pea family. The plant, which resembles vetch, grows 15-45 cm/6-18 in high and has white, blue, or purplish flowers. The seeds, contained in pods about 1.6 cm/0.6 in long, are widely used as food. (*Lens culinaris*, family Leguminosae.)

The most common varieties are the greyish French lentil and the red Egyptian lentil.

Lenz's law

in physics, a law stating that the direction of an electromagnetically induced current (generated by moving a magnet near a wire or a wire in a magnetic field) will be such as to oppose the motion producing it. It is named after the Russian physicist Heinrich Friedrich Lenz, who announced it in 1833.

Leo

zodiacal constellation in the northern hemisphere, represented as a lion. The Sun passes through Leo from mid-August to mid-September. Its brightest star is first-magnitude Regulus at the base of a pattern of stars called the Sickle. Gamma Leonis is a double star. In astrology, the dates for Leo are between about 23 July and 22 August (see precession).

Leonardo da Vinci (1452-1519)

Italian painter, sculptor, architect, engineer, and scientist. One of the greatest figures of the Italian Renaissance, he was active in Florence, Milan, and, from 1516, France. As state engineer and court painter to the Duke of Milan, he painted the *Last Supper* mural (*c.* 1495; Sta Maria delle Grazie, Milan), and on his return to Florence painted the *Mona Lisa* (*c.* 1503-05; Louvre, Paris). His notebooks and drawings show an immensely inventive and enquiring mind, studying aspects of the natural and scientific world from anatomy and botany to aerodynamics and hydraulics.

Milan

Leonardo left Florence for Milan in *c.* 1482, offering his services to Ludovico Sforza, the Duke of Milan, primarily as a military and naval engineer, as a sculptor next, and as a painter incidentally. As a military engineer he was responsible for the construction of assault machines, pontoons, a steam cannon, and a tortoise-shaped assault tank. For a castle in Milan he created a forced-air central heating system and also a water-pumping mechanism. Leonardo's inventions ranged from complex cranes to pulley systems, lathes, drilling machines, a paddlewheel boat, flying machines, and an underwater breathing apparatus.

Soon after his arrival, however, he painted Ludovico's mistress, Cecilia Gallerani (the *Lady with an Ermine*, Kraków, Czartoryski Collection), and, in partnership with Ambrogio da Predis in 1483, an altarpiece to which Leonardo contributed the central panel, *The Virgin of the Rocks*. (The existence of two versions, one in the Louvre, Paris, and one in the National Gallery, London, may be explained by the revision of the altarpiece in 1506 after a long period of haggling, when presumably a first version of the panel was sent to France and the other was finally accepted by the confraternity of the Immaculate Conception.)

Other undertakings were the bronze equestrian monument to Francesco Sforza, of which only the model was completed, and the world-famous fresco of the *Last Supper* in the refectory of Sta Maria delle Grazie. This painting, in which he used an experimental oil medium, suffered from the damp wall on which it was painted.

Venice, Rome, and Florence

Having left Milan to return to Florence in 1499, the following year Leonardo travelled to Venice, where he may have met the Italian painter Giorgione, who was greatly impressed by his treatment of light and shade. Leonardo developed the use of both *chiaroscuro* (the contrast of light and shadow) and also *sfumato* (the subtle graduation of colours and tones), both techniques helping to extend the emotional depth and complexity of painting.

After mapping the country and planning canals and harbours for Caesar Borgia in Rome, in 1503 Leonardo was commissioned by the Signory of Florence to produce a battle scene on the walls of the Council Hall. Michelangelo was commissioned the same time for a similar work. After working on the *Battle of Anghiari* for two years, Leonardo left the work unfinished, and an experimental technique again destroyed what he had done. Over the same time, Leonardo also worked on the portrait of *Mona Lisa* (*La Gioconda*; Louvre), the wife of wealthy merchant Francesco Zanobi del Giocondo. The mysterious smiling picture depicted all the subtle elusiveness of expression that Leonardo loved.

later years

In 1506 Leonardo returned to Milan (now under French domination) as the city's engineer and architect, moved on to Rome in 1513 for three years, and then accepted Francis I's invitation to France. He spent his last years in the small castle of Cloux near the royal residence of Amboise on the Loire. His last painting was the *St John the Baptist* (*c.* 1514–15), now in the Louvre.

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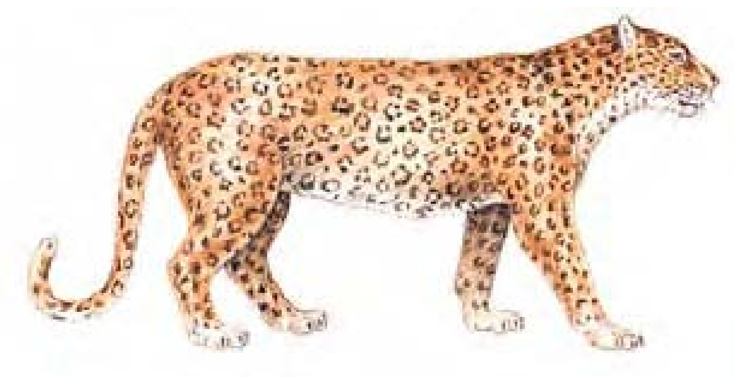
leopard

or panther

large wild cat found in Africa and Asia. The background colour of the coat is golden, and the black spots form rosettes that differ according to the variety; **black panthers** are simply a colour variation and retain the patterning as a 'watered-silk' effect. The leopard is 1.5–2.5 m/5–8 ft long, including the tail, which may measure 1 m/3 ft. (Species *Panthera pardus*, family Felidae.)

The **snow leopard** or **ounce** (*Panthera uncia*), which has irregular rosettes of much larger black spots on a light cream or grey background, is a native of mountains in central Asia. The **clouded leopard** (*Neofelis nebulosa*) is rather smaller, about 1.75 m/5.8 ft overall, with large blotchy markings rather than rosettes, and is found in Southeast Asia. There are seven subspecies, of which six are in danger of extinction, including the **Amur leopard** and the **South Arabian leopard**. One subspecies, the **Zanzibar leopard**, may already be extinct. The last **Judean desert leopard** died May 1995, although a small population survives in the Negev Desert.

leopard



(Image © Research Machines plc)

The leopard has exceptionally acute hearing, together with good sight and sense of smell. Leopards are agile and have been known to leap from trees on to prey. They climb well, often dragging prey high into trees for safety.

Lepenski Vir

prehistoric settlement site in the valley of the River Danube, where it runs through the Iron Gates gorge, in Serbia and Montenegro on the Romanian border. One of Europe's oldest farming settlements, dating from the 6th millennium BC, it is possibly the earliest and best preserved late Mesolithic to Neolithic (Middle to New Stone Age) site in the Balkans. The site is now submerged by an artificial lake.

A series of unusual trapezoidal dwellings were found, dating from the mid-6th millennium BC, associated with large limestone sculptures of fishlike human beings, belonging to a preceding camp of hunter-fisher people. All the dwellings had their wide end pointing towards the river, with limestone plaster floors and probably a wooden structure over. Hearths comprised limestone blocks inside elongated pits; in some cases human burials were made close by. The roofs of the dwellings may have been covered in hides or reed thatch. A larger central house may indicate social stratification.

Diet depended on fish and the development of fishing and boat technology. The life style of the inhabitants was sedentary but had arisen out of adaptation from a previous hunting tradition. Resources included catfish, carp, deer, and wild pigs.

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leprosy

or Hansen's disease

chronic, progressive disease caused by the bacterium *Mycobacterium leprae*, closely related to that of tuberculosis. The infection attacks the skin and nerves. Leprosy is endemic in 28 countries, and confined almost entirely to the tropics. It is controlled with drugs. Worldwide, there were 400,000 new cases of leprosy in 2004, a 21% decrease from the previous year.

There are two principal manifestations.
Lepromatous leprosy is a contagious, progressive form distinguished by the appearance of raised blotches and lumps on the skin and thickening of the skin and nerves, with numbness, weakness, paralysis, and ultimately deformity of the affected parts. In **tuberculoid leprosy**, sensation is lost in some areas of the skin; sometimes there is loss of pigmentation and hair. The visible effects of long-standing leprosy (joint damage, paralysis, loss of fingers or toes) are due to nerve damage and injuries of which the sufferer may be unaware. A technique that uses the patient's muscle material to encourage nerve regrowth is being explored.

In 2005 the World Health Organization (WHO) presented a global strategy for reducing and controlling leprosy for the years 2006–10. Countries where leprosy control remains a challenge include: Angola, Brazil, Central African Republic, Democratic Republic of Congo, India, Madagascar, Mozambique, Nepal, and Tanzania.

Leptis Magna

ruined city in Libya, 120 km/75 mi east of Tripoli. It was founded by the Phoenicians, then came under Carthage, and in 47 BC under Rome. Excavation in the 20th century revealed remains of fine Roman buildings.

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lepton

any of a class of elementary particles that are not affected by the strong nuclear force. The leptons comprise the electron, muon, and tau, and their neutrinos (the electron neutrino, muon neutrino, and tau neutrino), as well as their six antiparticles.

In July 2000, researchers at Fermilab, in the USA, amassed the first direct evidence for the existence of last neutrino remaining to be discovered, the tau lepton.

The Top Quark

the standard model

All forms of matter are made from two types of particles called quarks and leptons. These particles interact with each other through four forces: gravity, electromagnetism, and the strong and weak nuclear forces. All these forces are thought to be carried by other particles known as gauge bosons. This model of fundamental particles and their interactions is known as the 'Standard Model of Particle Physics'.

Particle families

Quarks and leptons come in families. The lightest family contains the up quark, the down quark, the electron and the electron neutrino. The up quark has an electric charge of +2/3, the down quark has a charge of -1/3 and the electron has a charge of -1. The neutrino has no mass (i.e. it does not weigh anything) and no charge. Everyday matter is made up of up and down quarks and electrons. Single quarks have never been observed in experiments – they always combine in twos and threes to form other particles known as mesons and baryons. Each particle in the Standard Model also has an anti-particle with the same mass but opposite electric charge. One of the biggest mysteries in particle physics is why the universe is made of matter rather than anti-matter.

heavy particles

By the middle of 1980 physicists knew that there were only three families of particles. The second family comprised the charm and strange quarks, the muon, and the muon neutrino. These particles had the same pattern of behaviour as the particles in the first family but were heavier: the muon, for example, was 212 times heavier than the electron. The particles were also short-lived and decayed into lighter particles.

The particles in the third family were heavier still and even more short-lived. The third family included the bottom quark and the tau lepton, both discovered in the mid 1970s. A sixth quark was needed to complete the picture but the top quark remained elusive until it was discovered at FermiLab in the USA in 1995.

how to make new particles

The top quark was the last quark to be discovered because it was the heaviest. Physicists discover new particles by colliding high-energy beams of other particles together: the more energetic the collisions, the heavier the particles that can be discovered. The top quark turned out to have a mass of 175 gigaelectronvolts - as heavy as an atom of gold.

what next?

The top quark is not the end of the story. Physicists now hope to find the particle (or particles) which could explain why all the fundamental particles have very different masses. This particle is named after the British theoretical physicist Peter Higgs. Physicists hope to discover the Higgs particle at the large hadron collider (LHC), which is due to start in 2005 at the CERN laboratory near Geneva. The LHC will collide beams of high-energy protons in a circular particle accelerator with a circumference of 27 km/17 mi. LHC physicists also hope to discover supersymmetric particles. Supersymmetry is a theory which predicts that the two types of fundamental particles - quarks and leptons - are in fact related.

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leptospirosis

any of several infectious diseases of domestic animals and humans caused by spirochetes of the genus *Leptospira*, found in sewage and natural waters. One such disease in cattle causes abortion; in humans, eyes, liver, and kidneys may be affected; meningitis (inflammation of the membrane surrounding the brain) is another symptom.

Leptospirosis can be transmitted to humans by rats and mice. The leptospira are carried in the kidneys, and transmitted via excreted urine in damp soils or water. For example, children may be infected if water from infected puddles splashes into their eyes. Many cases remain undiagnosed as symptoms may be no more serious than a mild dose of influenza. 1996 figures indicate that there are approximately 50 cases annually in the USA. If the symptoms become more serious, kidney and liver failure may result. The illness at this stage is called Weil's disease.

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lesion

any change in a body tissue that is a manifestation of disease or injury.

Lesseps, Ferdinand Marie (1805-1894)

Vicomte de Lesseps

French engineer. He designed and built the Suez Canal 1859-69. He began work on the Panama Canal in 1881, but withdrew after failing to construct it without locks.

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lethargy

in medicine, apathetic state that may arise from a variety of causes, including physical illnesses, such as glandular fever and other viral infections and anaemia; excessive fatigue due, for example, to insomnia; or as a symptom of mental illnesses, such as depression or anxiety. It can also be due to an adverse effect of some drugs, such as beta-blockers. It is important to treat the underlying cause of lethargy.

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letterpress

method of printing from raised type, pioneered by Johann Gutenberg in Europe in the 1450s.

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lettuce

annual plant whose large edible leaves are commonly used in salads. There are many varieties, including the cabbage lettuce, with round or loose heads, the Cos lettuce, with long, upright heads, and the Iceberg lettuce, with tight heads of crisp leaves. They are all believed to have been derived from the wild species *L. serriola*. (Genus *Lactuca*, especially *L. sativa*, family Compositae.)

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leucine

one of the nine essential amino acids.

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leucite

silicate mineral, $KAlSi_2O_6$, occurring frequently in some potassium-rich volcanic rocks. It is dull white to grey, and usually opaque. It is used as a source of potassium for fertilizer.

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leucotomy

or lobotomy

brain operation to sever the connections between the frontal lobe and underlying structures. It was widely used in the 1940s and 1950s to treat severe psychotic or depressive illness. Though it achieved some success, it left patients dull and apathetic; there was also a considerable risk of epilepsy. It was largely replaced by the use of psychotropic drugs from the late 1950s.

Today, a limited amount of psychosurgery is performed in specialist centres under strict controls. It includes the creation of tiny, precise frontal lobe lesions to relieve severe conditions that have not responded to other treatments.

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leukaemia

any one of a group of cancers of the blood cells, with widespread involvement of the bone marrow and other blood-forming tissue. The central feature of leukaemia is runaway production of white blood cells that are immature or in some way abnormal. These rogue cells, which lack the defensive capacity of healthy white cells, overwhelm the normal ones, leaving the victim vulnerable to infection. Treatment is with radiotherapy and cytotoxic drugs to suppress replication of abnormal cells, or by bone-marrow transplantation.

Abnormal functioning of the bone marrow also suppresses production of red blood cells and blood platelets, resulting in anaemia and a failure of the blood to clot.

Leukaemias are classified into acute or chronic, depending on their known rates of progression. They are also grouped according to the type of white cell involved.

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leukocyte

or leucocyte

white blood cell. Leukocytes play a part in the body's defences and give immunity against disease. There are several different types. Some (phagocytes and macrophages) engulf invading micro-organisms, others kill infected cells, while lymphocytes produce more specific immune responses. Leukocytes are colorless, with clear or granulated cytoplasm, and are capable of independent amoeboid movement. They occur in the blood, lymph, and elsewhere in the body's tissues.

Unlike mammalian red blood cells, leukocytes possess a nucleus. Human blood contains about 11,000 leukocytes to the cubic millimeter - about 1 to every 500 red cells.

Leukocyte numbers may be reduced (leukopenia) by starvation, pernicious anemia, and certain infections, such as typhoid and malaria. An increase in the numbers (leukocytosis) is a reaction to normal events such as digestion, exertion, and pregnancy, and to abnormal ones such as loss of blood, cancer, and most infections.

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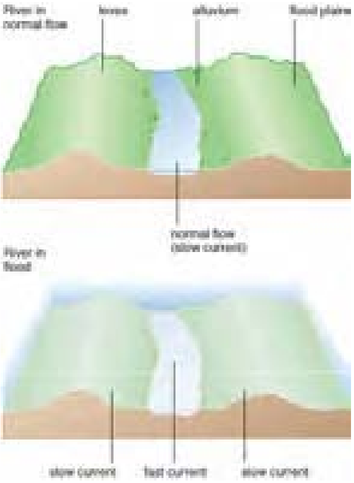
levee

naturally formed raised bank along the side of a river channel. When a river overflows its banks, the rate of flow is less than that in the channel, and silt is deposited on the banks. With each successive flood the levee increases in height so that eventually the river may be above the surface of the surrounding flood plain. Notable levees are found on the lower reaches of the Mississippi in the USA, and along the Po in Italy. The Hwang Ho in China also has well-developed levees.

levee


River in normal flow
levee
alluvium
flood plain
normal flow (slow current)
River in flood
slow current
fast current
slow current

(Image © Research Machines plc)

Levees are formed on the banks of meandering rivers when the river floods over its flood plain. The flow of the flood water is slower over the levees than it is in the river bed and so silt is deposited there.

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level

or spirit level

instrument for finding horizontal level, or adjusting a surface to an even level, used in surveying, building construction, and archaeology. It has a glass tube of coloured liquid, in which a bubble is trapped, mounted in an elongated frame. When the tube is horizontal, the bubble moves to the centre.

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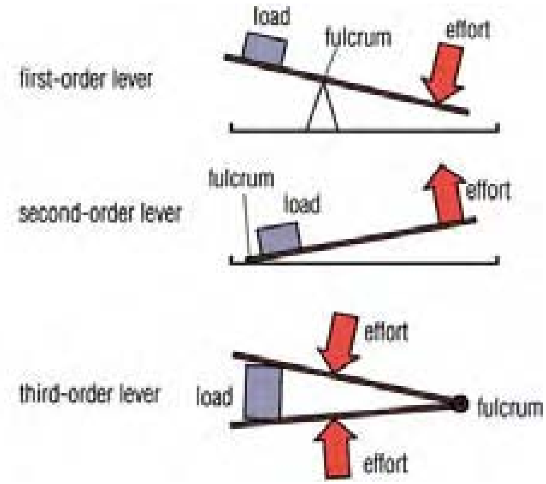
lever

simple machine consisting of a rigid rod pivoted at a fixed point called the fulcrum, used for shifting or raising a heavy load or applying force. Levers are classified into orders according to where the effort is applied, and the load-moving force developed, in relation to the position of the fulcrum.

A see-saw is an example of a simple lever. An effort force at one end is used to lift a load force at the opposite end, with a turning motion about the pivot. A see-saw can also be used to demonstrate the balancing of the moments of a force. The formula used to work out the force needed and the distance of the force from the pivot to balance the see-saw is: effort force × distance from pivot = load force × distance from pivot.

A **first-order** lever has the load and the effort on opposite sides of the fulcrum – for example, a see-saw or pair of scissors. A **second-order** lever has the load and the effort on the same side of the fulcrum, with the load nearer the fulcrum – for example, nutcrackers or a wheelbarrow. A **third-order** lever has the effort nearer the fulcrum than the load, with both on the same side of it – for example, a pair of tweezers or tongs. The mechanical advantage of a lever is the ratio of load to effort, equal to the perpendicular distance of the effort's line of action from the fulcrum divided by the distance to the load's line of action. Thus tweezers, for instance, have a mechanical advantage of less than one.

lever


first-order lever
load
fulcrum
effort
second-order lever
fulcrum
load
effort
third-order lever
effort
load
fulcrum
effort

(Image © Research Machines plc)

Types of lever. Practical applications of the first-order lever include the crowbar, seesaw, and scissors. The wheelbarrow is a second-order lever; tweezers or tongs are third-order levers.

Leverrier, Urbain Jean Joseph (1811-1877)

French astronomer. He predicted the existence and position of the planet Neptune from its influence on the orbit of the planet Uranus. It was discovered in 1846.

The possibility that another planet might exist beyond Uranus, influencing its orbit, had already been suggested. Leverrier calculated the orbit and apparent diameter of the hypothetical planet, and wrote to a number of observatories, asking them to test his prediction of its position. Johann Galle at the Berlin Observatory found it immediately, within 1° of Leverrier's coordinates.

Unbeknown to Leverrier, English astronomer John Couch Adams had carried out virtually identical calculations a year earlier, but had failed to persuade anyone to act on them.

Leverrier, Urbain Jean Joseph

Go to site

Devoted to the life and contributions of astronomer Urbain Leverrier. In addition to biographical information, you will find a list of references about Leverrier and links to essays that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Leverrier. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

Levi-Montalcini, Rita (1909-2000)

Italian neurologist who was awarded a Nobel Prize for Physiology or Medicine in 1986 with her co-worker, US biochemist Stanley Cohen, for their discovery of factors that promote the growth of nerve and epidermal cells. This nerve-growth factor controls how many cells make up the adult nervous system.

LF

in physics, abbreviation for low frequency. LF radio waves have frequencies in the range 30-300 kHz.

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liana

woody, perennial climbing plant with very long stems, which grows around trees right up to the top, where there is more sunlight. Lianas are common in tropical rainforests, where individual stems may grow up to 78 m/255 ft long. They have an unusual stem structure that makes them flexible, despite being woody.

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libido

in Freudian psychology, the energy of the sex instinct, which is to be found even in a newborn child. The libido develops through a number of phases, described by Sigmund Freud in his theory of infantile sexuality. The source of the libido is the id.

The phases of the libido are identified by Freud as the **oral stage**, when a child tests everything by mouth, the **anal stage**, when the child gets satisfaction from control of its body, and the **genital stage**, when the libido becomes concentrated in the sex organs.

Loss of adult libido is seen in some diseases; see also impotence.

Libra

faint zodiacal constellation on the celestial equator (see celestial sphere) adjoining Scorpius, and represented as the scales of justice. The Sun passes through Libra during November. The constellation was once considered to be a part of Scorpius, seen as the scorpion's claws. In astrology, the dates for Libra are between about 23 September and 23 October (see precession). The name is said to reflect the fact that the entrance of the Sun into the sign once marked the September equinox, when day and night are approximately equal. Its brightest star, Zubeneschamali (or Beta Librae), is about 120 light years from Earth.

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libration

in astronomy, slight apparent wobble in the rotation of the Moon due to its variable speed of rotation and the tilt of its axis.

Generally, the Moon rotates on its axis in the same time as it takes to complete one orbit, causing it to keep one face turned permanently towards the Earth (see captured rotation). Its speed in orbit varies, however, because its orbit is not circular but elliptical; hence at times the Moon's axial rotation appears to get either slightly ahead of or slightly behind its orbital motion, so that part of the 'dark side' of the Moon is visible around the east and west edges. This is known as **libration in longitude**.

Libration in latitude occurs because the Moon's axis is slightly tilted with respect to its orbital plane, so we can see over the north and south poles. In combination, these effects mean that a total of 59% of the Moon's surface is visible, rather than just 50%, as would be the case if libration did not occur.

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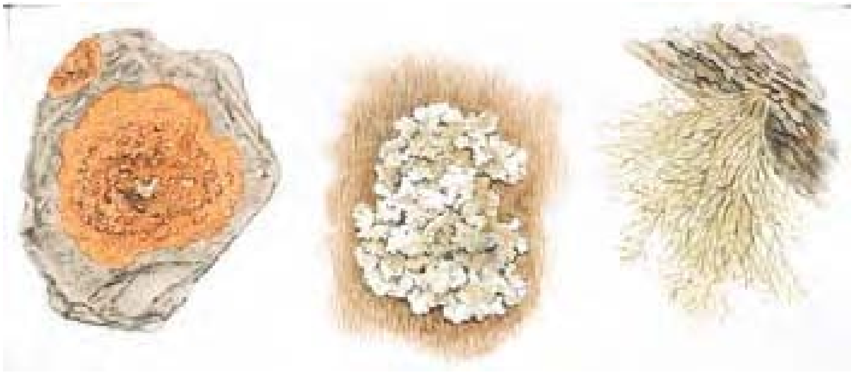
lichen

any organism of a unique group that consists of associations of a specific fungus and a specific photosynthetic organism (an alga or a cyanobacterium) living together in a mutually beneficial relationship (symbiosis). Found as coloured patches or spongelike masses on trees, rocks, and other surfaces, lichens flourish in harsh conditions, for example on exposed rock faces in Antarctica. (Group Lichenes.)

Some lichens are edible, for example, reindeer moss and Iceland moss; others are a source of colour dyes, such as litmus, or are used in medicine. They are sensitive to pollution in the air (see indicator species).

lichen



(Image © Research Machines plc)

A lichen is a symbiotic association between an alga and a fungus – in other words, each lichen is not one organism but two. Lichens grow very slowly, usually as encrustations on rocks, walls, or wood. They are found throughout the world but are unable to survive where the atmosphere is polluted, so they are good indicators of clean air.

lichen

To remember that **lichen** are made up of **algae** and **fungi**:

She was all gal (**algal**) and he was a fun guy (**fungi**). They took a likin' (**lichen**) to each other

Fun With Lichens

Go to site

Thorough guide to these unique fungus-alga combinations. Written by a lichen enthusiast at the University of Oregon, this is a good introduction to the subject. The textual content is well supported with photographs. There are sections suitable for the general reader, schoolchildren, and professional botanists, ecologists, and foresters.

Lick Observatory

observatory of the University of California at Mount Hamilton, California. Established in 1888, its main instruments are the 3.04-m/120-in Shane reflector, opened in 1959, and a 91-cm/36-in refractor, opened in 1988, the second-largest refractor in the world. The Automated Planet Finder (APF) is a robotically operated telescope that will search automatically on every clear night for tiny wobbles in the motion of stars. Such wobbles will reveal the presence of small, rocky planets orbiting the stars.

Liebig, Justus (1803-1873)

Baron von Liebig

German organic chemist who extended chemical research into other scientific fields, such as agricultural chemistry and biochemistry. He introduced the theory of compound radicals and discovered chloroform and chloral, and demonstrated the use of fertilizers.

isomers

In the 1820s, Liebig began a long collaboration with Friedrich Wöhler. Liebig investigated fulminates, at the same time that Wöhler was independently working with cyanates. In 1826, Liebig prepared silver fulminate (modern formula AgCNO) and Wöhler made silver cyanate (AgNCO). When they reported their results they assigned the same formula to the two different compounds, which stimulated Jöns Berzelius' work that led to the concept of isomers.

compound radicals

Liebig and Wöhler became friends and continued their researches together. They introduced the idea of **compound radicals** in organic chemistry- the idea that a family of chemicals can be made from the same molecular unit, or radical. In 1832, from a study of oil of bitter almonds (benzaldehyde; phenylmethanal), they discovered the benzoyl radical (C_6H_5CO-). They showed that benzaldehyde can be converted to benzoic acid and made a number of other related compounds, such as benzyl alcohol and benzoyl chloride. The benzene ring had, in fact, conferred unusual stability to the benzoyl grouping, allowing it to persist in the various reactions. Although they found no other radicals that supported their theory as convincingly, they introduced a degree of systematization into the confused field of organic chemistry. Liebig devised many new methods of organic analysis, specifically ways of determining hydrogen, carbon and halogen content in organic compounds.

biochemistry

From 1838 Liebig's work centred on what we would now call biochemistry. He studied fermentation, but would not acknowledge that yeast is a living substance, a view to which Berzelius also subscribed. Their view brought them both into contention with Louis Pasteur. Liebig analysed various body fluids, and calculated the calorific values of foods, emphasizing the role of fats as a source of dietary energy and developing a beef extract - marketed as Liebig extract.

agricultural chemistry

Liebig also applied his chemical knowledge to agriculture. He demonstrated that plants absorb minerals, water, and nitrogen from the soil, although he incorrectly thought that the nitrogen came from ammonia in rainwater. He demonstrated that the carbon used by plants does not come from humus in the soil, postulating instead that the carbon comes from carbon dioxide in the air. He was also correct in thinking that adding minerals and nitrates to the soil would improve plant growth and advocated the use of artificial fertilizers in agriculture.

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lie detector

instrument that records graphically certain body activities, such as thoracic and abdominal respiration, blood pressure, pulse rate, and galvanic skin response (changes in electrical resistance of the skin). Marked changes in these activities when a person answers a question may indicate that the person is lying.

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life

ability to grow, reproduce, and respond to such stimuli as light, heat, and sound. Life on Earth may have begun about 4 billion years ago when a chemical reaction produced the first organic substance. Over time, life has evolved from primitive single-celled organisms to complex multicellular ones. There are now some 10 million different species of plants and animals living on the Earth. The earliest fossil evidence of life is threadlike chains of cells discovered in 1980 in deposits in northwestern Australia; these 'stromatolites' have been dated as being 3.5 billion years old.

Biology is the study of living organisms - their evolution, structure, functioning, classification, and distribution - while biochemistry is the study of the chemistry of living organisms. Biochemistry is especially concerned with the function of the chemical components of organisms such as proteins, carbohydrates, lipids, and nucleic acids.

Life probably originated in the primitive oceans. The original atmosphere, 4 billion years ago, consisted of carbon dioxide, nitrogen, and water. Laboratory experiments have shown that more complex organic molecules, such as amino acids and nucleotides, can be produced from these ingredients by passing electric sparks through a mixture. The climate of the early atmosphere was probably very violent, with lightning a common feature, and these conditions could have resulted in the oceans becoming rich in organic molecules, producing the so-called 'primeval soup'. These molecules may then have organized themselves into clusters capable of reproducing and eventually developing into simple cells. Soon after life developed, photosynthesis would have become the primary source of energy for life. By this process, life would have substantially affected the chemistry of the atmosphere and, in turn, that of its own environment. Once the atmosphere had changed to its present composition, life could only be created by the replication of living organisms (a process called biogenesis).

life: characteristics of living organisms

To remember the seven characteristics of a living organism:

R3GFEC

Respond, **r**espire, **r**eproduce, **g**row, **f**eed, **e**xcrete, (have) **c**ells

GCSE Biology

Go to site

Attractive and easy-to-use Web site covering all the main elements of the GCSE topic 'Life Processes and Living Things'. It is broken down into sections, such as 'Animal and plant cells', 'Blood', 'Vitamins', and so on. Each topic page contains hypertext links to further information where needed.

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life cycle

in biology, the sequence of developmental stages through which members of a given species pass. Most vertebrates have a simple life cycle consisting of fertilization of sex cells or gametes, a period of development as an embryo, a period of juvenile growth after hatching or birth, an adulthood including sexual reproduction, and finally death.

Invertebrate life cycles are generally more complex and may involve major reconstitution of the individual's appearance (metamorphosis) and completely different styles of life. Plants have a special type of life cycle with two distinct phases, known as alternation of generations. Many insects such as cicadas, dragonflies, and mayflies have a long larvae or pupae phase and a short adult phase. Dragonflies live an aquatic life as larvae and an aerial life during the adult phase. In many invertebrates and protozoa there is a sequence of stages in the life cycle, and in parasites different stages often occur in different host organisms.

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life expectancy

average lifespan that can be presumed of a person at birth. It depends on nutrition, disease control, environmental contaminants, war, stress, and living standards in general.

There is a marked difference between industrialized countries, which generally have an ageing population, and the poorest countries, where life expectancy is much shorter. In Bangladesh, life expectancy is currently 48; in Nigeria 49. In famine-prone Ethiopia it is only 41.

Countries with the highest life expectancy

2006	
Women	
Andorra	87
Japan	85
San Marino	86
Singapore	84
Australia	84
Canada	84
Sweden	83
Switzerland	83
Italy	83
Spain	83
Iceland	82
Norway	82
Israel	82
Greece	82
Belgium	82
Austria	82
Netherlands	82
New Zealand	82
Germany	82
Finland	82
Men	
Andorra	81
Singapore	79
Japan	78
San Marino	78
Sweden	78
Switzerland	78
Australia	78
Iceland	78
Canada	77
Italy	77
Israel	77
Norway	77
Greece	77
Malta	77
Belgium	76
Netherlands	76
New Zealand	76
United Kingdom	76
Austria	76
France	76

Liechtenstein	76
Monaco	76
Spain	76
Germany	76

Countries with the lowest life expectancy

2006	
Women	
Swaziland	33
Lesotho	33
Botswana	34
Zimbabwe	38
Mozambique	40
Zambia	40
Angola	40
Malawi	41
Liberia	41
Sierra Leone	42
South Africa	42
Namibia	42
Men	
Swaziland	32
Botswana	34
Lesotho	36
Angola	37
Liberia	38
Sierra Leone	38
Zimbabwe	40
Mozambique	40
Zambia	40
Malawi	42
Djibouti	42
South Africa	43
Afghanistan	43
Central African Republic	43

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life sciences

scientific study of the living world as a whole, a new synthesis of several traditional scientific disciplines including biology, zoology, and botany, and newer, more specialized areas of study such as biophysics and sociobiology.

This approach has led to many new ideas and discoveries as well as to an emphasis on ecology, the study of living organisms in their natural environments.

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ligament

strong, flexible connective tissue, made of the protein collagen, which joins bone to bone at moveable joints and sometimes encloses the joints. Ligaments prevent bone dislocation (under normal circumstances) but allow joint flexion. The ligaments around the joints are composed of white fibrous tissue. Other ligaments are composed of yellow elastic tissue, which is adapted to support a continuous but varying stress, as in the ligament connecting the various cartilages of the larynx (voice box).

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ligature

any surgical device (nylon, gut, wire) used for tying a blood vessel to stop it bleeding, or to tie round the base of a growth to constrict its blood supply.

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light

electromagnetic waves (made up of electric and magnetic components) in the visible range, having a wavelength from about 400 nanometres in the extreme violet to about 700 nanometres in the extreme red. Light is considered to exhibit particle and wave properties, and the fundamental particle, or quantum, of light is called the photon. A light wave comprises two transverse waves of electric and magnetic fields travelling at right angles to each other, and as such is a form of electromagnetic radiation. The speed of light (and of all electromagnetic radiation) in a vacuum is approximately 300,000 km/186,000 mi per second, and is a universal constant denoted by *c*.

Light is a form of energy that is mainly visible to the human eye. Light is radiated by hot objects such as the Sun or an electric light bulb.

The nature of light travelling through a medium can be explained with the help of Young's double-slit experiment. A double slit is placed between a light source and a screen. Light diffracted by the double slit forms a pattern of bright and dark bands (called fringes) on the screen. The fringe pattern is due to the light waves moving through the slits and being diffracted. At a point where light waves are in phase (a crest and crest meeting at the same point) a constructive wave front is formed with a larger amplitude than that of the two waves forming the constructive wave front. This is seen as a bright band on the screen. At a point where the light waves are out of phase (a crest and a trough meeting at the same point) a destructive wave front is formed with zero amplitude (the waves effectively cancel each other out). This is seen as a dark band on the screen.

Light: Experiments to Determine its Nature

and all was light

Alexander Pope, the poet, wrote of Isaac Newton's work:

'Nature, and Nature's Laws lay hid in Night: God said, **Let Newton be!** and All was **Light**.'

Newton discovers the spectrum

Isaac Newton, the English physicist and mathematician (1642-1727), would have been remembered as a great scientist for any one of his many discoveries. He made outstanding contributions to mathematics, astronomy, mechanics, and to understanding gravitation and the nature of light.

The first microscopes revealed the world of the very small to scientists for the very first time. They saw in great detail what micro-organisms were really like. In the same way, at the other end of the scale, the first telescopes revealed to astronomers vast numbers of stars and the beauty of the Earth's planets. But there was a problem. Any image formed by the combination of the lenses then available to make microscopes or telescopes was surrounded by a colour fringe. This blurred the outline - an effect which became worse at higher magnifications.

from prisms and rainbows ..

People had long been familiar with the rainbow colours produced when light shone through a chandelier. Now, in order to improve their instruments, scientists needed to know why these colours were formed. Newton ground his own glass lenses and had, since he was an undergraduate student at Cambridge, been interested in the effect of a glass prism on sunlight.

Newton wrote: 'In the year 1666 (at which time I applied myself to the grinding of optick glass or other figures than spherical) I procured me a triangular glass prism, to try the celebrated phaenomena of colours.'

Newton made a small hole in the shutter covering the window in his room to let in a beam of sunlight. He placed the prism in front of this hole and viewed the vivid and intense spectrum of rainbow colours cast on the opposite wall.

Newton now examined these colours individually, using a second prism. He took two boards, each with a small hole in it. The first he placed behind the prism at the window. He positioned the second board so that only a single colour produced by the first prism fell on the hole in it. The second prism was placed so as to cast the light passing through the hole in the second board on to the wall. Newton saw at once that the coloured beam of light passing through the second prism was unchanged. This proved to be true for all the rainbow colours produced by the first prism.

Newton had performed the crucial experiment, because it had been assumed previously that light was basically white, and that colours could be added to it. Now it was clear that white light was a mixture of the colours of the rainbow; the prism simply split them up or refracted the light. A second prism could not 'split' them up further.

... to modern telescopes

In his book *Opticks*, published in 1704, Newton described a further experiment in which he used the second prism to recombine the rainbow colours of the spectrum to produce white light. Here for the first time was a simple explanation of the nature of light. The book had a great impact on 18th-century writers. What Newton had to say about what happened when white light passed through a prism could be immediately applied to rainbows, and this captured the imagination of artists and poets.

Because Newton suspected that the colour fringes or chromatic aberration produced by lenses in telescopes could not be avoided, in 1668 he designed a telescope that depended instead on the use of a curved mirror. Light reflected from a surface produces no colour effects, unlike light passing through a lens. Nowadays all large astronomical telescopes are of the reflecting type.

As a result of his elegant experiments with prisms and light, Newton also speculated about the ultimate nature of light itself. He proposed that light consisted of small 'corpuscules' (small particles) which are shot out from the source of light, rather in the same way that pellets are ejected from a shot gun. He was able to explain many of the known properties of light with this theory, which was widely accepted. Light has proved remarkably difficult to understand; nowadays it is regarded as having both particlelike and wavelike properties.

Animated Holographer

Go to site

Holograms, holography, and lasers are clearly explained in this 'slide show' demonstration of how holograms are made. Each slide has an associated RealAudio commentary to help illuminate each stage of this scientific technique.

Light & Optics Readings

Go to site

Clear illustrated pages introduce concepts in light and optics. The site is part of Arizona State University's Patterns in Nature pages; topics covered include the path of light (and how to make a pinhole camera), colour, lenses, lasers, and spectroscopy.

Speed of Light

Go to site

Thought-provoking site on the physics of light. The site provides a short introduction to get the user thinking about the speed of light, then cites historical discoveries to introduce and reinforce the concepts. There are links to pages on colour, reflection, refraction, and lasers.

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light bulb

incandescent filament lamp, first demonstrated by Joseph Swan in the UK in 1878 and Thomas Edison in the USA in 1879. The present-day light bulb is a thin glass bulb filled with an inert mixture of nitrogen and argon gas. It contains a filament made of fine tungsten wire. When electricity is passed through the wire, it glows white hot, producing light.

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light curve

in astronomy, graph showing how the brightness of an astronomical object varies with time. Analysis of the light curves of variable stars, for example, gives information about the physical processes causing the variation.

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light-emitting diode

LED

electronic component that converts electrical energy into light or infrared radiation in the range of 550 nm (green light) to 1,300 nm (infrared). They are used for displaying symbols in electronic instruments and devices. An LED is a diode made of semiconductor material, such as gallium arsenide phosphide, that glows when electricity is passed through it. The first digital watches and calculators had LED displays, but many later models use liquid-crystal displays.

In 1993 chemists at the University of Cambridge, England, developed LEDs from the polymer poly (*p*-phenylenevinyl) (PPV) that emit as much light as conventional LEDs and in a variety of colours.

A new generation of LEDs that can produce light in the mid-infrared range (300-1,000 nm) safely and cheaply were developed by British researchers in 1995, using thin alternating layers of indium arsenide and indium arsenide antimonide.

---

lighthouse

elevated structure equipped with a powerful flashing light for use as a maritime navigational aid. The light signals to ships that they are approaching land, or dangerous waters. Increasingly lighthouses are automated rather than staffed; later designs also emit radio signals that enable the ship to establish its position.

Lights may be either **flashing**, when the dark period exceeds the light, or **occulting**, when the dark period is equal to or less than the light; fixed lights are liable to cause confusion. The pattern of lighting is individually varied so that ships or aircraft can identify the lighthouse. In fog, sound signals may also be used, such as horns and sirens.

The light is magnified by one of two methods: catoptric, which uses reflection; dioptric, which uses refraction. Modern lighthouses are catadioptric, a combination of the two.

Lighthouse Society of Great Britain

Go to site

Site providing information on the many lighthouses around the coast of Great Britain and Ireland. In addition to a listing of all British and Irish lighthouses, the site describes the history of the lighthouse, lighthouse builders, and 20th-century changes to lighthouses. A section of educational material for younger users is also provided, probably the best feature of which is a virtual visit to Eddystone Light.

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lightning

high-voltage electrical discharge between two rainclouds or between a cloud and the Earth, caused by the build-up of electrical charges. Air in the path of lightning ionizes (becomes a conductor), and expands; the accompanying noise is heard as thunder. Currents of 20,000 amperes and temperatures of 30,000° C/54,000°F are common. Lightning causes nitrogen oxides to form in the atmosphere and approximately 25% of atmospheric nitrogen oxides are formed in this way.

According to a 1997 US survey on lightning strength and frequency, using information gathered from satellite images and data from the US Lightning Detection Network, there are 70-100 lightning flashes per second worldwide, with an average peak current of 36 kiloamps.

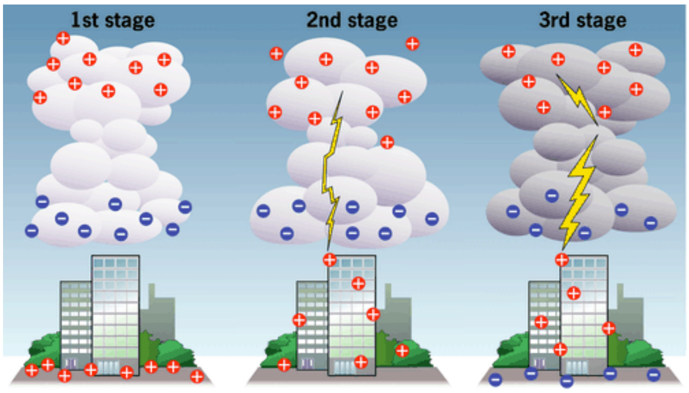
lightning: bolts

There are an estimated 8 million bolts of lightning worldwide every day.

lightning: flashes

Around the world there are a total of 70 to 100 lightning flashes every second.

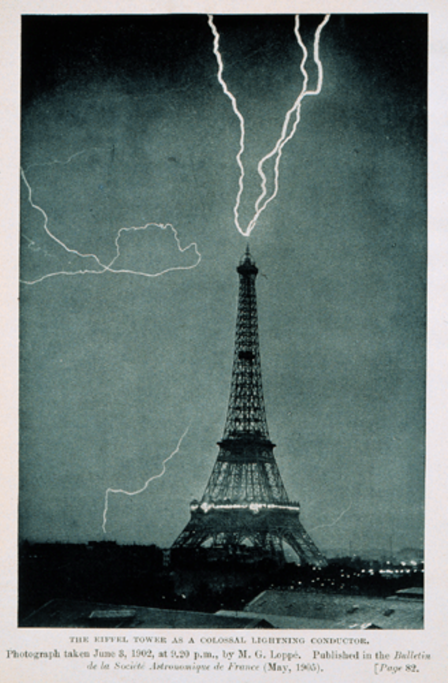
lightning



(Image © Research Machines plc)

The build-up of electrical charge during a thunderstorm that causes lightning. Negative charge builds up at the bottom of a cloud; positive charges rise from the ground and also within the cloud, moving to the top of it. A conducting channel forms through the cloud and a giant spark jumps between opposite charges causing lightning to strike within the cloud and from cloud to ground.

lightning



THE EIFFEL TOWER AS A COLOSSAL LIGHTNING CONDUCTOR.

Photograph taken June 3, 1902, at 9.20 p.m., by M. G. Loppé. Published in the *Bulletin de la Société Astronomique de France* (May, 1905). [*Page* 82.

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

All isolated high buildings attract lightning, and particularly those of predominantly metal construction like the mainly iron Eiffel Tower in Paris, France. This photo was taken on the morning of 3 June 1902 and is one of the earliest photographs of lightning in an urban setting (although that setting has changed fairly radically in the intervening century).

lightning conductor

device that protects a tall building from lightning strike, by providing an easier path for current to flow to earth than through the building. It consists of a thick copper strip of very low resistance connected to the ground below. A good connection to the ground is essential and is made by burying a large metal plate deep in the damp earth. In the event of a direct lightning strike, the current in the conductor may be so great as to melt or even vaporize the metal, but the damage to the building will nevertheless be limited.

light pen

in computing, a device resembling an ordinary pen, used to indicate locations on a computer screen. With certain computer-aided design (CAD) programs, the light pen can be used to instruct the computer to change the shape, size, position, and colours of sections of a screen image.

The pen has a photoreceptor at its tip that emits signals when light from the screen passes beneath it. From the timing of this signal and a gridlike representation of the screen in the computer memory, a computer program can calculate the position of the light pen.

light second

unit of length, equal to the distance travelled by a beam of light in a vacuum in one second. It is equal to 2.99792458×10^8 m/9.83571056×10^8 ft. See light year.

light watt

unit of radiant power (brightness of light). One light watt is the power required to produce a perceived brightness equal to that of light at a wavelength of 550 nanometres and 680 lumens.

light year

distance travelled by a beam of light in a vacuum in one year. It is equal to approximately 9.4605×10^{12} km/5.9128×10^{12}mi.

lignin

naturally occurring substance produced by plants to strengthen their tissues. It is difficult for enzymes to attack lignin, so living organisms cannot digest wood, with the exception of a few specialized fungi and bacteria. Lignin is the essential ingredient of all wood and is, therefore, of great commercial importance.

Chemically, lignin is made up of thousands of rings of carbon atoms joined together in a long chain. The way in which they are linked up varies along the chain.

lignite

type of coal that is brown and fibrous, with a relatively low carbon content. As a fuel it is less efficient because more of it must be burned to produce the same amount of energy generated by bituminous coal. Lignite also has a high sulphur content and is more polluting. It is burned to generate power in Scandinavia and some European countries because it is the only fuel resource available without importing.

lignocaine

short-term local anaesthetic injected into tissues or applied to skin. It is effective for brief, invasive procedures such as dental care or insertion of a cannula (small tube) into a vein. Temporary paralysis (to prevent involuntary movement during eye surgery, for example) can be achieved by injection directly into the nerve serving the region.

Rapidly absorbed by mucous membranes (lining tissues), lignocaine may be sprayed into the nose or throat to allow comfortable insertion of a viewing instrument during endoscopy. Its action makes it a potent anti-arrhythmia drug as well: given intravenously during or following a heart attack, it reduces the risk of cardiac arrest.

lilac

any of a group of flowering Old World shrubs, with clusters (panicles) of small, sweetly scented, white or purple flowers on the main stems. The common lilac (*S. vulgaris*) is a popular garden ornamental. (Genus *Syringa*, family Oleaceae.)

Lilienthal, Otto (1848-1896)

German aviation pioneer who inspired US aviators Orville and Wilbur Wright. From 1891 he made and successfully flew many gliders, including two biplanes, before he was killed in a glider crash.

Lilienthal demonstrated the superiority of cambered wings over flat wings – the principle of the aerofoil. In his planes the pilot was suspended by the arms, as in a modern hang-glider. He achieved glides of more than 300 m/1,000 ft, and gliding began to catch on as a sport.

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lily

any of a group of plants belonging to the lily family, of which there are about 80 species, most with showy, trumpet-shaped flowers growing from bulbs. The lily family includes hyacinths, tulips, asparagus, and plants of the onion genus. The name 'lily' is also applied to many lilylike plants of related genera and families. (Genus *Lilium*, family Liliaceae.)

lily

(Image © Research Machines plc)

Fireball lily *Scadoxus multiflorus*, Mount Meru, Tanzania. The genus *Lilium* contains some 80 to 100 species. Lilies are highly valued as ornamental plants and are among the oldest cultivated plants, with evidence for their use for medicinal purposes during the 2nd millennium BC in Asia Minor.

---

lily of the valley

plant belonging to the lily family, growing in woods in Europe, northern Asia, and North America. The small bell-shaped white flowers hang downwards from short stalks attached to a central stem; they are strongly scented. The plant is often cultivated. (*Convallaria majalis*, family Liliaceae.)

---

lime

or quicklime; technical name calcium oxide; CaO

white powdery substance used in making mortar and cement. It is made commercially by heating calcium carbonate ($CaCO_3$), obtained from limestone or chalk, in a lime kiln. Quicklime readily absorbs water to become calcium hydroxide $Ca(OH)_2$, known as slaked lime, which is used to reduce soil acidity.

lime

The theatrical expression 'in the limelight' comes from the 19th-century method of lighting the stage. From about 1838, a powerful flood of white light was produced by heating quicklime in a stream of oxygen – a dangerous chemical reaction.

---

lime

sharp-tasting green or greenish-yellow citrus fruit of the small thorny lime bush, native to India. The white flowers are followed by the fruits, which resemble lemons but are more round in shape; they are rich in vitamin C. (*Citrus aurantifolia*, family Rutaceae.)

---

lime

or linden

any of a group of deciduous trees native to the northern hemisphere. The leaves are heart-shaped and coarsely toothed, and the flowers are cream-coloured and fragrant. (Genus *Tilia*, family Tiliaceae.)

---

lime kiln

oven used to make quicklime (calcium oxide, CaO) by heating limestone (calcium carbonate, $CaCO_3$) in the absence of air. The carbon dioxide is carried away to heat other kilns and to ensure that the reversible reaction proceeds in the right direction: $CaCO_3 \leftrightarrow CaO + CO_2$.

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limestone

sedimentary rock composed chiefly of calcium carbonate ($CaCO_3$), either derived from the shells of marine organisms or precipitated from solution, mostly in the ocean. Various types of limestone are used as building stone.

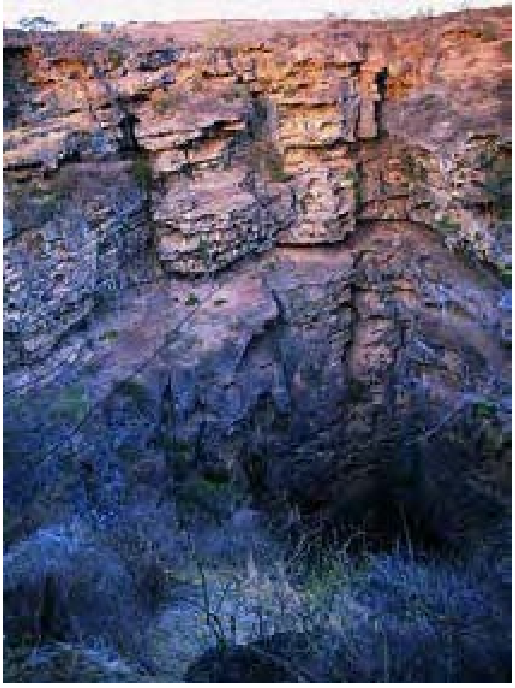
Karst is a type of limestone landscape. Caves commonly occur in limestone. Marble is metamorphosed limestone. Certain so-called marbles are not in fact marbles but fine-grained fossiliferous limestones that have been polished.

limestone

(Image © Garret Nagle)

Biological weathering is an important form of rock breakdown on rocky coasts. Many organisms, such as barnacles and limpets, secrete organic acids that help to dissolve the rock. This is especially important in rock pools, where there is only a small amount of water. This means that the water can become quite acidic and break down the rock. It most commonly affects limestone and chalk, although it is also important for its effects on granite.

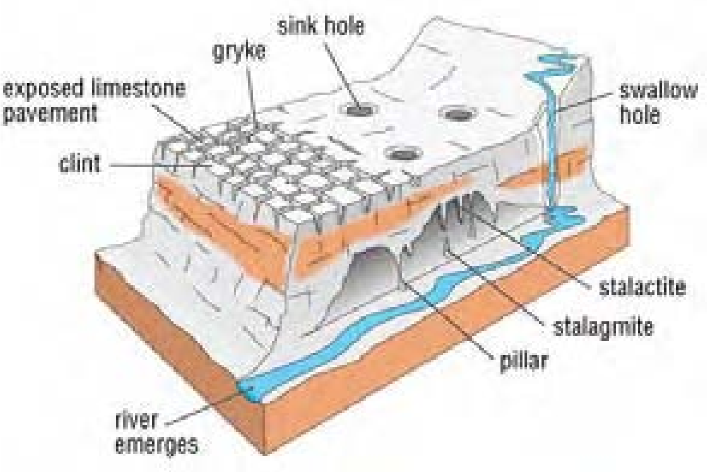
limestone



(Image © Research Machines plc)

A limestone sink hole in Oman. Sink holes can be many metres deep, and often lead to underground caves. They are usually formed when water dissolves the edges of a join or crack, gradually enlarging it.

limestone



(Image © Research Machines plc)

The physical weathering and erosion of a limestone landscape. The freezing and thawing of rain and its mild acidic properties cause cracks and joints to enlarge, forming limestone pavements, potholes, caves, and caverns.

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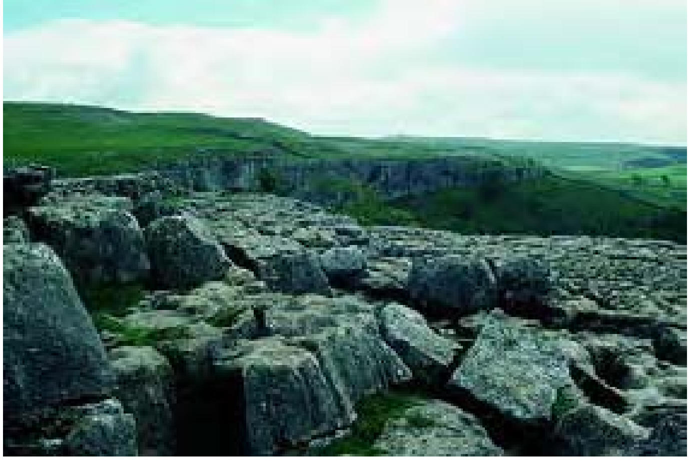
limestone pavement

bare rock surface resembling a block of chocolate, found on limestone plateaus. It is formed by the weathering of limestone into individual upstanding blocks, called clints, separated from each other by joints, called grykes. The weathering process is thought to entail a combination of freeze-thaw (the alternate freezing and thawing of ice in cracks) and carbonation (the dissolving of minerals in the limestone by weakly acidic rainwater). Malham Tarn in North Yorkshire is an example of a limestone pavement.

limestone pavement



(Image © Research Machines plc)

The limestone pavement at Malham, North Yorkshire. It is an excellent example of this particular geological feature. More or less horizontal, the pavement has a bare limestone surface, cut into by grikes (deep fissures) running at right angles to each other, leaving clints (the slabs of limestone) between them.

limewater

common name for a dilute solution of slaked lime (calcium hydroxide, $Ca(OH)_2$). In chemistry, it is used to detect the presence of carbon dioxide.

If a gas containing carbon dioxide is bubbled through limewater, the solution turns milky owing to the formation of calcium carbonate ($CaCO_3$). Continued bubbling of the gas causes the limewater to clear again as the calcium carbonate is converted to the more soluble calcium hydrogencarbonate ($Ca(HCO_3)_2$).

limiting factor

in biology, any factor affecting the rate of a metabolic reaction. Levels of light or of carbon dioxide are limiting factors in photosynthesis because both are necessary for the production of carbohydrates.
In experiments, photosynthesis is observed to slow down and eventually stop as the levels of light decrease.

It is believed that the concentrations of carbon dioxide building up in the atmosphere through the burning of fossil fuels will allow faster plant growth.

limnology

study of lakes and other bodies of open fresh water, in terms of their plant and animal biology, chemistry, and physical properties.

limonite

iron ore, mostly poorly crystalline iron oxyhydroxide, but usually mixed with haematite and other iron oxides. Also known as brown iron ore, it is often found in bog deposits.

limpet

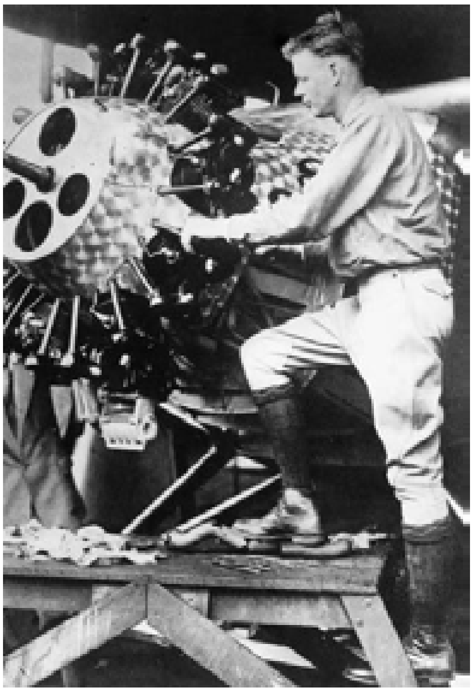
any of various marine snails belonging to several families and genera, found in the Atlantic and Pacific oceans. A limpet has a conical shell and adheres firmly to rocks by its disclike foot. Limpets leave their fixed positions only to graze on seaweeds, always returning to the same spot. The **common limpet** (*P. vulgata*) can be seen on rocks at low tide (especially genera *Acmaea* and *Patella*).

Lindbergh, Charles A(ugustus) (1902-1974)

US aviator. He made the first solo nonstop flight in 33.5 hours across the Atlantic (Roosevelt Field, Long Island, New York, to Le Bourget airport, Paris) in 1927 in the *Spirit of St Louis*, a Ryan monoplane designed by him.

Lindbergh was born in Detroit, Michigan. He was a barnstorming pilot before attending the US Army School in Texas 1924 and becoming an officer in the Army Air Service Reserve 1925. Learning that Raymond B Orteig had offered a prize of £25,000 for the person who first made a nonstop air flight between New York and Paris, he appealed to some St Louis businessmen who agreed to finance him.

Lindbergh



(Image © Billie Love)

Charles A Lindbergh tinkering with his plane, the *Spirit of St Louis*, in 1927, the year in which he made the first non-stop flight across the Atlantic. 'Lindy' became a celebrity as soon as he arrived in Paris, and was greeted as a hero on his return to the USA.

American Experience: Lindbergh

Go to site

Features a number of articles relating to US aviator Lindbergh's life. There is information on the *Spirit of St Louis*, the plane that carried Lindbergh across the Atlantic, as well as an account of the kidnapping of his son. There is also a time line of Lindbergh's life and an interactive map charting his historic flight.

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linden

another name for the lime tree.

Lindow Man

remains of an Iron Age man discovered in a peat bog at Lindow Marsh, Cheshire, UK, in 1984. The chemicals in the bog had kept the body in an excellent state of preservation.

'Pete Marsh', as the archaeologists nicknamed him, had been knocked unconscious, strangled, and then had his throat cut before being thrown into the bog. He may have been a sacrificial victim, as Celtic peoples often threw offerings to the gods into rivers and marshes. His stomach contained part of an unleavened barley 'bannock' that might have been given as a sacrificial offering. His well-cared-for nails indicate that he might have been a Druid prince who became a willing sacrifice.

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linear accelerator

or linac

see accelerator.

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linear equation

in mathematics, a relationship between two variables that, when plotted on Cartesian axes, produces a straight-line graph; the equation has the general form $y = mx + c$, where m is the slope of the line represented by the equation and c is the y-intercept, or the value of y where the line crosses the y-axis in the Cartesian coordinate system. Sets of linear equations can be used to describe the behaviour of buildings, bridges, trusses, and other static structures.

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linear motor

type of electric motor, an induction motor in which the fixed stator and moving armature are straight and parallel to each other (rather than being circular and one inside the other as in an ordinary induction motor). Linear motors are used, for example, to power sliding doors. There is a magnetic force between the stator and armature; this force has been used to support a vehicle, as in the experimental maglev linear motor train.

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linear programming

in mathematics and economics, a set of techniques for finding the maxima or minima of certain variables governed by linear equations or inequalities. These maxima and minima are used to represent 'best' solutions in terms of goals such as maximizing profit or minimizing cost.

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linen

yarn spun and the textile woven from the fibres of the stem of the flax plant. Pieces of linen cloth have been found in the remains of Stone Age settlements and wrapped around mummies from Ancient Egypt. Linen was introduced by the Romans to northern Europe, where production became widespread. Religious refugees from the Low Countries in the 16th century helped to establish the linen industry in England, but it began to decline in competition with cotton in the 18th century. Linen is cool to wear and very resilient, but it is expensive to produce and can crease quite badly unless treated with a crease-resistant finish.

To get the longest possible fibres, flax is pulled, rather than cut by hand or machine, just as the ripened fruits, or bolls, are beginning to set. After preliminary drying, it is steeped in water so that the fibre can be more easily separated from the wood of the stem, then hackled (combed), classified, drawn into continuous fibres, and spun. Bleaching, weaving, and finishing processes vary according to the final product, which can be sailcloth, canvas, sacking, cambric, or lawn. Because of the length of its fibre, linen yarn has twice the strength of cotton, and yet is superior in delicacy, so that it is suitable for lacemaking. It mixes well with synthetic fibres.

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line of force

in physics, an imaginary line representing the direction of force at any point in a magnetic, gravitational, or electrical field.

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line printer

computer printer that prints a complete line of characters at a time. Line printers can achieve very high printing speeds of up to 2,500 lines a minute, but can print in only one typeface, cannot print graphics, and are very noisy. Today, most users prefer laser printers.

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ling

any of several deepwater long-bodied fishes of the cod family found in the North Atlantic. (Genus *Molva*, family Gadidae.)

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ling

another name for common heather.

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linkage

in genetics, the association between two or more genes that tend to be inherited together because they are on the same chromosome. The closer together they are on the chromosome, the less likely they are to be separated by crossing over (one of the processes of recombination) and they are then described as being 'tightly linked'.

Linnaeus, Carolus (1707-1778)

(Latinized form of Carl von Linné)

Swedish naturalist and physician. His botanical work *Systema naturae* (1735) contained his system for classifying plants into groups depending on shared characteristics (such as the number of stamens in flowers), providing a much-needed framework for identification. He also devised the concise and precise system for naming plants and animals, using one Latin (or Latinized) word to represent the genus and a second to distinguish the species.

For example, in the Latin name of the daisy, *Bellis perennis*, *Bellis* is the name of the genus to which the plant belongs, and *perennis* distinguishes the species from others of the same genus. By tradition the generic name always begins with a capital letter. The author who first described a particular species is often indicated after the name, for example, *Bellis perennis* Linnaeus, showing that the author was Linnaeus.

linnet

small seed-eating bird belonging to the finch family, which is very abundant in Europe, Asia, and northwestern Africa. The male has a chestnut back with a pink breast and grey head, and a red breast and forehead during the breeding season; the female is mainly a dull brown. The linnet measures barely 13 cm/5 in in length, begins to breed in April, and generally chooses low-lying bush for its home. The eggs, ranging from four to six in number, are a delicate pale blue streaked with a purplish brown. (Species *Acanthis cannabina*, family Fringillidae, order Passeriformes.)

linoleum

(Latin lini oleum 'linseed oil')

floor covering made from linseed oil, tall oil, rosin, cork, woodflour, chalk, clay, and pigments, pressed into sheets with a jute backing. Oxidation of the oil is accelerated by heating, so that the oil mixture solidifies into a tough, resilient material. Linoleum tiles have a backing made of polyester and glass.

Linoleum was invented in England in 1860 by Frederick Walton. In the early 20th century he invented a straight-line inlay machine which was able to produce patterned linoleum. Today, the manufacture of linoleum still follows the basic principles of Walton's process although production is much faster. Synthetic floor coverings are now popular and the use of linoleum has declined.

Linotype

trademark for a typesetting machine once universally used for newspaper work, which sets complete lines (slugs) of hot-metal type as operators type the copy at a keyboard. It was invented in the USA in 1884 by German-born Ottmar Mergenthaler. It has been replaced by phototypesetting.

linseed

seeds of the flax plant, from which linseed oil is produced, the residue being used as cattle feed. The oil is used in paint, wood treatments, and varnishes, and in the manufacture of linoleum floor coverings.

lion

large wild cat with a tawny coat. The young have darker spot markings to camouflage them; these usually disappear with adulthood. The male has a heavy mane and a tuft at the end of the tail. Head and body measure about 2 m/6 ft, plus 1 m/3 ft of tail; lionesses are slightly smaller. Lions produce litters of two to six cubs, and often live in groups (prides) of several adult males and females with young. They are carnivores and are found only in Africa, south of the Sahara desert, and in the Gir Forest of northwest India.

behaviour

Capable of short bursts of speed, lionesses do most of the hunting, working together to run down grazing animals. Females remain with the pride permanently; young males remain until they about three years old and one or more adult males (usually brothers) stay a couple of years or so until they are supplanted by a competing coalition of males. The incoming males, or male, kill all the cubs in a pride so that the lionesses become ready to breed again. When not hunting, lions spend most of their time dozing and sleeping. The average lifespan of a lion is 15-20 years in the wild and 20–25 years in captivity.

They belong to the cat family, Felidae, genus *Panthera* (which also includes tigers, leopards, and jaguars), species *P. Leo*.

lion and lioness

(Image © Corel)

Lion and lioness in the sun. The male is easily identified by its shaggy mane; the female is slightly smaller in stature and has no mane.

African lion

Go to site

Illustrated guide to the African lion including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

Asiatic Lion Information Centre

Go to site

General information page about the decline and conservation of the Asiatic subspecies of lion. Click to find out about the Gir National Park, the lions' last remaining wild habitat, differences between African and Asiatic lions, and methods of conservation. There are also links to a map showing the Asiatic lion's past and present distribution and to a photo gallery.

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lipase

enzyme responsible for breaking down fats into fatty acids and glycerol. It is produced by the pancreas and requires a slightly alkaline environment. The products of fat digestion are absorbed by the intestinal wall.

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lipid

any of a large number of esters of fatty acids, commonly formed by the reaction of a fatty acid with glycerol (see glyceride). They are soluble in alcohol but not in water. Lipids are the chief constituents of plant and animal waxes, fats, and oils.

Phospholipids are lipids that also contain a phosphate group, usually linked to an organic base; they are major components of biological cell membranes.

Lipmann, Fritz Albert (1899-1986)

German-born US biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1953 for his discovery of coenzyme A, a nonprotein compound that acts in conjunction with enzymes to catalyse metabolic reactions leading up to the Krebs cycle. He investigated the means by which the cell acquires energy and highlighted the crucial role played by the energy-rich phosphate molecule adenosine triphosphate (ATP). He shared the prize with Hans Krebs.

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lipophilic

(Greek 'fat-loving')

in chemistry, describing functional groups with an affinity for fats and oils.

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lipophobic

(Greek 'fat-hating')

in chemistry, describing functional groups that tend to repel fats and oils.

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liposome

in medicine, a minute droplet of oil that is separated from a medium containing water by a phospholipid layer. Drugs, such as cytotoxic agents, can be incorporated into liposomes and given by injection or by mouth. The liposomes allow the drug to reach the site of action, such as a tumour, without being broken down in the body.

Lippershey, Hans (c. 1570-c. 1619)

Dutch lensmaker, credited with inventing the telescope in 1608.

Lippmann, Gabriel (1845-1921)

French doctor. He invented the direct colour process in photography. He was awarded the Nobel Prize for Physics in 1908 for his photographic reproduction of colours by interference.

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liquefaction

process of converting a gas to a liquid, normally associated with low temperatures and high pressures (see condensation).

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liquefaction

in earth science, the conversion of a soft deposit, such as clay, to a jellylike state by severe shaking. During an earthquake buildings and lines of communication built on materials prone to liquefaction will sink and topple. In the Alaskan earthquake of 1964 liquefaction led to the destruction of much of the city of Anchorage.

---

liquefied petroleum gas

LPG

liquid form of butane, propane, or pentane, produced by the distillation of petroleum during oil refining. At room temperature these substances are gases, although they can be easily liquefied and stored under pressure in metal containers. They are used for heating and cooking where other fuels are not available: camping stoves and cigarette lighters, for instance, often use liquefied butane as fuel.

---

liquid

state of matter between a solid and a gas. A liquid forms a level surface and assumes the shape of its container. The way that liquids behave can be explained by the kinetic theory of matter and particle theory. Its atoms do not occupy fixed positions as in a crystalline solid, nor do they have total freedom of movement as in a gas. Unlike a gas, a liquid is difficult to compress since pressure applied at one point is equally transmitted throughout (Pascal's principle). Hydraulics makes use of this property.

---

liquid air

air that has been cooled so much that it has liquefied. This happens at temperatures below about -196°C/-321°F. The various constituent gases, including nitrogen, oxygen, argon, and neon, can be separated from liquid air by the technique of fractional distillation.

Air is liquefied by the **Linde process**, in which air is alternately compressed, cooled, and expanded, the expansion resulting each time in a considerable reduction in temperature. With the lower temperature the molecules move more slowly and occupy less space, so the air changes phase to become liquid.

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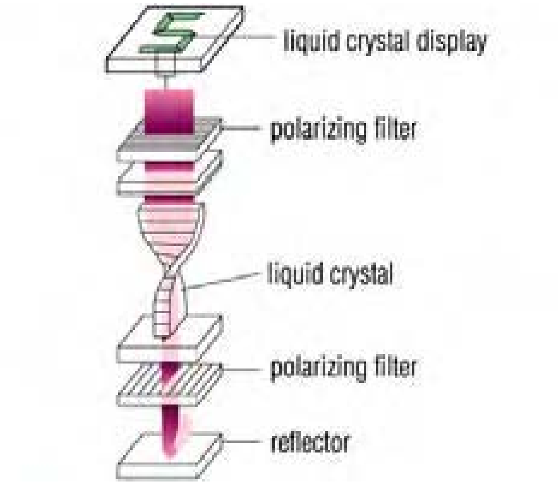
liquid-crystal display

LCD

display of numbers (for example, in a calculator) or pictures (such as on a pocket television screen) produced by molecules of a substance in a semi-liquid state with some crystalline properties, so that clusters of molecules align in parallel formations. The display is a blank until the application of an electric field, which 'twists' the molecules so that they reflect or transmit light falling on them. The two main types of LCD are **passive matrix** and **active matrix**. LCD manufacture has advanced significantly and LCDs are now used in making colour mobile phone displays, computer monitors, and television displays.

liquid-crystal display



(Image © Research Machines plc)

A liquid-crystal display consists of a liquid crystal sandwiched between polarizing filters similar to polaroid sunglasses. When a segment of the seven-segment display is electrified, the liquid crystal twists the polarized light from the front filter, allowing the light to bounce off the rear reflector and illuminate the segment.

Polymers and Liquid Crystals

Go to site

Online tutorial about two modern physical wonders. The site is divided into a 'Virtual textbook' and a 'Virtual laboratory', with corresponding explanations and experiments.

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liquorice

perennial European herb belonging to the legume family. The long sweet root yields an extract that is made into a hard black paste and used in confectionery and medicines. (*Glycyrrhiza glabra*, family Leguminosae.)

LISP

contraction of list processing

high-level computer-programming language designed for manipulating lists of data items. It is used primarily in research into artificial intelligence (AI).

Developed in the late 1950s, and until recently common only in university laboratories, LISP is used more in the USA than in Europe, where the language PROLOG is often preferred for AI work.

Lister, Joseph (1827-1912)

1st Baron Lister

English surgeon. He was the founder of antiseptic surgery, influenced by Louis Pasteur's work on bacteria. He introduced dressings soaked in carbolic acid and strict rules of hygiene to combat wound sepsis in hospitals. He was made a baronet in 1883, and a baron in 1897.

The number of surgical operations greatly increased following the introduction of anaesthetics, but death rates were more than 40%. Under Lister's regime they fell dramatically.

---

listeriosis

disease of animals that may occasionally infect humans, caused by the bacterium *Listeria monocytogenes*. The bacteria multiply at temperatures close to 0°C/32°F, which means they may flourish in precooked frozen meals if the cooking has not been thorough. Listeriosis causes flulike symptoms and inflammation of the brain and its surrounding membranes. It can be treated with penicillin.

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litchi

or lychee

evergreen tree belonging to the soapberry family. The delicately flavoured egg-shaped fruit has a rough brownish outer skin and a hard seed. The litchi is native to southern China, where it has been cultivated for 2,000 years. (*Litchi chinensis*, family Sapindaceae.)

liter

symbol l

metric unit of volume, equal since 1964 to one cubic decimeter (61.025 cu in, 1.057 liquid qt, or 0.91 dry qt). It was formerly defined as the volume occupied by one kilogram of pure water at 4°C at standard pressure, but this is slightly larger than one cubic decimeter.

lithification

conversion of an unconsolidated (loose) sediment into solid sedimentary rock by **compaction** of mineral grains that make up the sediment, **cementation** by crystallization of new minerals from percolating water solutions, and new growth of the original mineral grains. The term is less commonly used to refer to solidification of magma to form igneous rock.

lithium

chemical symbol Li

(Greek lithos 'stone')

soft, ductile, silver-white, metallic element, atomic number 3, relative atomic mass 6.941. It is one of the alkali metals (being found at the top of Group 1 of the periodic table). It has a very low density (far less than most woods), and floats on water (relative density 0.57); it is the lightest of all metals. Although in the reactivity series it is the least reactive of the alkali metals, it reacts readily with water and the oxygen in air, and so has to be kept under oil. Lithium is used to harden alloys, and in batteries; its compounds are used in medicine to treat manic depression.

Lithium was named in 1818 by Swedish chemist Jöns Berzelius, having been discovered the previous year by his student Johan A Arfwedson. Berzelius named it after 'stone' because it is found in most igneous rocks and many mineral springs.

lithography

printmaking technique invented in 1798 by Aloys Senefelder, based on the mutual repulsion of grease and water. A drawing is made with greasy crayon on an absorbent stone, which is then wetted. The wet stone repels ink (which is greasy) applied to the surface and the crayon absorbs it, so that the drawing can be printed. Lithographic printing is used in book production, posters, and prints, and this basic principle has developed into complex processes.

Many artists have made brilliant use of the process since the early 19th century, including Delacroix, Goya, Isabey, Bonington, Daumier, Gavarni, Whistler, Toulouse-Lautrec (who devised colour effects of the most striking and original kind), Bonnard, and Vuillard.

lithosphere

upper rocky layer of the Earth that forms the jigsaw of plates that take part in the movements of plate tectonics. The lithosphere comprises the crust and a portion of the upper mantle. It is regarded as being rigid and brittle and moves about on the more plastic and less brittle asthenosphere. The lithosphere ranges in thickness from 2-3 km/1-2 mi at mid-ocean ridges to 150 km/93 mi beneath old ocean crust, to 250 km/155 mi under cratons.

litmus

dye obtained from various lichens and used in chemistry as an indicator to test the acidic or alkaline nature of aqueous solutions; it turns red in the presence of acid, and blue in the presence of alkali.

Little Dipper

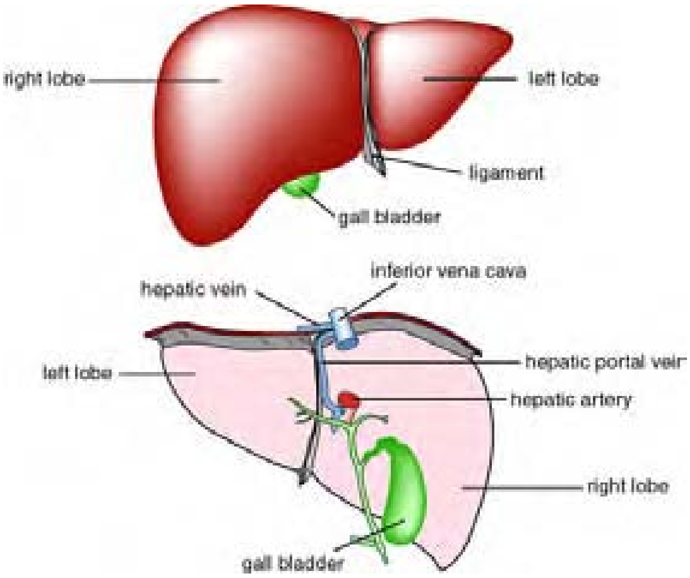
another name for the most distinctive part of the constellation Ursa Minor, the Little Bear.

liver

in vertebrates, large organ with many regulatory and storage functions. The human liver is situated in the upper abdomen, and weighs about 2 kg/4.5 lb. It is divided into four lobes. The liver receives the products of digestion (food absorbed from the gut and carried to the liver by the bloodstream), converts glucose to glycogen (a long-chain carbohydrate used for storage), and then back to glucose when needed. In this way the liver regulates the level of glucose in the blood (see homeostasis). This is partly controlled by a hormone, insulin. The liver removes excess amino acids from the blood, converting them to urea, which is excreted by the kidneys. The liver also synthesizes vitamins, produces bile and blood-clotting factors, and removes damaged red cells and toxins such as alcohol from the blood.

If more protein is eaten than is needed to make different proteins for the body, the excess is broken down. This breakdown takes place in the liver. One product of this breakdown is urea and this has to be lost from the body in the urine. The liver also stores some vitamins, produces bile, and breaks down red blood cells.

liver



(Image © Research Machines plc)

The structure of the human liver, front view (top) and cross-section.

Body Systems and Homeostasis

Go to site

Thorough text-only description of the way in which the systems of the body act to preserve homeostasis (constancy of the body's internal environment irrespective of external factors). The page, a supplement to a textbook written by Sylvia Mader, includes a table of the major endocrine glands and the hormones they produce.

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liverwort

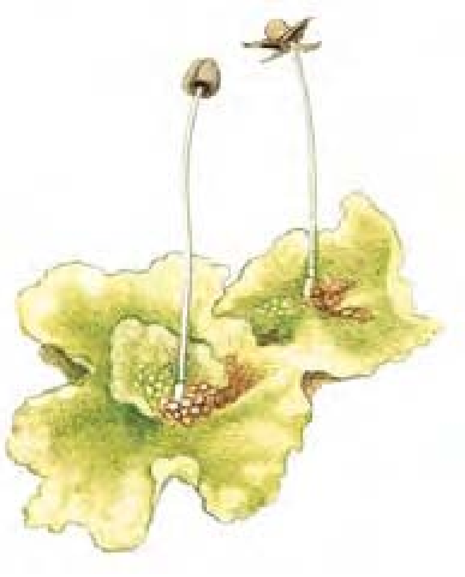
nonvascular plant (with no 'veins' to carry water and food), related to hornworts and mosses; it is found growing in damp places. (Class Hepaticae, order Bryophyta.)

The plant exists in two different reproductive forms, sexual and asexual, which appear alternately (see alternation of generations). The main sexual form consists of a plant body, or thallus, which may be flat, green, and lobed like a small leaf, or leafy and mosslike. The asexual, spore-bearing form is smaller, typically parasitic on the thallus, and produces a capsule from which spores are scattered.

first land plants

US molecular botanists analysed the mitochondrial DNA of 352 land plants and concluded 1998 that liverworts were the first land plants to evolve, possibly around 475 million years ago.

liverwort



(Image © Research Machines plc)

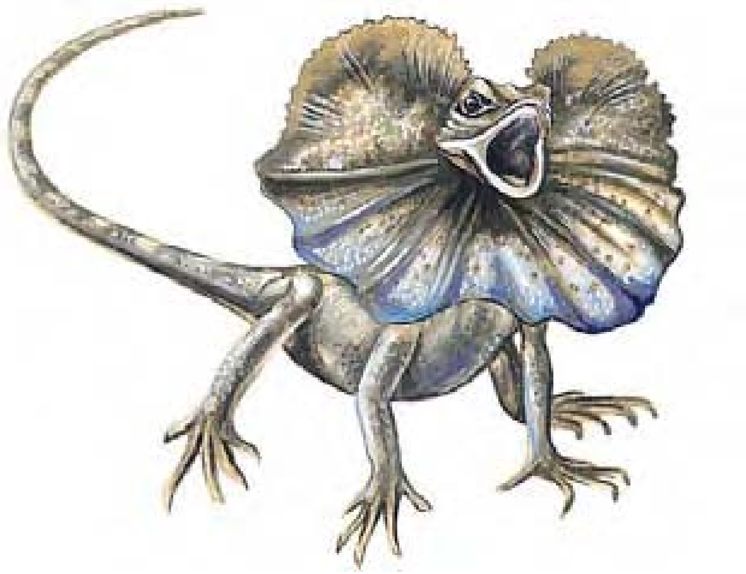
Liverworts belong to a group of plants, called the Bryophyta, which also includes the mosses. Neither mosses nor liverworts possess true roots and both require water to enable the male gametes to swim to the female sex organs to fertilize the eggs. Unlike mosses most liverworts have no, or only very frail, leaves.

lizard

reptile generally distinguishable from snakes, which belong to the same order, by having four legs, moveable eyelids, eardrums, and a fleshy tongue, although some lizards are legless and snakelike in appearance. There are over 3,000 species of lizard worldwide. (Suborder Lacertilia, order Squamata.)

Like other reptiles, lizards are abundant in the tropics, although some species live as far north as the Arctic circle. There are about 20 families of lizards, including geckos, chameleons, skinks, monitors, agamas, and iguanas. The **common** or **viviparous lizard** (*Lacerta vivipara*), about 15 cm/6 in long, is found throughout Europe; in the far north, it hibernates through the long winter. Like many other species, it can shed its tail as a defence, later regrowing it. The **frilled lizard** (*Chlamydosaurus kingi*) of Australia has an erectile collar to frighten its enemies. There are two poisonous species of lizard, the **Mexican bearded lizard** and the **gila monster**. A new lizard species discovered in the West Indies in 2001, *Sphaerodactylus ariasae*, measures only 1.6 cm/0.6 in. (For flying lizard see flying dragon.)

lizard



(Image © Research Machines plc)

The frilled lizard of North Australia and New Guinea has a rufflike collar of skin - up to 25 cm/10 in across - around its neck. The collar normally lies flat but, if alarmed, the lizard raises the brightly coloured collar and opens its mouth to intimidate an enemy.

llama

South American even-toed hoofed mammal belonging to the camel family, about 1.2 m/4 ft high at the shoulder. Llamas can be white, brown, or dark, sometimes with spots or patches. They are very hardy, and require little food or water. They spit when annoyed. (Species *Lama glama*, family Camelidae.)

Llamas are used in Peru as beasts of burden, and also for their wool, milk, and meat. Llamas and alpacas are both domesticated forms of the guanaco.

llama

(Image © Corel)

A group of domestic llamas in the Altiplano in Peru. Male llamas are used as pack animals throughout the Andes and females are raised for their milk and meat. The wool of both sexes is used for making textiles and the dried dung is burnt as fuel.

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lm

in physics, symbol for lumen, the SI unit of luminous flux, equal to the flux emitted by a 1-candela point source in a 1-steradian solid angle.

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loach

carplike freshwater fish with a long narrow body and no teeth in the small downward-pointing mouth, which is surrounded by barbels (sensitive bristles). Loaches are native to Asian and European waters.
(Family Cobitidae.)

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loam

type of fertile soil, a mixture of sand, silt, clay, and organic material. It is porous, which allows for good air circulation and retention of moisture.

Lobachevsky, Nikolai Ivanovich (1792-1856)

Russian mathematician who founded non-Euclidean geometry, concurrently with, but independently of, Karl Gauss in Germany and János Bolyai in Hungary. Lobachevsky published the first account of the subject in 1829, but his work went unrecognized until Georg Riemann's system was published.

In Euclid's system, two parallel lines will remain equidistant from each other, whereas in Lobachevskian geometry, the two lines will approach zero in one direction and infinity in the other. In Euclidean geometry the sum of the angles of a triangle is always equal to the sum of two right angles; in Lobachevskian geometry, the sum of the angles is always less than the sum of two right angles. In Lobachevskian space, also, two geometric figures cannot have the same shape but different sizes.

Lobachevsky, Nikolai Ivanovich

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of Nikolai Lobachevsky. In addition to biographical information, you will find a list of references about Lobachevsky and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Lobachevsky. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

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lobelia

any of a group of temperate and tropical plants with white to mauve flowers. Lobelias may grow to shrub size but are mostly small annual plants. (Genus *Lobelia*, family Lobeliaceae.)

lobelia

(Image © Research Machines plc)

Lobelia, Shira Plateau, Tanzania. The lobelia family contains over 750 species of flowering plant, native to both hemispheres. They are mostly small annual plants, but the tall tree-lobelias of East Africa grow for about twenty years and flower only once.

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lobotomy

another name for the brain operation leucotomy.

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lobster

any of various large marine crustaceans. Lobsters are grouped with freshwater crayfish in the suborder Reptantia ('walking'), although both lobsters and crayfish can also swim, using their fanlike tails. Lobsters have eyes on stalks and long antennae, and are mainly nocturnal. They scavenge and eat dead or dying fish. (Family Homaridae, order Decapoda.)

True lobsters are distinguished by having very large 'claws' or pincers on their first pair of legs, and smaller ones on their second and third pairs. Spiny lobsters (family Palinuridae) have no large pincers.
They communicate by means of a serrated pad at the base of their antennae, the 'sound' being picked up by sensory nerves located on hairlike outgrowths on their fellow lobsters up to 60 m/180 ft away.

lobster

When spiny lobsters migrate, they do so by walking in queues of up to 65 along the sea-bed, each clinging with its claws to the rear of the one in front. Scientific experiments with dead lobsters, weights, and pulleys have shown that such an arrangement reduces drag and allows a 25% improvement in speed through the water.

lobster

(Image © Research Machines plc)

A lobster fisherman in the town of Le Guilvinec-Lechiagat in Brittany, northeast France. Lobsters are traditionally caught by means of baited traps. Modern traps are made with plastic-coated steel rods and braided nylon net, as opposed to the more traditional baskets. Typical baits include mackerel and crab bodies.

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local anaesthetic

in medicine, an anaesthetic that is applied only to the specific area under treatment.

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local area network

LAN

in computing, a network restricted to small groups of rooms or buildings. Local area networks may range in size from only a few devices to as many as a few thousand devices, usually personal computers acting as workstations, as well as peripheral devices, such as printers.

Central to the LAN is the **file server**, which controls user access to the network. The **print server** processes and controls all print jobs being sent via the network to a connected printer, and a **router** enables connections to other networks or to the Internet.

Local Group

in astronomy, cluster of over 30 galaxies that includes our own, the Milky Way. Like other groups of galaxies, the Local Group is held together by the gravitational attraction between its members, and does not expand with the expanding universe. Its two largest galaxies are the Milky Way and the Andromeda galaxy; most of the others are small and faint.

---

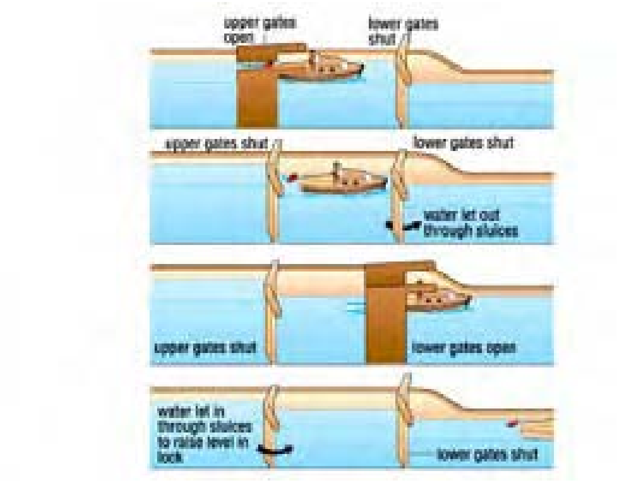
lock

construction installed in waterways to allow boats or ships to travel from one level to another. The earliest form, the **flash lock**, was first seen in the East in 1st-century-AD China and in the West in 11th-century Holland. By this method barriers temporarily dammed a river and when removed allowed the flash flood to propel the waiting boat through or over any obstacle. This was followed in 12th-century China and 14th-century Holland by the **pound lock**. In this system the lock has gates at each end. Boats enter through one gate when the levels are the same both outside and inside. Water is then allowed in (or out of) the lock until the level rises (or falls) to the new level outside the other gate.

Locks are important to shipping where canals link oceans of differing levels, such as the Panama Canal, or where falls or rapids are replaced by these adjustable water 'steps'.

In a 4 km/2.5 mi stretch of the Worcester and Birmingham Canal at Tardebigge, Worcestershire, England, there are 36 locks that drop the canal nearly 79 m/260 ft.

lock



(Image © Research Machines plc)

Travelling downstream, a boat enters the lock with the lower gates closed. The upper gates are then shut and the water level lowered by draining through sluices. When the water level in the lock reaches the downstream level, the lower gates are opened.

lock and key

devices that provide security, usually fitted to a door of some kind. In 1778 English locksmith Robert Barron made the forerunner of the **mortise lock**, which contains levers that the key must raise to an exact height before the bolt can be moved. The **Yale lock**, a pin-tumbler cylinder design, was invented by US locksmith Linus Yale, Jr, in 1865. More secure locks include **combination locks**, with a dial mechanism that must be turned certain distances backwards and forwards to open, and **time locks**, which are set to be opened only at specific times.

Locks originated in the Far East over 4,000 years ago. The Romans developed the warded lock, which contains obstacles (wards) that the key must pass to turn.

Lockheed Martin

formerly Lockheed

US aircraft manufacturer, the world's largest military contractor. Its Space Systems Company has built or contributed to major spacecraft. It designed and built the Hubble Space Telescope, provided the eight solar arrays for the *International Space Station*, built the Terra and the Gravity Probe-B spacecrafts and has been chosen to build the IMAGE spacecraft. The Lockheed company was founded in 1916 by two brothers, Allan and Malcolm Loughead (they later changed the spelling of their name), who had built their first seaplane in 1913, with headquarters in Burbank, California. Lockheed built the Vega plane in 1926 (later used by Amelia Earhart in her solo transatlantic flight), the first fully pressurized aircraft, the XC-35, in 1937, the P-38 Lightning fighter of World War II, and the TriStar passenger plane of the 1960s. It has been heavily involved in space exploration, building nearly 1,000 spacecraft for the military, NASA, and the commercial sector. In the late 1990s, it developed the F-22, an advanced tactical surveillance (ATS) and fighter aircraft. A STOL (short takeoff and landing) type, it combined stealth with unprecedented agility.

The P-38 Lightning shot down more Japanese aircraft than any other US fighter in the Pacific campaign. In 1974, the company was implicated in a scandal with the Japanese government, in which the then premier, Kakuei Tanake, was found guilty of accepting bribes from the Lockheed corporation and forced to resign.

After a merger in 1995 of Lockheed with the Martin Marietta Corporation, the company became Lockheed Martin Aeronautical Systems, the largest defence company in the world.

lockjaw

former name for tetanus, a type of bacterial infection.

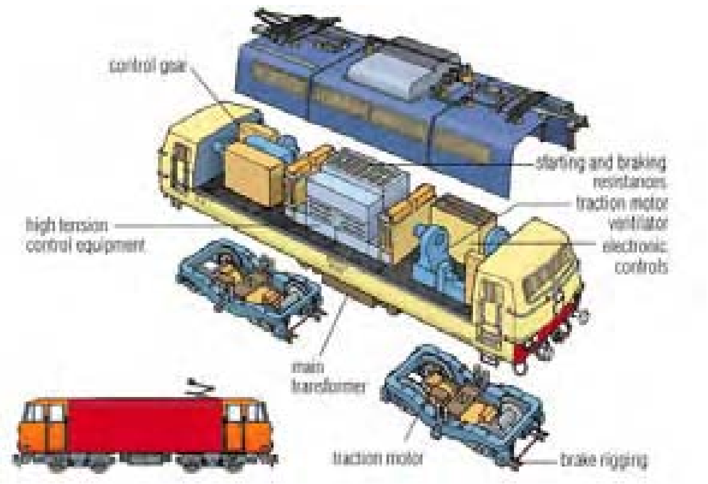
locomotive

engine for hauling railway trains. In 1804 Cornish engineer Richard Trevithick built the first steam engine to run on rails. Locomotive design did not radically improve until English engineer George Stephenson built the *Rocket* in 1829, which featured a multitube boiler and blastpipe, standard in all following **steam locomotives**. Today most locomotives are diesel or electric: **diesel locomotives** have a powerful diesel engine, and **electric locomotives** draw their power from either an overhead cable or a third rail alongside the ordinary track.

In a steam locomotive, fuel (usually coal, sometimes wood) is burned in a furnace. The hot gases and flames produced are drawn through tubes running through a huge water-filled boiler and heat up the water until it turns to steam. The steam is then fed to the cylinders, where it forces the pistons back and forth. Movement of the pistons is conveyed to the wheels by cranks and connecting rods. Diesel locomotives have a powerful diesel engine, burning oil.

The engine may drive a generator to produce electricity to power electric motors that turn the wheels, or the engine drives the wheels mechanically or through a hydraulic link. A number of **gas-turbine locomotives** are in use, in which a turbine spun by hot gases provides the power to drive the wheels.

locomotive


control gear
starting and braking resistances
traction motor ventilator
electronic controls
high tension control equipment
main transformer
traction motor
brake rigging

(Image © Research Machines plc)

The drive of an electric locomotive is provided by powerful electric motors (traction motors) in the bogies beneath the body of the locomotive. The motors are controlled by equipment inside the locomotive. Both AC and DC power supplies are used, although most modern systems use a 2500 V supply.

locus

(Latin 'place')

in mathematics, traditionally the path traced out by a moving point, but now defined as the set of all points on a curve satisfying given conditions. The locus of points a fixed distance from a fixed point is a circle. The locus of a point equidistant from two fixed points is a straight line that perpendicularly bisects the line joining them. The locus of points a fixed distance from a line is two parallel lines running either side.

locust

swarming grasshopper with short feelers, or antennae, and hearing organs on the abdomen (rear segment of the body). As winged adults, flying in swarms, locusts may be carried by the wind hundreds of miles from their breeding grounds; on landing they devour all vegetation. Locusts occur in nearly every continent. (Family Acrididae, order Orthoptera.)

locust

Locust swarms can contain up to 10 billion individuals and cover a surface of 1,000 sq km/400 sq mi. The swarm can remain together for weeks, devastating crops and other vegetation for thousands of kilometres. Each square kilometre of locusts (up to 80 million) can consume 250 tonnes of food a day, the daily amount required to feed 80,000 people.

locust tree

in botany, any of several trees of the genera *Robinia* and *Gleditsia* of the legume family, with primate compound leaves and many-seeded pods, of the eastern USA. The black locust *R. pseudoacacia* and the honeylocust *G. triacanthos* are examples. The name locust tree is also applied to the carob, a small European tree.

lode

geological deposit rich in certain minerals, generally consisting of a large vein or set of veins containing ore minerals. A system of veins that can be mined directly forms a lode, for example the mother lode of the California gold rush.

Lodes form because hot hydrothermal liquids and gases from magmas penetrate surrounding rocks, especially when these are limestones; on cooling, veins of ores formed from the magma then extend from the igneous mass into the local rock.

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lodestar

or loadstar

star used in navigation or astronomy, often Polaris, the Pole Star.

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loess

yellow loam, derived from glacial meltwater deposits and accumulated by wind in periglacial regions during the ice ages. Loess usually attains considerable depths, and the soil derived from it is very fertile. There are large deposits in central Europe (Hungary), China, and North America. It was first described in 1821 in the Rhine area, and takes its name from a village in Alsace.

Loewi, Otto (1873-1961)

German physiologist who was awarded a Nobel Prize for Physiology or Medicine in 1936 for his work on the chemical transmission of nerve impulses. He established that a chemical substance is responsible for the stimulation of one nerve cell (neuron) by another.

The substance was shown by the physiologist Henry Dale to be acetylcholine, now known to be one of the most vital neurotransmitters. For this work Loewi and Dale were jointly awarded the Nobel Prize.

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log

in mathematics, abbreviation for logarithm.

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log

any apparatus for measuring the speed of a ship; also the daily record of events on board a ship or aircraft.

The log originally consisted of a piece of weighted wood attached to a line with knots at equal intervals that was cast from the rear of a ship. The vessel's speed was estimated by timing the passage of the knots with a sandglass (like an egg timer). Today logs use electromagnetism and sonar.

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loganberry

hybrid between a blackberry and a raspberry with large, tart, dull-red fruit. It was developed in 1881 by US judge James H Logan.

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logarithm

or log

the exponent or index of a number to a specified base - usually 10. For example, the logarithm to the base 10 of 1,000 is 3 because $10^3 = 1{,}000$; the logarithm of 2 is 0.3010 because $2 = 10^{0.3010}$. The whole-number part of a logarithm is called the **characteristic**; the fractional part is called the **mantissa**.

Before the advent of cheap electronic calculators, multiplication and division could be simplified by being replaced with the addition and subtraction of logarithms.

For any two numbers x and y (where $x = b^a$ and $y = b^c$), $x \times y = b^a \times b^c = b^{a+c}$; hence one would add the logarithms of x and y, and look up this answer in antilogarithm tables.

Tables of logarithms and antilogarithms are available that show conversions of numbers into logarithms, and vice versa. For example, to multiply 6,560 by 980, one looks up their logarithms (3.8169 and 2.9912), adds them together (6.8081), then looks up the antilogarithm of this to get the answer (6,428,800). **Natural** or **Napierian logarithms** are to the base e, an irrational number equal to approximately 2.7183.

The principle of logarithms is also the basis of the slide rule. With the general availability of the electronic pocket calculator, the need for logarithms has been reduced. The first log tables (to base e) were published by the Scottish mathematician John Napier in 1614. Base-ten logs were introduced by the Englishman Henry Briggs (1561-1631) and Dutch mathematician Adriaen Vlacq (1600-1667).

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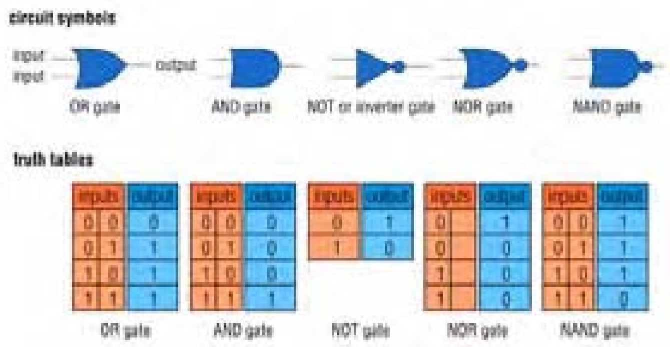
logic gate

or logic circuit

in electronics, one of the basic components used in building integrated circuits. The five basic types of gate make logical decisions based on the functions NOT, AND, OR, NAND (NOT AND), and NOR (NOT OR). With the exception of the NOT gate, each has two or more inputs.

logic gate



OR gate

inputs		output
0	0	0
0	1	1
1	0	1
1	1	1

AND gate

inputs		output
0	0	0
0	1	0
1	0	0
1	1	1

NOT gate

inputs	output
0	1
1	0

NOR gate

inputs		output
0		1
0		0
1		0
1		0

NAND gate

inputs		output
0	0	1
0	1	1
1	0	1
1	1	0

(Image © Research Machines plc)

The circuit symbols for the five basic types of logic gate: OR, AND, NOT, NOR, and NAND. The truth table displays the output results of each possible combination of input signal.

LOGO

(Greek logos 'word')

high-level computer programming language designed to teach mathematical concepts. Developed in about 1970 at the Massachusetts Institute of Technology, it became popular in schools and with home computer users because of its 'turtle graphics' feature. This allows the user to write programs that create line drawings on a computer screen, or drive a small mobile robot (a 'turtle' or 'buggy') around the floor.

LOGO encourages the use of languages in a logical and structured way, leading to 'microworlds', in which problems can be solved by using a few standard solutions.

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lomentum

fruit similar to a pod but constricted between the seeds. When ripe, it splits into one-seeded units, as seen, for example, in the fruit of sainfoin *Onobrychis viciifolia* and radish *Raphanus raphanistrum*. It is a type of schizocarp.

---

lone pair

in chemistry, a pair of electrons in the outermost shell of an atom that are not used in bonding. In certain circumstances, they will allow the atom to bond with atoms, ions, or molecules (such as boron trifluoride, BF_3) that are deficient in electrons, forming coordinate covalent (dative) bonds in which they provide both of the bonding electrons.

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long.

abbreviation for **longitude**; see latitude and longitude.

---

longhorn beetle

beetle with extremely long antennae, usually equalling the length of the entire body, and often twice its length. Their bodies are 2-150 mm/0.1-6 in long, usually cylindrical, and often mimic wasps, moss, or lichens. The larvae, white or yellow grubs, are wood-borers, mostly attacking decaying or dead wood, but they may bore into healthy trees causing much damage.

(Order Coleoptera, class Insecta, phylum Arthropoda.)

longitude

see latitude and longitude.

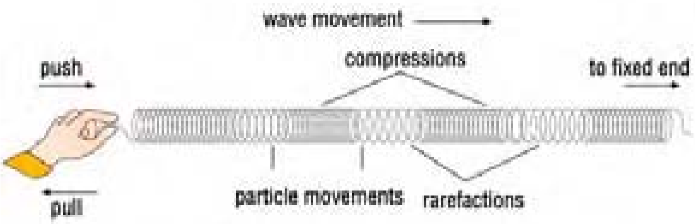
---

longitudinal wave

wave in which the displacement of the medium's particles is in line with or parallel to the direction of travel of the wave motion.

Various methods are used to reproduce waves, such as a ripple tank or a loosely-coiled spring, in order to understand their properties. If a loosely-coiled spring is given a slight 'pushing' force, the wave travels in the same direction as the movement of the coils. The waves consist of a series of compressions (where the coils of the spring are pressed together) and rarefactions (where the coils of the spring are more widely spaced). This is known as a longitudinal wave. The moving coils represent waves travelling along the spring. The spring remains as it was after the wave has travelled along the spring; waves carry energy from one place to another but they do not transfer matter. Sound waves are an example of longitudinal waves.

longitudinal wave



(Image © Research Machines plc)

The diagram illustrates the motion of a longitudinal wave. Sound, for example, travels through air in longitudinal waves: the waves vibrate back and forth in the direction of travel. In the compressions the particles are pushed together, and in the rarefactions they are pulled apart.

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longship

Viking warship, probably developed in the 8th century. Longships were manoeuvrable and fast, well designed for raiding coastal settlements. They could carry 60 or more warriors and travelled under sail or by rowing. There were up to 30 rowing benches in standard longships (the 'great ships' of the late Viking Age had even more). The length-to-breadth ratio of the longship is greater than 6:1 (11.4:1 in one case) enabling them to cut swiftly through the water. Speed was further enhanced by lightness; the timbers of the shell were planed to a width of only 2 cm/0.8 in.

In 1997 Danish archaeologists discovered a longship dating from AD 1025, in the mud of Roskilde harbour. At 35 m/115 ft, it is the longest discovered so far.

---

loom

any machine for weaving yarn or thread into cloth. The first looms are thought to have been used to weave sheep's wool in about 5000 BC. A loom is a frame on which a set of lengthwise threads (warp) is strung. A second set of threads (weft), traditionally carried in a shuttle, is inserted at right angles over and under the warp.

In most looms the warp threads are separated by a device called a heddle to create a gap, or shed, through which the shuttle can be passed in a straight line. A kind of comb called a reed presses each new weft tight against the previous ones. All looms have similar features, but on the power loom, weaving takes place automatically at great speed. Mechanization of weaving began in 1733 when British inventor John Kay invented the flying shuttle. In 1785 British inventor Edmund Cartwright introduced a steam-powered loom. Among recent developments are shuttleless looms, which work at very high speed, passing the weft through the warp by means of 'rapiers', and jets of air or water.

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loon

any of various birds of the genus *Gavia*, family Gavidae, found in northern regions of the northern hemisphere. Loons are specialized for swimming and diving. Their legs are set so far back that walking is almost impossible, and they come to land only to nest, but loons are powerful swimmers and good flyers.

They have straight bills and long bodies and feed on fish, crustaceans, and some water plants. There are just five species, the largest, the yellow-billed loon *G. adamsii*, being an Arctic species 2.5 ft/75 cm long.

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loop

in computing, short for program loop.

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loosestrife

genus *Lysimachia* of plants of the primrose family (Primulaceae) including swampcandles *L. terrestris* of North America, with yellow and purple-streaked flowers on a spike. The name is also applied to members of the genus *Lythrum* of the loosestrife family, such as the European willow loosestrife *L. salicaria*, now a weed in the northeastern USA.

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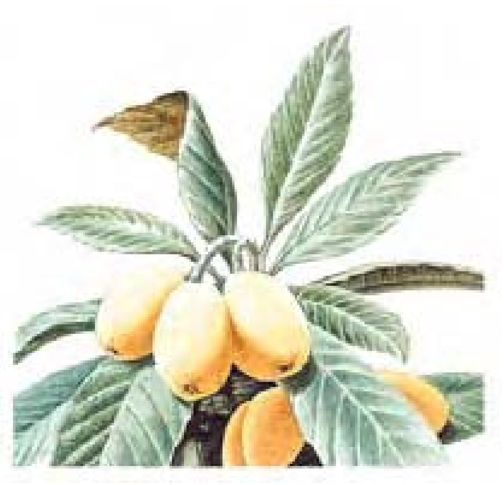
loquat

evergreen tree native to China and Japan, also known as the **Japan medlar**. The golden pear-shaped fruit has a delicate sweet-sour taste. (*Eriobotrya japonica*, family Rosaceae.)

loquat



(Image © Research Machines plc)

The loquat is a small, evergreen tree or shrub belonging to the Rosaceae family. It is native to China and Japan and is also known as the Japanese medlar. It is widely cultivated both as a decorative tree and for its edible, plumlike, yellowish fruits. The fruit is especially good for preserving.

Loran navigation system

LOng-RANge radio-based aid to Navigation. The current system (Loran C) consists of a master radio transmitter and two to four secondary transmitters situated within 1,000-2,000 km/600-1,250 mi. Signals from the transmitters are detected by the ship or aircraft's navigation receiver, and slight differences (phase differences) between the master and secondary transmitter signals indicate the position of the receiver. The system is accurate to within 500 m/1,640 ft at a range of 2,000 km/1,250 mi, and covers the North Atlantic and North Pacific oceans, and adjacent areas such as the Mediterranean and the Gulf.

The original Loran system (Loran A) was used to guide bombers on night raids in Europe and North Africa in 1944.

Lorenz, Konrad Zacharias (1903-1989)

Austrian ethologist who was awarded the Nobel Prize for Physiology or Medicine in 1973 with Nikolaas Tinbergen and Karl von Frisch for their work on animal behaviour patterns. He studied the relationship between instinct and behaviour, particularly in birds, and described the phenomenon of imprinting in 1935. His books include *King Solomon's Ring* (1952) on animal behaviour, and *On Aggression* (1966) on human behaviour.

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lorikeet

any of various small, brightly coloured parrots found in Southeast Asia and Australasia.

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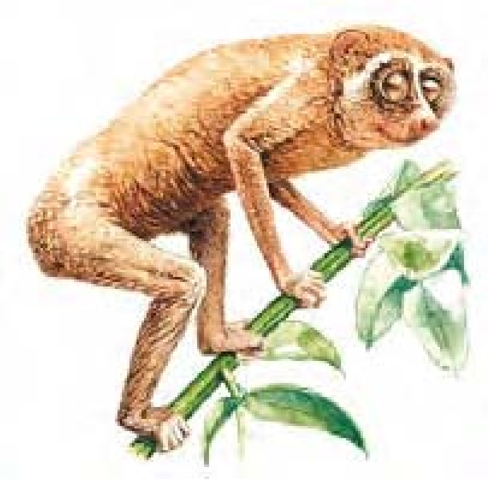
loris

any of a group of small prosimian primates native to Southeast Asia. Lorises are slow-moving, tree-dwelling, and nocturnal. They have very large eyes; true lorises have no tails. They climb without leaping, gripping branches tightly and moving on or hanging below them. (Family Lorisidae.)

The **slender loris** (*Loris tardigradus*) of southern India and Sri Lanka is about 20 cm/8 in long. The tubbier **slow loris** (*Nycticebus coucang*) of Southeast Asia is 30 cm/1 ft.

The **angwantibo** (genus *Arctocebus*), **potto** (genus *Perodicticus*), and **galagos** or **bushbabies** (genera *Galago* and *Euoticus*) are similar African forms.

loris



(Image © Research Machines plc)

The two species of loris are primitive primates related to bush babies and pottos. The slow loris lives among the trees of the rainforests in South and Southeast Asia where it feeds at night, mainly on insects and plant material, although it will take small birds and their eggs. It gets its name from its slow, deliberate movements.

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lory

any of various small Australasian parrots. Lories are very brightly coloured and characterized by a tongue with a brushlike tip adapted for feeding on pollen and nectar from flowers. (Subfamily Loriinae, order Psittaciformes.)

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lotus

any of several different plants, especially the **water lily** (*Nymphaea lotus*), frequent in Egyptian art, and the pink **Asiatic lotus** (*Nelumbo nucifera*), a sacred symbol in Hinduism and Buddhism, whose flower head floats erect above the water.

Others are those of the genus *Lotus* (family Leguminosae), including the **bird's foot trefoil** (*L. corniculatus*); the **jujube shrub** (*Zizyphus lotus*), known to the ancient Greeks who used its fruit to make a type of bread and also a wine supposed to induce happy oblivion – hence **lotus-eaters**; and the **American lotus** (*Nelumbo lutea*), a pale yellow water lily of the southern USA.

lotus

The sacred lotus *Nelumbo nucifera* heats up when it is ready for pollination. For up to four days it maintains steamy temperatures of 30–35°C to attract insects and encourage them to move from one flower to another.

lotus

(Image © Corel)

A lotus flower in Bali. The lotus flower, a species of water lily, is a sacred symbol in Hindu and Buddhist cultures.

Lotus 1-2-3

spreadsheet computer program, produced by Lotus Development Corporation. It first appeared in 1982 and its combination of spreadsheet, graphics display, and data management contributed to the rapid acceptance of the IBM personal computer in businesses. Over 20 years later, Lotus 1-2-3 forms part of the Lotus SmartSuite office productivity software suite, which also includes Word Pro, Freelance Graphics, Approach, and Organizer.

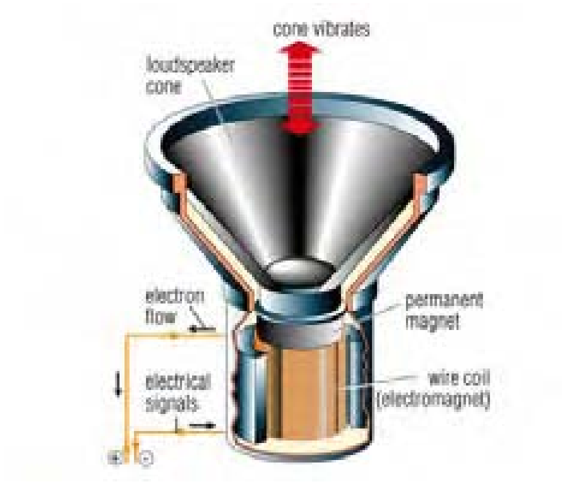
loudness

subjective judgement of the level or power of sound reaching the ear. The human ear cannot give an absolute value to the loudness of a single sound, but can only make comparisons between two different sounds. The precise measure of the power of a sound wave at a particular point is called its intensity. Accurate comparisons of sound levels may be made using sound-level meters, which are calibrated in units called decibels.

loudspeaker

electromechanical device that converts electrical signals into sound waves, which are radiated into the air. The most common type of loudspeaker is the **moving-coil speaker**. For example, electrical signals from a radio are fed to a coil of fine wire wound around the top of a cone. The coil is positioned between the poles of a permanent magnet. When signals pass through it, the coil becomes an electromagnet, experiencing a force at right angles to the direction of the current and magnetic field, causing the coil to move. As the signal varies, the coil and the cone vibrate, setting up sound waves. If the electrical signals have a frequency of 2,000 hertz (Hz), sound with a frequency of 2,000 Hz is produced.

loudspeaker



(Image © Research Machines plc)

A moving-coil loudspeaker. Electrical signals flowing through the wire coil turn it into an electromagnet, which moves as the signals vary. The attached cone vibrates, producing sound waves.

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louse

parasitic insect that lives on mammals. It has a flat, segmented body without wings, and a tube attached to the head, used for sucking blood from its host. (Order Anoplura.)

Some lice occur on humans, including the **head louse** (*Pediculus capitis*) and the **body louse** (*P. corporis*), a typhus carrier. Pediculosis is a skin disease caused by infestation of lice. Most mammals have a species of lice adapted to living on them. Biting lice belong to a different order of insects (Mallophaga) and feed on the skin, feathers, or hair. Each year 14 million children in the USA alone suffer from head lice.

louse: election

In Sweden in the Middle Ages, a mayor was once elected by a louse. The candidates rested their beards on a table and the louse was placed in the middle. The louse's chosen host was elected mayor.

louse: environment

The human pubic (crab) louse, *Phthirus pubis*, lives on any coarse hair on the body, and may thus be found in eyebrows, beards, and armpits. It spends almost all its life attached to the same hair.

louse: feeding

The bee louse feeds by crawling down to the bee's mouthparts and lapping up any surrounding nectar.

Louse

Go to site

Colour photographs of lice from Iowa State University's Entomology Image Gallery. These include pictures of body, cattle, crab or pubic, and hog lice. Click on a link to view each louse. There is a search engine at the top of the page to look for other species of insect.

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lovebird

any of a group of birds belonging to the parrot family, found in Africa south of the Sahara. They take their name from the affection the male displays towards the female. Lovebirds are generally just larger than sparrows (about 16 cm/6 in) and coloured green with red, yellow, and black markings on the head. (Genus *Agapornis*, family Psittacidae, order Psittaciformes.)

Lovebird FAQ

Go to site

Guide to lovebirds and how to keep and breed them. There are descriptions of the nine breeds of lovebirds and comprehensive advice on diet, housing, and training. There is a bibliography of recommended books on lovebirds.

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love-in-a-mist

perennial plant of southern Europe with fine leaves that create a soft haze around the delicate blue or white flowers; these are followed by large seedheads and, later, a profusion of new plants. (*Nigella damascena*, family Ranunculaceae.)

Lovell, (Alfred Charles) Bernard (1913-)

English radio astronomer, director 1951-81 of Jodrell Bank Experimental Station (now Nuffield Radio Astronomy Laboratories), Cheshire, England.

During World War II Lovell worked on developing a radar system to improve the aim of bombers in night raids. After the war he showed that radar could be a useful tool in astronomy, and lobbied for the setting-up of a radio-astronomy station. Jodrell Bank was built in Cheshire 1951-57. Several large radio telescopes were constructed, including a 76-m/250-ft instrument. Although its high cost was criticized, it proved a success after tracking the Soviet satellite Sputnik 1 in 1957.

Lowell, Percival (1855-1916)

US astronomer who predicted the existence of a planet beyond Neptune, starting the search that led to the discovery of Pluto in 1930. In 1894 he founded the Lowell Observatory in Flagstaff, Arizona, where he reported seeing 'canals' (now known to be optical effects and natural formations) on the surface of Mars.

Lowell Observatory

US astronomical observatory founded by Percival Lowell at Flagstaff, Arizona, with a 61-cm/24-in refractor opened in 1896. The observatory now operates other telescopes at a nearby site on Anderson Mesa, including the 1.83-m/72-in Perkins reflector of Ohio State and Ohio Wesleyan universities. In 2003, it announced a joint project with Discovery Communications to build a 4-metre telescope called the Discovery Channel Telescope for ultrawide field images and spectroscopy. The instrument is scheduled to be completed by the end of 2006.

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low-level language

in computing, a programming language designed for a particular computer and reflecting its internal machine code; low-level languages are therefore often described as **machine-oriented** languages. They cannot easily be converted to run on a computer with a different central processing unit, and they are relatively difficult to learn because a detailed knowledge of the internal working of the computer is required. Since they must be translated into machine code by an assembler program, low-level languages are also called assembly languages.

A mnemonic-based low-level language replaces binary machine-code instructions, which are very hard to remember, write down, or correct, with short codes chosen to remind the programmer of the instructions they represent. For example, the binary-code instruction that means '**sto**re the contents of the **a**ccumulator' may be represented with the mnemonic STA.

In contrast, high-level languages are designed to solve particular problems and are therefore described as **problem-oriented languages**.

LSD

abbreviation for lysergic acid diethylamide

psychedelic drug, a hallucinogen. Colourless, odourless, and easily synthesized, it is nonaddictive and nontoxic, but its effects are unpredictable. Its use is illegal in most countries.

The initials are from the German *Lysergsäurediäthylamid*; the drug was first synthesized by Swiss chemist Albert Hofmann (1906-) in 1943. In 1947 the US Central Intelligence Agency began experiments with LSD, often on unsuspecting victims. Many psychiatrists in North America used it in treatment in the 1950s. Its use as a means to increased awareness and enhanced perception was popularized in the 1960s by US psychologist Timothy Leary, novelist Ken Kesey, and chemist Augustus Owsley Stanley III (1935-). A series of laws to ban LSD were passed in the USA from 1965 (by which time 4 million Americans were estimated to have taken it) and in the UK in 1966; other countries followed suit. The drug had great influence on the hippie movement.

LSI

abbreviation for large-scale integration

technology that enables whole electrical circuits to be etched into a piece of semiconducting material just a few millimetres square.

By the late 1960s a complete computer processor could be integrated on a single chip, or integrated circuit, and in 1971 the US electronics company Intel produced the first commercially available microprocessor. Very large-scale integration (VLSI) results in even smaller chips.

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lubricant

substance used between moving surfaces to reduce friction. Carbon-based (organic) lubricants, commonly called grease and oil, are recovered from petroleum distillation.

Extensive research has been carried out on chemical additives to lubricants, which can reduce corrosive wear, prevent the accumulation of 'cold sludge' (often the result of stop-start driving in city traffic jams), keep pace with the higher working temperatures of aviation gas turbines, or provide radiation-resistant greases for nuclear power plants. Silicon-based spray-on lubricants are also used; they tend to attract dust and dirt less than carbon-based ones.

A solid lubricant is graphite, an allotropic form of carbon, either flaked or emulsified (colloidal) in water or oil.

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lucerne

another name for the plant alfalfa.

Ludwig, Carl Friedrich Wilhelm (1816-1895)

German physiologist who invented graphic methods of recording events within the body. He demonstrated that the circulation of the blood is purely mechanical in nature and involves no occult vital forces.

In 1847 Ludwig invented the kymograph, a rotating drum on which a stylus charts a continuous record of blood pressure and temperature. This was a forerunner of today's monitoring systems.

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lugworm

any of a group of marine annelid worms that grow up to 10 in/25 cm long. They are common burrowers between tidemarks and are useful for their cleansing and powdering of the beach sand, of which they may annually bring to the surface about 5,000 tonnes per hectare/2,000 tons per acre. (Genus *Arenicola*.)

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lumbago

pain in the lower region of the back, usually due to strain or faulty posture. If it occurs with sciatica, it may be due to pressure on spinal nerves from a slipped disc. Treatment includes rest, application of heat, and skilled manipulation. Surgery may be needed in rare cases.

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lumbar puncture

another term for spinal tap, a medical test.

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lumen

symbol lm

SI unit of luminous flux (the amount of light passing through an area per second).

The lumen is defined in terms of the light falling on a unit area at a unit distance from a light source of luminous intensity of one candela. One lumen at a wavelength of 5,550 angstroms equals 0.0014706 watts.

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lumen

in biology, the space enclosed by an organ, such as the bladder, or a tubular structure, such as the gastrointestinal tract.

Lumière

Auguste Marie Louis Nicolas (1862-1954) and Louis Jean (1864-1948)

French brothers who pioneered cinematography. In February 1895 they patented their cinematograph, a combined camera and projector operating at 16 frames per second, screening short films for the first time on 22 March, and in December opening the world's first cinema in Paris. Their simple documentary short *La Sortie des usines Lumière/Workers Leaving the Lumière Factory* (1895) is considered the first motion picture.

Other early films include *L'Arrivée d'un train en gare de La Ciotat/The Arrival of a Train at Ciotat Station* (1895), and the comedy *L'Arroseur arrosé/The Hoser Hosed* (1895). Between 1896 and 1900, the Lumières employed a number of camera operators to travel around the world and both demonstrate their invention and film new documentary shorts. Production was abandoned in 1900 after their films were displayed at the Paris Exposition. The brothers withdrew from film-making itself to concentrate on developing film technology and marketing their inventions.

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luminescence

emission of light from a body when its atoms are excited by means other than raising its temperature. Short-lived luminescence is called fluorescence; longer-lived luminescence is called phosphorescence.

When exposed to an external source of energy, the outer electrons in atoms of a luminescent substance absorb energy and 'jump' to a higher energy level. When these electrons 'jump' back to their former level they emit their excess energy as light. Many different exciting mechanisms are possible: visible light or other forms of electromagnetic radiation (ultraviolet rays or X-rays), electron bombardment, chemical reactions, friction, and radioactivity. Certain living organisms produce bioluminescence.

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luminosity

or brightness

in astronomy, amount of light emitted by a star, expressed as the rate at which it emits energy, as absolute magnitude, or as a ratio to the luminosity of the Sun. The apparent brightness of an object results from its luminosity and its distance from the observer.

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luminous paint

preparation containing a mixture of pigment, oil, and a phosphorescent sulphide, usually calcium or barium. After exposure to light it appears luminous in the dark. The luminous paint used on watch faces contains radium, is radioactive, and therefore does not require exposure to light.

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lumpsucker

marine bony fish so called from the frequent presence of a sucking disc formed from the united ventral fins. It is also distinguished by an absence of scales and the presence of spined plates along its side. Lumpsuckers feed mainly on small crustaceans and jellyfish.

classification

The lumpsuckers belong to the genus *Cyclopterus*, family Cyclopteridae, order Scorpaeniformes, class Osteichthyes.

Lunar Alps

conspicuous mountain range on the Moon, northeast of the Sea of Showers (Mare Imbrium), cut by a valley 150 km/93 mi long. The highest peak (about 3,660 m/12,000 ft) is Mont Blanc.

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lung

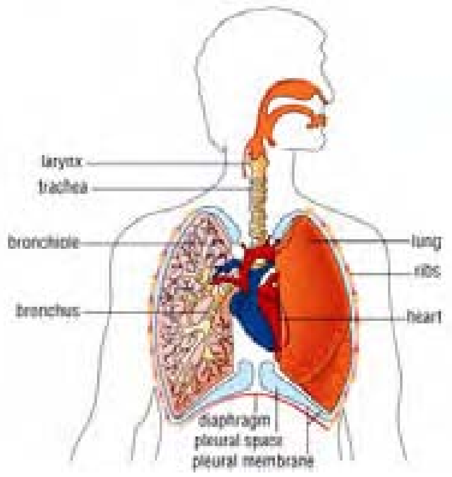
in mammals, large cavity of the body, used for gas exchange. Most tetrapod (four-limbed) vertebrates have a pair of lungs occupying the thorax. The lungs are essentially an infolding of the body surface – a sheet of thin, moist membrane made of a single layer of cells, which is folded so as to occupy less space while having a large surface area for the uptake of oxygen and loss of carbon dioxide. The folding creates tiny sacs called alveoli. Outside the walls of the alveoli there are lots of blood capillaries for transporting the products of gas exchange. The lung tissue, consisting of multitudes of air sacs and blood vessels, is very light and spongy, and functions by bringing inhaled air into close contact with the blood for efficient gas exchange. The efficiency of lungs is enhanced by breathing movements, by the thinness and moistness of their surfaces, and by a constant supply of circulating blood.

The lungs inflate and deflate as a result of breathing movements (ventilation). Breathing movements are caused by movements of muscles between the ribs and the muscles of the diaphragm. Air flows into the mouth and then along ever narrower tubes, trachea, bronchi, and tiny broncheoles. However, the last part of the journey to the alveoli is by diffusion only, as is the exchange with the blood.

Dust in the air is usually trapped by the mucus lining the tubes leading to the lungs. Cells lining the tubes are specialized cells (see epithelium) and have hair-like structures – cilia – that sweep the trapped dust up to the mouth where it is swallowed. Some dust may reach the lungs where white blood cells may destroy it. However, the lungs can be damaged if dust is not removed. Many miners suffer from lungs damaged by the effects of coal dust, and many other forms of industrial dusts are equally dangerous.

In humans, the principal diseases of the lungs are tuberculosis, pneumonia, bronchitis, emphysema, and cancer. Bronchitis is an irritation of the airways resulting in them becoming narrower than normal so that a person cannot breathe fully. Emphysema is permanent damage to the alveolar walls resulting in too little surface for gas exchange. This too results in difficulties in breathing. The commonest cause of both bronchitis and emphysema is smoking.

lung



(Image © Research Machines plc)

The human lungs contain 300,000 million tiny blood vessels which would stretch for 2,400 km/1,500 mi if laid end to end. A healthy adult at rest breathes 12 times a minute; a baby breathes at twice this rate. Each breath brings 350 millilitres of fresh air into the lungs, and expels 150 millilitres of stale air from the nose and throat.

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lung cancer

in medicine, cancer of the lung. The main risk factor is smoking, with almost nine out of ten cases attributed to it. Other risk factors include workspace exposure to carcinogenic substances such as asbestos and radiation. Warning symptoms include a persistent and otherwise unexplained cough, breathing difficulties, and pain in the chest or shoulder. Treatment is with chemotherapy, radiotherapy, and surgery.

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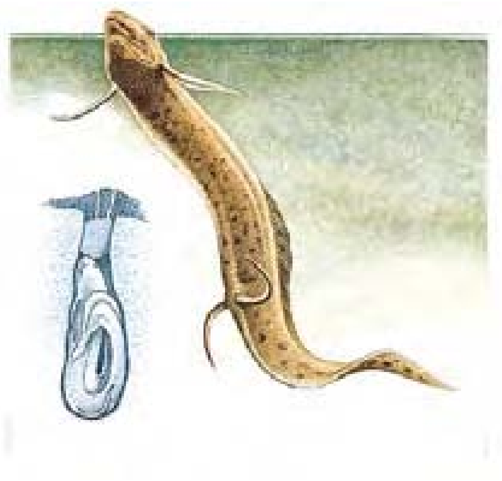
lungfish

any of a group of fleshy-finned bony fishes found in South America, Australia, and Africa. They have elongated bodies, and grow to about 2 m/6 ft, and in addition to gills have 'lungs' with which they can breathe air during periods of drought conditions. (Genera *Lepidosiren*, *Neoceratodus*, and *Protopterus*, subclass Dipnoi.)

Lungfish are related to the lobefins such as the coelacanth, and were abundant 350 million years ago.

lungfish



(Image © Research Machines plc)

The lungfish resembles a short-bodied eel. It has a pair of lungs and can breathe air in water that is poor in oxygen. The various species of lungfishes are found in the lakes and rivers of South America and central Africa but, when the water courses evaporate during the dry season, the fishes survive by burrowing into the mud.

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lupin

any plant of the genus *Lupinus*, of the pea family Leguminosae, including about 300 species. They are native to Mediterranean regions and parts of North and South America. Their spikes of pealike flowers may be white, yellow, blue, or pink.

The European lupin *L. albus* is cultivated in some places for cattle fodder and for manure.

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lupus

in medicine, any of various diseases characterized by lesions of the skin. One form (lupus vulgaris) is caused by the tubercle bacillus (see tuberculosis). The organism produces ulcers that spread and eat away the underlying tissues. Treatment is primarily with standard antituberculous drugs, but ultraviolet light may also be used.

Lupus erythematous (LE) has two forms: **discoid** LE, seen as red, scaly patches on the skin, especially the face; and **disseminated** or **systemic** LE, which may affect connective tissue anywhere in the body, often involving the internal organs. The latter is much more serious. Treatment is with corticosteroids. LE is an autoimmune disease.

Luria, Salvador Edward (1912-1991)

Italian-born US physician who was awarded the Nobel Prize for Physiology or Medicine in 1969 for his work on the replication mechanism and genetic structure of viruses. Luria was a pacifist and was identified with efforts to keep science humanistic.

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luteinizing hormone

hormone produced by the pituitary gland. In males, it stimulates the testes to produce androgens (male sex hormones). In females, it works together with follicle-stimulating hormone to initiate production of egg cells by the ovary. If fertilization occurs, it plays a part in maintaining the pregnancy by controlling the levels of the hormones oestrogen and progesterone in the body.

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lutetium

chemical symbol Lu

(Latin Lutetia 'Paris')

silver-white, metallic element, the last of the lanthanide series, atomic number 71, relative atomic mass 174.97. It is used in the 'cracking', or breakdown, of petroleum and in other chemical processes. It was named by its discoverer, French chemist Georges Urbain, after his native city.

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lux

symbol lx

SI unit of illuminance or illumination (the light falling on an object). It is equivalent to one lumen per square metre or to the illuminance of a surface one metre distant from a point source of one candela.

LW

abbreviation for **long wave**, a radio wave with a wavelength of over 1,000 m/3,300 ft; one of the main wavebands into which radio frequency transmissions are divided.

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lx

in physics, symbol for lux, the SI unit of illumination.

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lychee

alternative spelling of litchi, a fruit-bearing tree.

Lyell, Charles (1797-1875)

Scottish geologist. In his *Principles of Geology* (1830-33), he opposed the French anatomist Georges Cuvier's theory that the features of the Earth were formed by a series of catastrophes, and expounded the Scottish geologist James Hutton's view, known as uniformitarianism, that past events were brought about by the same processes that occur today - a view that influenced Charles Darwin's theory of evolution. He was knighted in 1848.

Lyell suggested that the Earth was as much as 240 million years old (in contrast to the 6,000 years of prevalent contemporary theory), and provided the first detailed description of the Tertiary period, dividing it into the Eocene, Miocene, and older and younger Pliocene periods. Darwin simply applied Lyell's geological method - explaining the past through what is observable in the present - to biology.

Lyme disease

disease transmitted by tick bites that affects all the systems of the body. It has a 10% mortality rate. First described in 1975 following an outbreak in children living around Lyme, Connecticut, USA, it is caused by the micro-organism *Borrelia burgdorferi*, isolated by Burgdorfer and Barbour in the USA in 1982. Symptoms include a red 'bull's eye' rash around the bite, but this only occurs in about two-thirds of cases and otherwise the early stages are difficult to distinguish from flu. Untreated, the disease attacks the joints, nervous system, heart, liver, kidneys, and eyes, but responds to penicillin or tetracycline.

The tick that carries the disease, *Ixodes dammini*, lives on deer, while *B. burgdorferi* relies on mice during its life cycle.

Childhood Infections - Lyme Disease

Go to site

Useful information about Lyme disease. There is a detailed, illustrated description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

Lyme Disease

Go to site

Overview of this disease - its transmission, symptoms, treatment, and prevention. This text-only site makes grim reading, but has plenty of practical information to help you avoid catching this tick-borne disease and also what to do if you do catch it.

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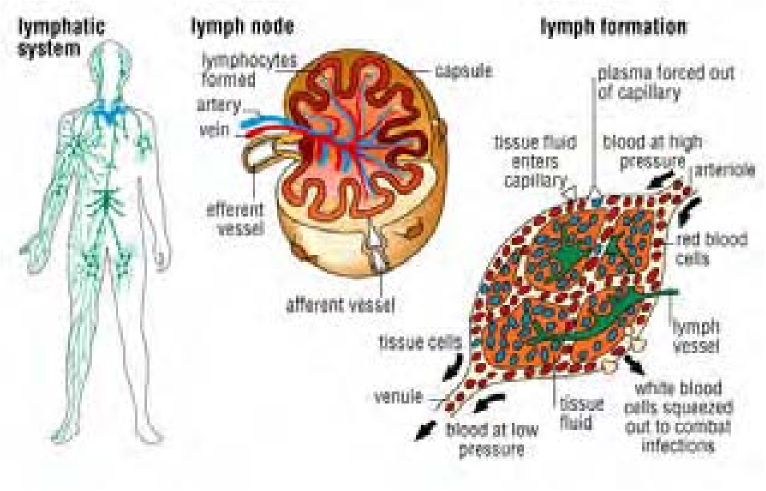
lymph

fluid found in the lymphatic system of vertebrates.

Lymph is drained from the tissues by lymph capillaries, which empty into larger lymph vessels (lymphatics). These lead to lymph nodes (small, round bodies chiefly situated in the neck, armpit, groin, thorax, and abdomen), which process the lymphocytes produced by the bone marrow, and filter out harmful substances and bacteria. From the lymph nodes, vessels carry the lymph to the thoracic duct and the right lymphatic duct, which drain into the large veins in the neck. Some vertebrates, such as amphibians, have a lymph heart, which pumps lymph through the lymph vessels.

lymph


lymphatic system
lymph node
lymphocytes formed
artery
vein
efferent vessel
capsule
afferent vessel
lymph formation
plasma forced out of capillary
tissue fluid enters capillary
blood at high pressure
arteriole
red blood cells
lymph vessel
tissue cells
venule
blood at low pressure
tissue fluid
white blood cells squeezed out to combat infections

(Image © Research Machines plc)

Lymph is the fluid that carries nutrients and white blood cells to the tissues. Lymph enters the tissue from the capillaries (right) and is drained from the tissues by lymph vessels. The lymph vessels form a network (left) called the lymphatic system. At various points in the lymphatic system, lymph nodes (centre) filter and clean the lymph.

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lymph nodes

small masses of lymphatic tissue in the body that occur at various points along the major lymphatic vessels. Tonsils and adenoids are large lymph nodes. As the lymph passes through them it is filtered, and bacteria and other micro-organisms are engulfed by cells known as macrophages.

Lymph nodes are sometimes mistakenly called lymph 'glands', and the term 'swollen glands' refers to swelling of the lymph nodes caused by infection.

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lymphocyte

type of white blood cell with a large nucleus, produced in the bone marrow. Most occur in the lymph and blood, and around sites of infection.
B lymphocytes or B cells are responsible for producing antibodies.
T lymphocytes or T cells have several roles in the mechanism of immunity.

lymphocyte

Fetal lymphocytes can persist in the mother's blood for up to 27 years.

lymphokines

chemical messengers produced by lymphocytes that carry messages between the cells of the immune system (see immunity). Examples include interferon, which initiates defensive reactions to viruses, and the interleukins, which activate specific immune cells.

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lynx

wild cat found in rocky and forested regions of North America and Europe. About 1 m/3 ft in length, it has a short tail, tufted ears, and long, silky fur which is reddish brown or grey with dark spots. The North American **bobcat** or **bay lynx** (*Felix rufus*) looks similar but is smaller. Some zoologists place the lynx, the bobcat, and the caracal in a separate genus, *Lynx*. (Species *Felis lynx*, family Felidae.)

Lynxes are nocturnal and solitary and need a large range, but the size of the range varies depending on the population size of the prey animal, from 300 sq km/115 sq mi to up to 1,900 sq km/734 sq mi. They feed mainly on small deer but are capable of killing prey much larger than themselves. Lynxes do not have dens, but mothers place cubs under a tree or close to rocks. Gestation lasts 9-10 weeks and litters contain 1-4 cubs. They reach independence at around 10 months and usually live for 10-15 years. In August 2001, it was estimated that there were only 500 Iberian lynxes left in the wild. The International Union for the Conservation of Nature (IUCN) classified this species as the world's most endangered cat.

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lyophilization

technical term for the freeze-drying process used for foods and drugs and in the preservation of organic archaeological remains.

Lyra

small but prominent constellation of the northern hemisphere, represented as the harp of Orpheus. Its brightest star is Vega.

Epsilon Lyrae is a system of four gravitationally linked stars. Beta Lyrae is an eclipsing binary. The Ring nebula, M57, is a planetary nebula.

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lyrebird

either of two species of large birds found in southeastern Australia. They have very stout beaks and short, rounded wings; the tail has 16 feathers, and in the males the exterior pair of feathers are curved in the shape of a lyre; the tail of the female is long, broad, and normal in shape. Lyrebirds nest on the ground, and feed on insects, worms, and snails. (Genus *Menura*, family Menuridae, order Passeriformes.)

Lyrebirds live in the thick undergrowth, or sandy gullies of forests; they rarely fly, but run or strut with the tail spread horizontally. *M. superba* is 1 m/3 ft long, and of a brownish colour, with blue tinges; *M. alberti* is of a warmer, reddish colour.

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lyretail

African freshwater fish, 6 cm/2.4 in long, whose tail has two outward-curving fin supports for a central fin area which looks like the strings of a lyre. The male is bright blue with red markings; the less brightly coloured female has plainer fins. (Species *Aphyosemion australe*.)

Lyretails lay their eggs in mud at the bottom of swamps. In the event of a drought, the eggs usually survive in a dormant state and hatch with the next rainfall.

Lysenko, Trofim Denisovich (1898-1976)

Soviet biologist who believed in the inheritance of acquired characteristics (changes acquired in an individual's lifetime) and used his position under Joseph Stalin officially to exclude Gregor Mendel's theory of inheritance. He was removed from office after the fall of Nikita Khrushchev in 1964.

As leader of the Soviet scientific world, Lysenko encouraged the defence of mechanistic views about the nature of heredity and speciation. This created an environment conducive to the spread of unverified facts and theories, such as the doctrine of the noncellular 'living' substance and the transformation of viruses into bacteria. Research in several areas of biology came to a halt.

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lysine

one of the nine essential amino acids.

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lysis

in biology, any process that destroys a cell by rupturing its membrane or cell wall (see lysosome).

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lysosome

membrane-enclosed structure, or organelle, inside a cell, principally found in animal cells. Lysosomes contain enzymes that can break down proteins and other biological substances. They play a part in digestion, and in the white blood cells known as phagocytes the lysosome enzymes attack ingested bacteria.

Lyssavirus

type of virus that includes rabies. A new lyssavirus was identified in Australian fruitbats in 1996.

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m

symbol for metre.

MA

abbreviation for mechanical advantage.

McAdam, John Loudon (1756-1836)

Scottish engineer, inventor of the **macadam** road surface. It originally consisted of broken granite bound together with slag or gravel, raised for drainage. Today, it is bound with tar or asphalt.

McAdam introduced a method of road building that raised the road above the surrounding terrain, compounding a surface of small stones bound with gravel on a firm base of large stones.

A camber, making the road slightly convex in section, ensured that rainwater rapidly drained off the road and did not penetrate the foundation. By the end of the 19th century, most of the main roads in Europe were built in this way.

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macadamia

edible nut of a group of trees native to Australia (especially *M. ternifolia*), and cultivated in Hawaii, South Africa, Zimbabwe, and Malawi. The nuts are slow-growing; they are harvested when they drop. (Genus *Macadamia*, family Proteaceae.)

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macaque

any of a group of medium-sized Old World monkeys. Various species live in forests from the Far East to North Africa. The rhesus monkey and the Barbary ape belong to this group. (Genus *Macaca*.)

Macaques range from long-tailed to tailless types, and have well-developed cheek pouches to carry food.

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macaw

any of a group of large, brilliantly coloured, long-tailed tropical American parrots, such as the blue and yellow macaw *Ara ararauna*. They can be recognized by the massive beak, about half the size of the head, and by the extremely long tail. (Genera *Ara*, *Aratinga*, and *Anodorhynchus*.)

Large Macaw FAQ

Go to site

Comprehensive answers to frequently asked questions about the large macaw. There is advice on the housing, dietary, and recreational requirements of these large and demanding birds. The breeds most commonly kept as pets are described, together with information on those listed as endangered species.

McClintock, Barbara (1902-1992)

US geneticist who was awarded a Nobel Prize for Physiology or Medicine in 1983 for her discovery of mobile genetic elements, meaning she discovered 'jumping'genes (genes that can change their position on a chromosome from generation to generation). This would explain how originally identical cells take on the specialized functions of skin, muscle, bone, and nerve, and also how evolution could give rise to the multiplicity of species.

maceration

in biology, a process of softening solids by soaking them in liquids. Food is macerated in the mouth as part of the process of digestion.

Mach, Ernst (1838-1916)

Austrian philosopher and physicist. He was an empiricist, believing that science is a record of facts perceived by the senses, and that acceptance of a scientific law depends solely on its standing the practical test of use; he opposed such concepts as Isaac Newton's 'absolute motion'.
Mach numbers are named after him.

machine

in mechanics, device that allows a small force (the effort) to overcome a larger one (the load). There are three basic machines: the inclined plane (ramp), the lever, and the wheel and axle. All other machines are combinations of these three basic types. Simple machines derived from the inclined plane include the wedge and the screw; the spanner is derived from the lever; the pulley from the wheel.

The principal features of a machine are its mechanical advantage, which is the ratio of load to effort, its velocity ratio, and its efficiency, which is the work done by the load divided by the work done by the effort; the latter is expressed as a percentage. In a perfect machine, with no friction, the efficiency would be 100%. All practical machines have efficiencies of less than 100%.

machine code

in computing, a set of instructions that a computer's central processing unit (CPU) can understand and obey directly, without any translation. Each type of CPU has its own machine code. Because machine-code programs consist entirely of binary digits (bits), most programmers write their programs in an easy-to-use high-level language. A high-level program must be translated into machine code - by means of a compiler or interpreter program - before it can be executed by a computer.

Where no suitable high-level language exists or where very efficient machine code is required, programmers may choose to write programs in a low-level, or assembly, language, which is eventually translated into machine code by means of an assembler program.

Microprocessors (CPUs based on a single integrated circuit) may be classified according to the number of machine-code instructions that they are capable of obeying: CISC (complex instruction set computer) microprocessors support up to 200 instructions, whereas RISC (reduced instruction set computer) microprocessors support far fewer instructions but execute programs more rapidly.

machine tool

automatic or semi-automatic power-driven mechanized tool. Machine tools have powerful electric motors to force cutting tools into metals: these are made from hardened steel containing heat-resistant metals such as tungsten and chromium. The use of precision machine tools in mass-production assembly methods ensures that all duplicate parts produced are virtually identical.

Many machine tools now work under computer control and are employed in factory automation. The most common machine tool is the lathe, which shapes shafts and similar objects. A milling machine cuts metal with a rotary-toothed cutting wheel. Other machine tools cut, plane, grind, drill, and polish.

Mach number

ratio of the speed of a body to the speed of sound in the medium through which the body travels. In the Earth's atmosphere, Mach 1 is reached when a body (such as an aircraft or spacecraft) 'passes the sound barrier', at a velocity of 331 m/1,087 ft per second (1,192 kph/740 mph) at sea level. A space shuttle reaches Mach 15 (about 17,700 kph/11,000 mph an hour) 6.5 minutes after launch.

The Mach number is named after Austrian physicist Ernst Mach.

Macintosh

range of microcomputers originally produced by Apple Computer. The Apple Macintosh, introduced in 1984, was the first popular microcomputer with a graphical user interface. The success of the Macintosh prompted other manufacturers and software companies to create their own graphical user interfaces. Most notable of these are Microsoft Windows, which runs on IBM PC-compatible microcomputers, and OSF/Motif, from the Open Software Foundation, which is used with many Unix systems.

Apple introduced its stylish iMac computer in 1998, followed by a laptop version, the iBook, in 1999.

Macintosh, Charles (1766-1843)

Scottish manufacturing chemist who discovered that rubber could be dissolved in coal-tar naptha, producing a liquid that could be applied to fabric for waterproofing. This waterproof fabric, was used for raincoats - hence **mackintosh**. Other waterproofing processes have now largely superseded this method.

In 1797 Macintosh set up the first alum works in Scotland, and in 1799 invented a process for making bleaching powder. While investigating uses for the waste products of the new Glasgow gasworks in 1818, he noticed coal-tar naphtha dissolved India rubber. He experimented by sandwiching wool fabric with this substance to make a waterproof material, and invented the mackintosh. The material was hard in winter and sticky in summer, and awaited the discovery of vulcanization of rubber by Charles Goodyear in 1839 for success.

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mackerel

any of various fishes of the mackerel family, especially the **common mackerel** (*Scomber scombrus*) found in the North Atlantic and Mediterranean. It weighs about 0.7 kg/1.5 lb, and is blue with irregular black bands down its sides, the sides and under surface having a metallic sheen. Like all mackerels, it has a deeply forked tail, and a sleek, streamlined body form. (Family Scombroidia.)

The largest of the mackerels is the **tuna**, which weighs up to 700 kg/1,550 lb.

mackerel

(Image © Research Machines plc)

The king mackerel, often referred to as the kingfish, is found mainly in the warm waters of the Indian Ocean. It usually reaches up to 2 m/6.6 ft in length and 45 kg/100 lb in weight. The king mackerel can be caught using live bait such as other fish, usually elf or mullet, or by an artificial lure.

MacMillan, Kirkpatrick (1813-1878)

Scottish blacksmith who invented the bicycle in 1839. His invention consisted of a 'hobby-horse' that was fitted with treadles and propelled by pedalling.

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macro

in computer programming, a new command created by combining a number of existing ones. For example, a word-processing macro might create a letterhead or fax cover sheet, inserting words, fonts, and logos with a single keystroke or mouse click. Macros are also useful to automate repetitive tasks – for example, users can write a macro to search a list of data in a spreadsheet and to delete duplicate items.
macro key on the keyboard combines the effects of pressing several individual keys.

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macro-

prefix meaning on a very large scale, as opposed to micro-.

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macromolecule

in chemistry, a very large molecule, generally a polymer.

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macrophage

type of white blood cell, or leucocyte, found in all vertebrate animals. Macrophages specialize in the removal of bacteria and other micro-organisms, or of cell debris after injury. Like phagocytes, they engulf foreign matter, but they are larger than phagocytes and have a longer lifespan. They are found throughout the body, but mainly in the lymph and connective tissues, and especially the lungs, where they ingest dust, fibres, and other inhaled particles.

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mad cow disease

common name for bovine spongiform encephalopathy, an incurable brain condition in cattle.

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madder

any of a group of plants bearing small funnel-shaped flowers, especially the perennial vine *R. tinctorum* which grows in Europe and Asia, the red root of which yields a red dye called alizarin (now made synthetically from coal tar). (Genus *Rubia*, family Rubiaceae.)

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mafic rock

plutonic rock composed chiefly of dark-coloured minerals such as olivine and pyroxene that contain abundant magnesium and iron. It is derived from **magnesium** and **ferric** (iron). The term **mafic** also applies to dark-coloured minerals rich in iron and magnesium as a group. 'Mafic rocks' usually refers to dark-coloured igneous rocks such as basalt, but can also refer to their metamorphic counterparts.

Magdalenian

final cultural phase of the Palaeolithic (Old Stone Age) in Western Europe, best known for its art, and lasting from *c.* 16,000–10,000 BC. It was named after the rock-shelter of La Madeleine in southwestern France.

Prehistoric Art of the Pyrenees

Go to site

Exhibition of the prehistoric art of the Pyrenees Mountains. The site offers a brief introduction to the Magdalenians, the prehistoric hunter-gatherers who, already extinct by the end of Ice Age, left behind about 450 samples of the art that died with them. Visitors are given the choice either to view the exhibits as they come or to follow an itinerary of the exhibition first.

Magellan

NASA space probe to the planet Venus, launched from the space shuttle *Atlantis* on 4 May 1989. The probe went into orbit around Venus in August 1990 to make a detailed map by radar of 99% of the planet. It revealed the existence of volcanoes, impact craters, and mountains, on the planet's surface.

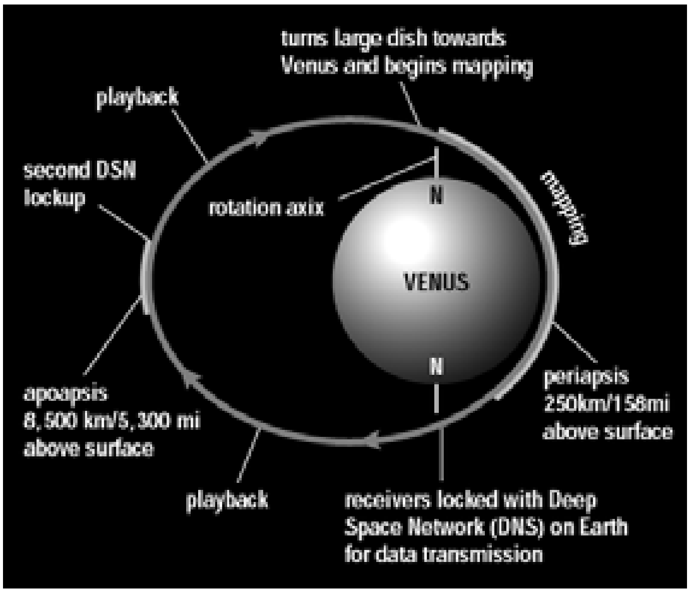
In October 1994, Magellan was purposely destroyed, entering the atmosphere around Venus, where it burned up.

Magellan

(Image © NASA)

The Magellan spacecraft installed in the payload bay of the shuttle *Atlantis*. The photograph of the Venus probe and its inertial upper stage booster was taken just before the closure of the doors in readiness for launch.

Magellan


turns large dish towards Venus and begins mapping
playback
second DSN lockup
rotation axix
N
mapping
VENUS
N
apoapsis 8,500 km/5,300 mi above surface
periapsis 250km/158mi above surface
playback
receivers locked with Deep Space Network (DNS) on Earth for data transmission

(Image © Research Machines plc)

Orbit of the Magellan space probe around Venus. Initially, the probe was in a 3.26-hour orbit, but after 70 orbits Magellan transferred to an almost circular 90-minute orbit. It succeeded in mapping virtually all of the planet's surface.

Magellan Mission to Venus

Go to site

Details of the NASA Magellan project that sent a probe to Venus. It includes a full mission overview, technical details about the planet, many images, and an animated view of Venus.

Magellanic Clouds

two galaxies close to our own galaxy. They are irregularly shaped, and appear as detached parts of the Milky Way, in the southern hemisphere.

The Large Magellanic Cloud spreads over the constellations of Dorado and Mensa. The Small Magellanic Cloud is in Tucana. The Large Magellanic Cloud is about 169,000 light years from Earth, and about a third the diameter of our Galaxy; the Small Magellanic Cloud, about 180,000 light years away, is about a fifth the diameter of our Galaxy. They are named after the early-16th-century Portuguese navigator Ferdinand Magellan, who first described them.

maggot

soft, plump, limbless larva of flies, a typical example being the larva of the blowfly which is deposited as an egg on flesh.

maggot

Wounds infested with maggots heal quickly and without spread of gangrene or other infection. This is because the maggots eat only the dead and suppurating flesh within a wound. This fact, first noted by World War I doctors in the trenches, is still used today in 'maggot therapy'.

magic bullet

term sometimes used for a drug that is specifically targeted on certain cells or tissues in the body, such as a small collection of cancerous cells (see cancer) or cells that have been invaded by a virus. Such drugs can be made in various ways, but monoclonal antibodies are increasingly being used to direct the drug to a specific target.

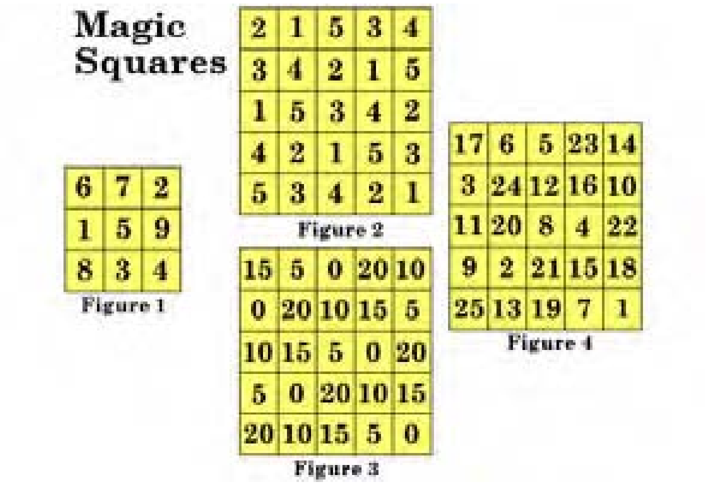
The term was originally associated with the German chemist Paul Ehrlich (1854-1915) who discovered the first specific against syphilis.

magic square

in mathematics, a square array of numbers in which the rows, columns, and diagonals add up to the same total. A simple example employing the numbers 1 to 9, with a total of 15, has a first row of 6, 7, 2, a second row of 1, 5, 9, and a third row of 8, 3, 4.

A **pandiagonal magic square** is one in which all the broken diagonals also add up to the magic constant.

magic squares


Magic Squares

6	7	2
1	5	9
8	3	4

Figure 1

2	1	5	3	4
3	4	2	1	5
1	5	3	4	2
4	2	1	5	3
5	3	4	2	1

Figure 2

15	5	0	20	10
0	20	10	15	5
10	15	5	0	20
5	0	20	10	15
20	10	15	5	0

Figure 3

17	6	5	23	14
3	24	12	16	10
11	20	8	4	22
9	2	21	15	18
25	13	19	7	1

Figure 4

(Image © Research Machines plc)

The simplest of all magic squares (figure 1) is formed by the 9 digits, with 5 in the centre and the even numbers at the corners, so that the sum of any row or column is 15. In figure 2 the numbers 1 to 5 are arranged in any order in the first row; the second commences with the fourth number from the first row and proceeds in the same relative order. The third row starts with the fourth number from the second row, and so on. Figure 3 consists of the numbers 0 to 4 multiplied by 5, and each row starts with the third number from the row above. Adding together the corresponding numbers from figures 2 and 3 produces the magic square in figure 4.

maglev

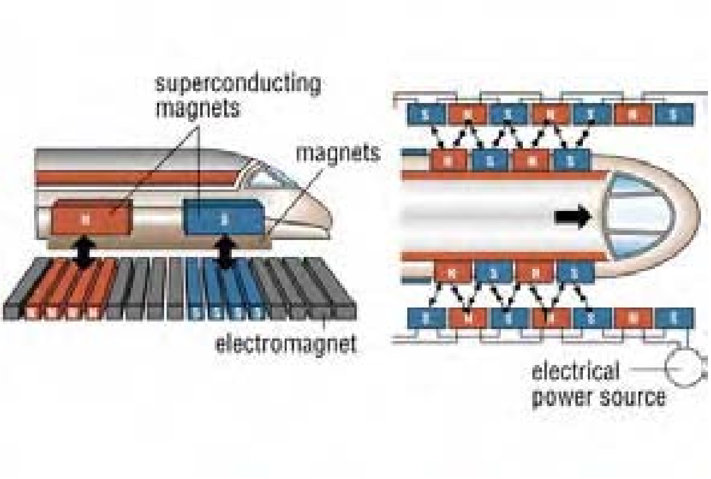
contraction of magnetic levitation

high-speed surface transport using the repellent force of superconductive magnets (see superconductivity) to propel and support, for example, a train above a track.

Technical trials on a maglev train track began in Japan in the 1970s, and a speed of 500 kph/310 mph was reached, with a cruising altitude of 10 cm/4 in. The train was levitated by electromagnets and forward thrust was provided by linear motors aboard the cars, propelling the train along a reaction plate.

Numerous similar systems have been built and tested, but they have proved so expensive that the only commercial maglev railway operating today is a 30-km/20-mi link between central Shanghai, China, and the cityseverals airport, which carries passengers at an average speed of 250 kph/150 mph.

maglev



(Image © Research Machines plc)

The repulsion of superconducting magnets and electromagnets in the track keeps a maglev train suspended above the track. By varying the strength and polarity of the track electromagnets, the train can be driven forward.

magma

molten rock material that originates in the lower part of the Earth's crust, or mantle, where it reaches temperatures as high as 1,000°C/1,832°F. Igneous rocks are formed from magma. Lava is magma that has extruded onto the surface.

magnesia

common name for magnesium oxide.

magnesium

chemical symbol Mg

lightweight, very ductile and malleable, silver-white, metallic element, atomic number 12, relative atomic mass 24.305. It is one of the alkaline-earth metals, and the lightest of the commonly used metals. Magnesium silicate, carbonate, and chloride are widely distributed in nature. The metal is used in alloys, flares, and flash bulbs. It is a necessary trace element in the human diet, and green plants cannot grow without it since it is an essential constituent of the photosynthetic pigment chlorophyll ($C_{55}H_{72}MgN_4O_5$).

It was named after the ancient Greek city of Magnesia, near where it was first found. It was first recognized as an element by Scottish chemist Joseph Black in 1755 and discovered in its oxide by English chemist Humphry Davy 1808. Pure magnesium was isolated in 1828 by French chemist Antoine-Alexandre-Brutus Bussy.

magnesium oxide

or magnesia; MgO

white powder or colourless crystals, formed when magnesium is burned in air or oxygen; a typical basic oxide. It is used to treat acidity of the stomach, and in some industrial processes; for example, as a lining brick in furnaces, because it is very stable when heated (refractory oxide).

magnet

any object that forms a magnetic field (displays magnetism), either permanently or temporarily through induction, causing it to attract materials such as iron, cobalt, nickel, and alloys of these. It always has two magnetic poles, called north and south.

The world's most powerful magnet was built in 1997 at the Lawrence Berkeley National Laboratory, California. It produces a field 250,000 times stronger than the Earth's magnetic field (13.5 teslas). The coil magnet is made of an alloy of niobium and tin.

---

magnetic compass

device for determining the direction of the horizontal component of the Earth's magnetic field. It consists of a magnetized needle (a small bar magnet) with its north-seeking pole clearly indicated, pivoted so that it can turn freely in a plane parallel to the surface of the Earth (in a horizontal circle). The needle aligns itself with the lines of force of the Earth's magnetic field, turning so that its north-seeking pole points towards the Earth's magnetic north pole. See also compass.

Walkers, sailors, and other travellers use a magnetic compass to find their direction. The direction of the geographic, or true, North Pole is, however, slightly different from that of the magnetic north pole, and so the readings obtained from a compass of this sort must be adjusted using tables of magnetic corrections or information marked on local maps.

A magnetic compass can also be used to check the direction of the magnetic field around a wire with a current flowing through it.

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magnetic declination

see angle of declination.

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magnetic dip

see dip, magnetic and angle of dip.

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magnetic dipole

the pair of north and south magnetic poles, separated by a short distance, that makes up all magnets. Individual magnets are often called 'magnetic dipoles'. Single magnetic poles, or monopoles, have never been observed despite being searched for. See also magnetic domain.

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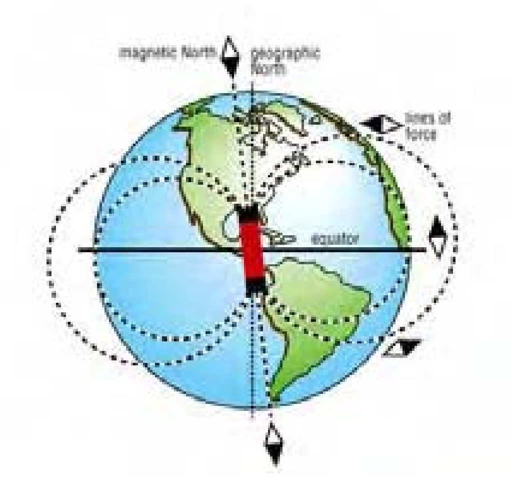
magnetic field

region around a permanent magnet, or around a conductor carrying an electric current, in which a force acts on a moving charge or on a magnet placed in the field. The force cannot be seen; only the effects it produces are visible. The field can be represented by lines of force parallel at each point to the direction of a small compass needle placed on them at that point. These invisible lines of force are called the magnetic field or the flux lines. A magnetic field's magnitude is given by the magnetic flux density (the number of flux lines per unit area), expressed in teslas. See also polar reversal.

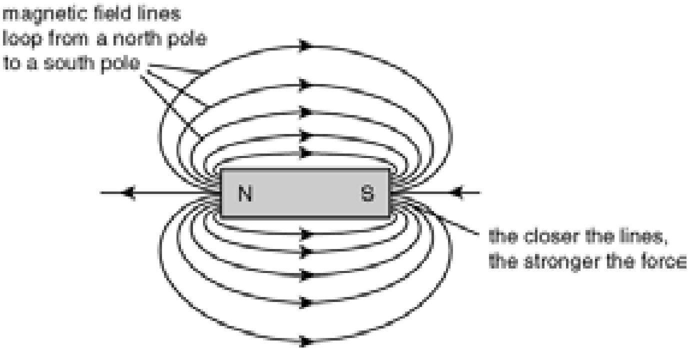
magnetic field



(Image © Research Machines plc)

The Earth's magnetic field is similar to that of a bar magnet with poles near, but not exactly at, the geographic poles. Compass needles align themselves with the magnetic field, which is horizontal near the equator and vertical at the magnetic poles.

magnetic field


magnetic field lines loop from a north pole to a south pole
N
S
the closer the lines, the stronger the force

(Image © Research Machines plc)

A magnet is an object that forms a magnetic field. It has a north pole and a south pole. As iron is a magnetic material, iron filings shaken around a magnet will form along the lines of force and produce the pattern of the magnetic field.

Electromagnetism

Go to site

Introduction to the theory of electromagnetism, explaining how and why it occurs, with reference to fundamental particles. There are graphics included to facilitate understanding.

Magnetic Fields and Mars

Go to site

In addition to covering magnetic fields and Mars, this site also includes a simple explanation of magnetism and how it occurs. It details different types of magnets, such as bar and horseshoe magnets. Comparisons between the Earth's magnetic field and those of other planets are also given, plus links for further exploration of the Earth's magnetosphere.

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magnetic flux

measurement of the strength of the magnetic field around electric currents and magnets. Its SI unit is the weber; one weber per square metre is equal to one tesla.

The amount of magnetic flux through an area equals the product of the area and the magnetic field strength at a point within that area.

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magnetic induction

production of magnetic properties in unmagnetized iron or other ferromagnetic material when it is brought close to a magnet. The material is influenced by the magnet's magnetic field. The magnetic lines of force pass through the material causing its particles to align themselves parallel to the lines of the magnetic field. The induced magnetism may be temporary, disappearing as soon as the magnet is removed, or permanent, depending on the nature of the material and the strength of the magnet.

Electromagnets make use of temporary induced magnetism to lift sheets of steel; the magnetism induced in the steel by the approach of the electromagnet enables it to be picked up and transported. To release the sheet, the current supplying the electromagnet is temporarily switched off and the induced magnetism disappears.

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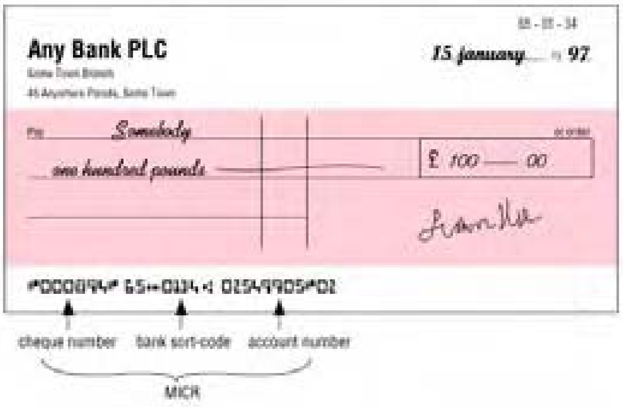
magnetic-ink character recognition

MICR

in computing, a technique that enables special characters printed in magnetic ink to be read and input rapidly to a computer. MICR is used extensively in banking because magnetic-ink characters can be machine-read with much greater accuracy than human reading or other optical character recognition (OCR) systems, and are therefore ideal for marking and identifying the account and sort code numbers on cheques.

magnetic-ink character recognition



(Image © Research Machines plc)

An example of one of the uses of magnetic ink in automatic character recognition. Because of the difficulties in forging magnetic-ink characters, and the speed with which they can be read by computer systems, MICR is used extensively in banking.

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magnetic material

one of a number of substances that are strongly attracted by magnets and can be magnetized. These include iron, nickel, and cobalt, and all those alloys that contain a proportion of these metals. Nonmagnetic materials are not attracted by magnets. These materials include paper, plastic, and rubber.

Magnetically soft materials can be magnetized very easily, but the magnetism induced in them (see magnetic induction) is only temporary. They include Stalloy, an alloy of iron with 4% silicon used to make the cores of electromagnets and transformers, and the materials used to make 'iron' nails and paper clips. Stroking a magnet over a steel pin from one end to the other will weakly magnetize the steel pin. This is because very large numbers of iron atoms (domains) of the steel become aligned in the same direction.

Magnetically hard materials can be permanently magnetized by a strong magnetic field. Steel and special alloys such as Alcomax, Alnico, and Ticonal, which contain various amounts of aluminium, nickel, cobalt, and copper, are used to make permanent magnets. The strongest permanent magnets are ceramic, made under high pressure and at high temperature from powders of various metal oxides. Iron is an example of a natural hard magnetic material. Its magnetic properties are due to its atomic structure. The electrons in the outer orbit of an iron atom behave as an electric charge and produce a strong magnetic field. In a magnetized piece of iron millions of individual iron atoms, called a domain, are aligned in the same direction. The domains have a north and a south pole.

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magnetic pole

region of a magnet in which its magnetic properties are strongest. Every magnet has two poles, called north and south. The north (or north-seeking) pole is so named because a freely-suspended magnet will turn so that this pole points towards the Earth's magnetic north pole. The north pole of one magnet will be attracted to the south pole of another, but will be repelled by its north pole. So unlike poles attract, like poles repel.

Magnetic North Pole

Go to site

Pages at the Woods Hole Oceanographic Institute providing a brief introduction to the attributes and behaviour of the magnetic poles. There are details of the institute's geomagnetic research and links to lots of other useful Web sites.

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magnetic resonance imaging

MRI

diagnostic scanning system based on the principles of nuclear magnetic resonance (NMR). MRI yields finely detailed three-dimensional images of structures within the body without exposing the patient to harmful radiation. The technique is invaluable for imaging the soft tissues of the body, in particular the brain and the spinal cord.

Claimed as the biggest breakthrough in diagnostic imaging since the discovery of X-rays, MRI is a noninvasive technique based on a magnet that is many thousands of times stronger than the Earth's magnetic field. It causes nuclei within the atoms of the body to align themselves in one direction. When a brief radio pulse is beamed at the body the nuclei spin, emitting weak radio signals as they realign themselves to the magnet. These signals, which are characteristic for each type of tissue, are converted electronically into images on a viewing screen.

Also developed around magnetic technology, **magnetic resonance spectroscopy (MRS)** is a technique for investigating conditions in which there is a disturbance of the body's energy metabolism, including ischaemia and toxic damage due to drugs or other chemicals. MRS is also of value in diagnosing some cancers.

magnetic storm

in meteorology, a sudden disturbance affecting the Earth's magnetic field, causing anomalies in radio transmissions and magnetic compasses. It is probably caused by sunspot activity.

magnetic strip

or magnetic stripe

thin strip of magnetic material attached to a plastic card and used for recording data. Magnetic strips are used on credit cards, bank cards (as used at cash dispensing machines), telephone cards, and railway tickets.

magnetic tape

narrow plastic ribbon coated with an easily magnetizable material on which data can be recorded. It is used in sound recording, audio-visual systems (videotape), and computing. For mass storage on commercial mainframe computers, large reel-to-reel tapes are still used, but cartridges are becoming popular. Various types of cartridge are now standard on minicomputers and PCs, while audio cassettes were used with early home computers.

Magnetic tape was first used in **sound recording** in 1947, and made overdubbing possible, unlike the direct-to-disc system it replaced. Two-track tape was introduced in the 1950s and four-track in the early 1960s; today, studios use 16-, 24-, or 32-track tape, from which the tracks are mixed down to a stereo master tape.

In computing, magnetic tape was first used to record data and programs in 1951 as part of the UNIVAC 1 system. It was very popular as a storage medium for external memory in the 1950s and 1960s. Since then it has been largely replaced by magnetic disks as a working medium, although tape is still used to make back-up copies of important data. Information is recorded on the tape in binary form, with two different strengths of signal representing 1 and 0.

magnetism

phenomena associated with magnetic fields. Magnetic fields are produced by moving charged particles. In electromagnets, electrons flow through a coil of wire connected to a battery; in permanent magnets, spinning electrons within the atoms generate the field.

Substances differ in the extent to which they can be magnetized by an external field (susceptibility). Materials that can be strongly magnetized, such as iron, cobalt, and nickel, are said to be **ferromagnetic**. This is due to the formation of areas called domains in which atoms, weakly magnetic because of their spinning electrons, align to form areas of strong magnetism. Magnetic materials lose their magnetism if heated to the Curie temperature. Most other materials are **paramagnetic**, being only weakly pulled towards a strong magnet. This is because their atoms have a low level of magnetism and do not form domains. **Diamagnetic** materials are weakly repelled by a magnet since electrons within their atoms act as electromagnets and oppose the applied magnetic force.
Antiferromagnetic materials have a very low susceptibility that increases with temperature; a similar phenomenon in materials such as ferrites is called **ferrimagnetism**.

application

Apart from its universal application in dynamos, electric motors, and switch gears, magnetism is of considerable importance in advanced technology – for example, in particle accelerators for nuclear research, memory stores for computers, tape recorders, and cryogenics.

Materials by Design: Magnetic Materials

Go to site

Short but effective page explaining why certain materials are magnetic, and how such materials can be used. Complete with complementary graphics, this site also provides links to other relevant topics, such as types of magnetism and the properties of other materials.

magnetite

black, strongly magnetic opaque mineral, Fe_3O_4, of the spinel group, an important ore of iron.

Widely distributed, magnetite is found in nearly all igneous and metamorphic rocks. Some deposits, called lodestone, are permanently magnetized. Lodestone has been used as a compass since the first millennium BC. Today the orientations of magnetite grains in rocks are used in the study of the Earth's magnetic field (see palaeomagnetism).

magneto

simple electric generator, often used to provide the electricity for the ignition system of motorcycles and used in early cars.

It consists of a rotating magnet that sets up an electric current in a coil, providing the spark.

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magnetohydrodynamics

MHD

field of science concerned with the behaviour of ionized gases or liquids in a magnetic field. Systems have been developed that use MHD to generate electrical power.

MHD-driven ships have been tested in Japan. In 1991 two cylindrical thrusters with electrodes and niobium-titanium superconducting coils, immersed in liquid helium, were placed under the passenger boat *Yamato 1*. The boat, 30 m/100 ft long, was designed to travel at 8 knots. An electric current passed through the electrodes accelerates water through the thrusters, like air through a jet engine, propelling the boat forward.

---

magnetometer

device for measuring the intensity and orientation of the magnetic field of a particular rock or of a certain area. In geology, magnetometers are used to determine the original orientation of a rock formation (or the orientation when the magnetic signature was locked in), which allows for past plate reconstruction. They are also used to delineate 'magnetic striping' on the sea floor in order to make plate reconstruction and to prospect for ore bodies such as iron ore, which can disrupt the local magnetic field.

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magnetosphere

volume of space, surrounding a planet, in which the planet's magnetic field has a significant influence. The Earth's magnetosphere extends 64,000 km/40,000 mi towards the Sun, but many times this distance on the side away from the Sun. That of Jupiter is much larger, and, if it were visible, would appear from the Earth to have roughly the same extent as the full Moon. The Russian-led space missions Coronas-I (launched in 1994) and Coronas-F (launched in 2001) were designed to investigate the magnetosphere of the Sun.

The Earth's magnetosphere is not symmetrical. The extension away from the Sun is called the **magnetotail**. The outer edge of the magnetosphere is the **magnetopause**. Beyond this is a turbulent region, the **magnetosheath**, where the solar wind is deflected around the magnetosphere. Inside the magnetosphere, atomic particles follow the Earth's lines of magnetic force. The magnetosphere contains the Van Allen radiation belts.

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magnetron

thermionic valve (electron tube) for generating very high-frequency oscillations, used in radar and to produce microwaves in a microwave oven. The flow of electrons from the tube's cathode to one or more anodes is controlled by an applied magnetic field.

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magnet therapy

in alternative medicine, use of applied magnetic fields to regulate potentially pathogenic disorders in the electrical charges of body cells and structures.

Physicians Hippocrates and Galen in the ancient world, Paracelsus in the Middle Ages, and more recently the founder of homeopathy, Samuel Hahnemann, practised magnet therapy. Today practitioners apply it as a stimulant of the body's self-healing processes, to enhance tissue repair and the healing of bone fractures, as an adjunct of structural therapies such as chiropractic, and as an alternative to needling in acupuncture.

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magnification

measure of the enlargement or reduction of an object in an imaging optical system.
Linear magnification is the ratio of the size (height) of the image to that of the object.
Angular magnification is the ratio of the angle subtended at the observer's eye by the image to the angle subtended by the object when viewed directly.

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magnitude

in astronomy, measure of the brightness of a star or other celestial object. The larger the number denoting the magnitude, the fainter the object. Zero or first magnitude indicates some of the brightest stars.

Still brighter are those of negative magnitude, such as Sirius, whose magnitude is -1.46. **Apparent magnitude** is the brightness of an object as seen from the Earth; **absolute magnitude** is the brightness at a standard distance of 10 parsecs (32.616 light years).

Each magnitude step is equal to a brightness difference of 2.512 times. Thus a star of magnitude 1 is $(2.512)^5$ or 100 times brighter than a sixth-magnitude star just visible to the naked eye. The apparent magnitude of the Sun is -26.8, its absolute magnitude +4.8.

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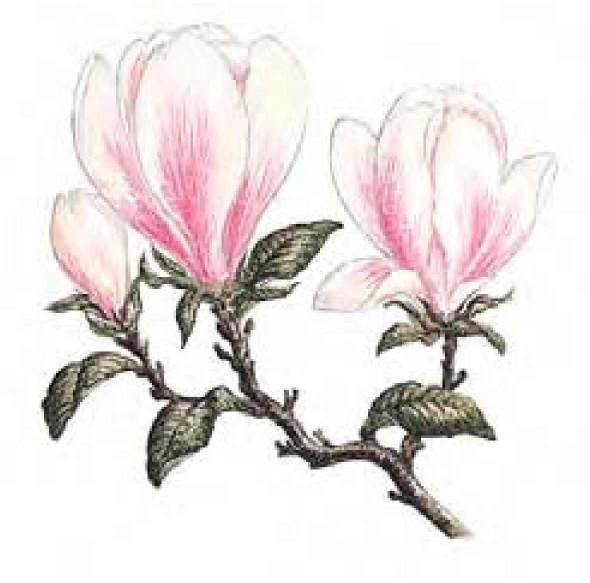
magnolia

any of a group of trees or shrubs belonging to the magnolia family, native to North America and East Asia, and cultivated as ornamentals. Magnolias vary in height from 60 cm/2 ft to 30 m/150 ft. The large, fragrant single flowers are white, pink, or purple. The southern magnolia (*M. grandiflora*) of the USA grows up to 24 m/80 ft tall and has white flowers 23 cm/9 in across. (Genus *Magnolia*, family Magnoliaceae.)

magnolia



(Image © Research Machines plc)

In the magnolia's large flowers, the sepals are often indistinguishable from the petals and leaves. The earliest flowering plants must have looked like these about 160 million years ago.

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magpie

any of various birds belonging to the crow family. They feed on insects, snails, young birds, and carrion, and are found in Europe, Asia, North Africa, and western North America. (Genus *Pica*, family Corvidae, order Passeriformes.)

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mahogany

timber from any of several trees found in the Americas and Africa. Mahogany is a tropical hardwood obtained chiefly by rainforest logging. It has a warm red colour and can be highly polished. True mahogany comes mainly from *S. mahagoni* and *S. macrophylla*, but other types come from the Spanish and Australian cedars, the Indian redwood, and other trees of the mahogany family, native to Africa and the East Indies. (True mahogany genus *Swietenia*, family Meliaceae.)

S. mahagoni is under threat due to its popularity in the West for use in musical instruments, furniture, and veneers. There are attempts to make it the first hardwood tree listed under the CITES convention (the Convention on International Trade in Endangered Species).

Maiden Castle

prehistoric hill fort with later additional earthworks 3 km/1.8 mi southwest of Dorchester in Dorset, England. The site was occupied from 4000 BC, although the first identifiable settlement is late Neolithic (New Stone Age, about 2000 BC). The fort was stormed by the Romans in AD 43.

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maidenhair

any of a group of ferns, especially *A. capillus-veneris*, with delicately hanging hairlike fronds ending in small kidney-shaped spore-bearing lobes. It is widely distributed in the Americas, and is sometimes found in the British Isles. (Genus *Adiantum*, family Polypodiaceae.)

maidenhair tree

another name for the ginkgo, a surviving member of an ancient group of plants.

mail merge

in computing, a feature offered by some word-processing packages that enables a list of personal details, such as names and addresses, to be combined with a general document outline to produce individualized documents.

For example, a club secretary might create a file containing a mailing list of the names and addresses of the club members. Whenever a letter is to be sent to all club members, a general letter outline is prepared with indications as to where individual names and addresses need to be added. The mail-merge feature then combines the file of names and addresses with the letter outline to produce and print individual letters addressed to each club member.

mainboard

new (and more politically correct) name for a motherboard.

mainframe

large computer used for commercial data processing and other large-scale operations. Because of the general increase in computing power, the differences between the mainframe, supercomputer, minicomputer, and microcomputer (personal computer) are becoming less marked.

Mainframe manufacturers include IBM, Amdahl, Fujitsu, and Hitachi. Typical mainframes have from 128 MB to 4 GB of memory and hundreds of gigabytes of disk storage. Their primary use is to conduct very fast transactions with a database and to be split into several independent partitions, each with its own operating system. A typical mainframe from IBM weighs between 1 and 2 tons.

main sequence

in astronomy, part of the Hertzsprung-Russell diagram that contains most of the stars, including the Sun. It runs diagonally from the top left of the diagram (hottest and brightest) to the bottom right(coolest and dimmest). The most massive (and hence the fastest-burning) stars are at the top left, with the least massive (slowest-burning) stars at the bottom right.

malabsorption syndrome

in medicine, a range of diseases that are characterized by impairment of absorption of essential nutrients from the gastrointestinal tract, for example coeliac disease and cystic fibrosis. Symptoms of malabsorption syndrome include anaemia, diarrhoea, and weight loss.

malachite

common copper ore, basic copper carbonate, $Cu_2CO_3(OH)_2$. It is a source of green pigment and is used as an antifungal agent in fish farming, as well as being polished for use in jewellery, ornaments, and art objects.

malaria

infectious parasitic disease of the tropics transmitted by mosquitoes, marked by periodic fever and an enlarged spleen. When a female mosquito of the *Anopheles* genus bites a human who has malaria, it takes in with the human blood one of four malaria protozoa of the genus *Plasmodium*. This matures within the insect and is then transferred when the mosquito bites a new victim. Malaria affects around 300-500 million people each year, in 103 countries, and in 1995 around 2.1 million people died of the disease. In sub-Saharan Africa alone between 1.5 and 2 million children die from malaria and its consequences each year. In November 1998, an agreement was reached to establish a multi-agency programme for research and control of the disease. The agencies involved include the World Health Organization (WHO), the World Bank, the United Nations Children's Fund, and the United Nations Development Programme. The Roll Back Malaria campaign aims to halve deaths from malaria by 2010.

infection

Inside the human body the parasite settles first in the liver, then multiplies to attack the red blood cells.

Within the red blood cells the parasites multiply, eventually causing the cells to rupture and other cells to become infected. The cell rupture tends to be synchronized, occurring every 2–3 days, when the symptoms of malaria become evident.

on the increase

Global warming is causing a worldwide increase in malaria. For example, in 1998 in Nairobi, where previously malaria cases had been limited to individuals who had travelled to lowland areas of Kenya, doctors were regularly reporting cases in people who had not left the city. In Irian Jaya, New Guinea, thousands of people who have never been exposed to malaria are now affected. According to a WHO report released in September 1999, cases of malaria in Europe rose from 2,882 in 1981 to 12,328 in 1997. African leaders met in Nigeria in April 2000 to discuss ways of fighting the disease, which was spreading across the continent, and, according to a WHO report, which had cost Africa £160 billion/$100 billion in productivity over the past 35 years.

treatment

Quinine, the first drug used against malaria, has now been replaced by synthetics, such as chloroquine, used to prevent or treat the disease. However, chloroquine-resistant strains of the main malaria parasite, *Plasmodium fulciparum*, are spreading rapidly in many parts of the world.

The drug mefloquine (Lariam) is widely prescribed for use in areas where chloroquine-resistant malaria prevails. It is surrounded by controversy, however, as it has been linked to unpleasant side effects, including psychiatric disturbances such as anxiety and hallucinations, epileptic seizures, and memory loss.

Another drug, artemether, derived from the shrub wormwood, was found in 1996 trials to be as effective as quinine in the treatment of cerebral malaria.

The insecticide DDT remains one of the most effective means of controlling malaria, and consequently is still used despite its persistence in the environment and subsequent danger to wildlife.

vaccine

An experimental malaria vaccine SPf66, developed by Colombian scientist Manuel Patarroyo, was trialled in 1994 in rural Tanzania, where villagers are bitten an average of 300 times a year by infected mosquitoes. It reduced the incidence of malaria by one third. However, further trials of SPf66 in the Gambia concluded that the vaccine provided only 8% protection for young children. A further trial in Thailand in 1996 failed to provide any evidence of its effectiveness. A new vaccine was successfully trialled in rabbits in 1999, with human trials anticipated in 2000. The vaccine attacks *Plasmodium falciparum*, the parasite that causes the symptoms of the disease, at each stage of the four main stages of its life cycle.

Malaria

Go to site

Page from the Malaria Foundation covering frequently asked questions on malaria. The Web site contains answers to a comprehensive list of questions regarding the disease, including thorough descriptions of the virus and its related diseases.

---

malic acid

or hydroxysuccinic acid; $HOOCCH_2CH(OH)COOH$

organic crystalline acid. It can be extracted from apples, plums, cherries, grapes, and other fruits, but occurs in most living cells in smaller amounts, being one of the intermediates of the Krebs cycle.

---

malignant hypertension

or accelerated hypertension

in medicine, very severe hypertension (high blood pressure) that can become fatal and requires urgent admission to hospital. It may develop in patients with untreated essential hypertension.

---

mallard

common wild duck from which domestic ducks were bred, found almost worldwide. The male can grow to a length of 60 cm/2 ft and usually has a glossy green head, white collar, and chestnut brown breast with a pale grey body, while the female is mottled brown. Mallards are omnivorous dabbling ducks. (Species *Anas platyrhynchos*, subfamily Anatinae, order Anseriformes.)

---

mallee

any of a group of small eucalyptus trees and shrubs with many small stems and thick underground roots that retain water. Before irrigation farming began, dense thickets of mallee characterized most of northwestern Victoria, Australia, known as the mallee region. (Genus *Eucalyptus*, family Myrtaceae.)

---

mallow

any plant of the family Malvaceae, especially the genus *Malva*, including the North American rose mallow *Hibiscus palustris* and the European marsh mallow *Althaea officinalis*. Most have showy pink or purple flowers. See also hollyhock, cotton, okra, hibiscus.

---

malnutrition

condition resulting from a defective diet where certain important food nutrients (such as proteins, vitamins, or carbohydrates) are absent. It can lead to deficiency diseases. A related problem is undernourishment. A high global death rate linked to malnutrition has arisen from famine situations caused by global warming, droughts, and the greenhouse effect, as well as by socio-political factors, such as alcohol and drug abuse, poverty, and war.

In 1998 there was an estimated 180 million malnourished children in the world and malnutrition contributed to 6 million deaths annually, mainly among children.

---

malt

in brewing, grain (barley, oats, or wheat) artificially germinated and then dried in a kiln. Malts are fermented to make beers or lagers, or fermented and then distilled to produce spirits such as whisky.

---

maltase

enzyme found in plants and animals that breaks down the disaccharide maltose into glucose.

Maltese dog

breed of long-coated lap dog. Its white coat is straight and silky and parted from head to tail and the short tail is doubled into the coat on the back. Maltese dogs have dark eyes, long drooping ears, and small feet. The ideal maximum height is 25 cm/10 in, and the weight is 3-4 kg/6.5-9 lb.

Maltese dogs are the most ancient lap-dog breed, their characteristics having been preserved for over 2,000 years.

---

maltose

$C_{12}H_{22}O_{11}$

disaccharide sugar in which both monosaccharide units are glucose.

It is produced by the enzymic hydrolysis of starch and is a major constituent of malt, produced in the early stages of beer and whisky manufacture.

---

mamba

either of two venomous snakes belonging to the cobra family, found in Africa south of the Sahara. Unlike cobras, they are not hooded. (Genus *Dendroaspis*, family Elapidae.)

The **green mamba** (*D. angusticeps*) is 1.5 m/5 ft long or more and lives in trees, feeding on birds and lizards. The **black mamba** (*D. polylepis*) is the largest venomous snake in Africa, occasionally as long as 3.4 m/11 ft, and spends more time on the ground.

---

mammal

any of a large group of warm-blooded vertebrate animals characterized by having mammary glands in the female; these are used for suckling the young. Other features of mammals are hair (very reduced in some species, such as whales); a middle ear formed of three small bones (ossicles); a lower jaw consisting of two bones only; seven vertebrae in the neck; and no nucleus in the red blood cells. (Class Mammalia.)

Mammals are divided into three groups:

placental mammals, where the young develop inside the mother's body, in the uterus, receiving nourishment from the blood of the mother via the placenta;

marsupials, where the young are born at an early stage of development and develop further in a pouch on the mother's body where they are attached to and fed from a nipple; and

monotremes, where the young hatch from an egg outside the mother's body and are then nourished with milk.

The monotremes are the least evolved and have been largely displaced by more sophisticated marsupials and placentals, so that there are only a few types surviving (platypus and echidna). Placentals have spread to all parts of the globe, and where placentals have competed with marsupials, the placentals have in general displaced marsupial types. However, marsupials occupy many specialized niches in South America and, especially, Australasia.

According to the Red List of endangered species published by the World Conservation Union for 1996, 25% of mammal species are threatened with extinction.

The theory that marsupials succeed only where they do not compete with placentals was shaken in 1992, when a tooth, 55 million years old and belonging to a placental mammal, was found in Murgon, Australia, indicating that placental animals appeared in Australia at the same time as the marsupials. The marsupials, however, still prevailed.

There are over 4,000 species of mammals, adapted to almost every way of life. The smallest shrew weighs only 2 g/0.07 oz, the largest whale up to 140 tonnes. A 50-million-year-old jaw discovered in 1998 is from the smallest mammal ever to have lived, *Batodonoides*, an insectivore weighing only 1.3 g/0.046 oz.

mammal: monogamy

Less than 3% of mammals are monogamous. Where monogamy is the norm, females usually synchronize their breeding as an extra precaution.

Classification of mammals

Order	Number of species	Examples
Leading class: Mammalia		
Subclass: Prototheria (egg-laying mammals)		
Monotremata	3	echidna, platypus
Subclass: Theria		
Infraclass: Metatheria (pouched mammals)		
Marsupiala	266	kangaroo, koala, opossum
Infraclass: Eutheria (placental mammals)		
Rodentia	1,700	rat, mouse, squirrel, porcupine
Chiroptera	970	all bats
Insectivora	378	shrew, hedgehog, mole
Carnivora	230	cat, dog, weasel, bear
Primates	180	lemur, monkey, ape, human
Artiodactyla	145	pig, deer, cattle, camel, giraffe
Cetacea	79	whale, dolphin
Lagomorpha	58	rabbit, hare, pika
Pinnipedia	33	seal, walrus
Edentata	29	anteater, armadillo, sloth
Perissodactyla	16	horse, rhinoceros, tapir
Hyracoidea	11	hyrax
Pholidota	7	pangolin
Sirenia	4	dugong, manatee
Dermoptera	2	flying lemur
Proboscidea	2	elephant
Tubulidentata	1	aardvark

---

mammary gland

in female mammals, a milk-producing gland derived from epithelial cells underlying the skin, active only after the production of young. In all but monotremes (egg-laying mammals), the mammary glands terminate in teats which aid infant suckling. The number of glands and their position vary between species. In humans there are 2, in cows 4, and in pigs between 10 and 14.

The hatched young of monotremes (egg-laying mammals) simply lick milk from a specialized area of skin on the mother's abdomen.

---

mammography

X-ray procedure used to screen for breast cancer. It can detect abnormal growths at an early stage, before they can be seen or felt. It is most effective for screening women over 35, as breast tissue is too dense in younger women.

mammoth

extinct elephant, remains of which have been found worldwide. Some were 50% taller than modern elephants; others were much smaller. (Genus *Mammuthus* (or **Elephas**).)

The **woolly mammoth** (*M. primigenius*) of northern zones, the size of an Indian elephant, had long fur and large inward-curving tusks. Various species of mammoth were abundant in both the Old World and the New World in Pleistocene times, and were hunted by humans for food.

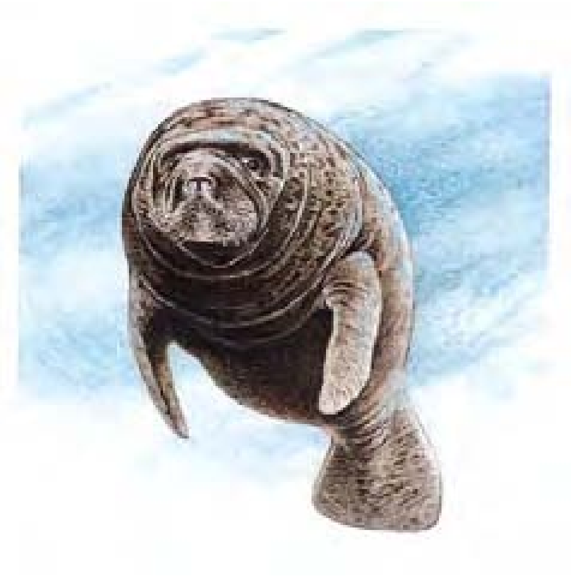
---

manatee

any of a group of plant-eating aquatic mammals found in marine bays and sluggish rivers, usually in thick, muddy water. They have flippers as forelimbs, no hindlimbs, and a short rounded and flattened tail used for swimming. The marine manatees can grow up to about 4.5 m/15 ft long and weigh up to 600 kg/1,323 lb. (Genus *Trichechus*, family Trichechidae, order Sirenia.)

All three species of manatee are in danger of becoming extinct as a result of pollution and because they are hunted for food. They are the **Amazonian manatee** (*T. Inunguis*), found in the River Amazon; the **African manatee** (*T. Senegalensis*), which lives in the rivers and coastal areas of West Africa; and the **West Indian manatee** (*T. manatus*), which lives in the Caribbean Sea and along the east coasts of tropical North and South America. Only about 2,400 West Indian manatees remain in the main population around Florida; more than 200 died in 1996, poisoned by an algal toxin.

manatee



(Image © Research Machines plc)

Manatees, dugongs, and sea-cows are plant-eating, aquatic mammals that belong to the order Sirenia. It has been suggested that mis-sightings of these animals gave rise to the tails of mermaids. There are three species of manatee; two inhabit the estuaries and coastal waters of the Americas while the other is found off the West African coast.

Save the Manatee Club

Go to site

Good source of information about the three species of manatee, with particular emphasis on the West Indian. The habitat, behaviour, and reproductive habits of the aquatic herbivore are well described with readable text and pictures. There is a guide on where to see manatees in the wild and reports on conservation efforts in Florida and elsewhere.

Manchester terrier

breed of smooth-haired black-and-tan terrier. Manchester terriers have a long, wedge-shaped head, small dark eyes, and V-shaped ears, hanging close to the head. The usual weight is 8 kg/17.5 lb and the height 38-41 cm/15-16 in.

The breed has a long neck tapering from the sloping shoulders to the head, and a narrow and deep chest. The legs are quite straight and the tail is thick where it joins the body, tapering to a point. The glossy coat should be jet black and rich mahogany tan on the head; the muzzle should be tanned to the nose, which, with the nasal bone, is jet black; the forelegs should be half tanned and the hind legs tanned on the inside, but not on the outside.

The earliest recognizable Manchester terrier is portrayed in an illuminated manuscript book of hours of the 15th century. It is generally accepted that the pure breed had its origin in and around Manchester, England.

---

mandarin

type of small orange.

Mandelbrot, Benoit B (1924-)

Polish-born French mathematician who coined the term **fractal** to describe geometrical figures in which an identical motif repeats itself on an ever-diminishing scale. The concept is associated with chaos theory.

Another way of describing a fractal is as a curve or surface generated by the repeated subdivision of a mathematical pattern.

Mandelbrot, Benoit

Go to site

Devoted to the life and contributions of Benoit Mandelbrot. In addition to biographical information, you will find a list of references about Mandelbrot and links to other essays that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Mandelbrot. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

---

mandragora

or mandrake

any of a group of almost stemless Old World plants with narcotic (pain-killing and sleep-inducing) properties, belonging to the nightshade family. They have large leaves, pale blue or violet flowers, and round berries known as devil's apples. (Genus *Mandragora*, family Solanaceae.)

The humanlike shape of the root of *M. officinarum* gave rise to the superstition that it shrieks when pulled from the ground.

---

mandrake

another name for the plant mandragora.

---

mandrill

large West African forest-living baboon, active mainly on the ground. It has large canine teeth like the drill (*M. leucophaeus*), to which it is closely related. The nose is bright red and the cheeks are striped with blue; the thick skin of the buttocks is also red, and the fur is brown, apart from a yellow beard. (Species *Mandrillus sphinx*.)

Males are much larger than females, showing greater sexual dimorphism than any other primate. Males weigh up to 35 kg/77 lb and females usually less than 12 kg/26 lb. Females exhibit none of the bright coloration of the male. A single infant is born after 5 months' gestation; it is weaned at 6 months. Females reach sexual maturity at about three years; males at around ten years.

mandrill

The splendidly-coloured male mandrill is nearly three times heavier than his drab mate. No other primate exhibits such marked differences between the sexes. Females mature at about the age of three, whereas males may not reach maturity for ten years.

---

manganese

chemical symbol Mn

hard, brittle, grey-white metallic element, atomic number 25, relative atomic mass 54.9380. It resembles iron (and rusts), but it is not magnetic and is softer. It is used chiefly in making steel alloys, also alloys with aluminium and copper. It is used in fertilizers, paints, and industrial chemicals. It is a necessary trace element in human nutrition. The name is old, deriving from the French and Latin forms of Magnesia, a mineral-rich region of Italy.

In addition to acting as a bivalent metal forming salts and alloys, manganese also forms the permanganate anion (MnO_4^-), which can be used in analytical titration, serving as a reactant and as a colour indicator at the same time.

---

manganese ore

any mineral from which manganese is produced. The main ores are the oxides, such as **pyrolusite**, MnO_2; **hausmannite**, Mn_3O_4; and **manganite**, MnO(OH).

Manganese ores may accumulate in metamorphic rocks or as sedimentary deposits, frequently forming nodules on the sea floor (since the 1970s many schemes have been put forward to harvest deep-sea manganese nodules). The world's main producers are Georgia, Ukraine, South Africa, Brazil, Gabon, and India.

---

manganese(IV) oxide

or manganese dioxide; MnO_2

brown solid that acts as a depolarizer in dry batteries by oxidizing the hydrogen gas produced to water; without this process, the performance of the battery is impaired.

It acts as a catalyst in decomposing hydrogen peroxide to obtain oxygen:

$$2H_2O_{2\ (aq)} \rightarrow 2H_2O_{\ (l)} + O_{2\ (g)}$$

It oxidizes concentrated hydrochloric acid to produce chlorine:.

$$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$$

---

mangelwurzel

or mangold

variety of the common beet *Beta vulgaris* used chiefly as feed for cattle and sheep.

---

mango

evergreen tree belonging to the cashew family, native to India but now widely cultivated for its large oval fruits in other tropical and subtropical areas, such as the West Indies. (*Mangifera indica*, family Anacardiaceae.)

---

mangrove

any of several shrubs and trees, especially of the mangrove family, found in the muddy swamps of tropical and subtropical coastlines and estuaries. By sending down aerial roots from their branches, they rapidly form close-growing mangrove thickets. Their timber is resistant to water penetration and damage by marine worms. Mangrove swamps are rich breeding grounds for fish and shellfish, but these habitats are being destroyed in many countries. (Genera *Rhizophora* and *Avicennia*, families Rhizophoraceae (mangrove) and Avicenniaceae (related).)

---

mania

in psychiatry, term used to describe high mood. The affected individual can appear cheerful and optimistic or irritable and angry. Sleep is reduced and the sufferer can be overactive to the point of physical exhaustion. Speech is rapid and can convey grandiose delusions. Mania often occurs as part of manic depression. It is treated with an antipsychotic drug to control the mood and, in the long term, with lithium.

---

manic depression

or bipolar disorder

mental disorder characterized by recurring periods of either depression or mania (inappropriate elation, agitation, and rapid thought and speech) or both. Sufferers may be genetically predisposed to the condition. Some cases have been improved by taking prescribed doses of lithium.

Some manic-depressive patients have only manic attacks, others only depressive, and in others the alternating, or circular, form exists. The episodes may be of varying severity, from mild to psychotic (when the patient loses touch with reality and may experience hallucinations), and sometimes continue for years without interruption.

Depression Central

Go to site

Jumping-off point for information on all types of depressive disorders and on their most effective treatment. This site is divided into many useful sections, including 'Bipolar disorder', 'Depression in the elderly', and 'Electroconvulsive therapy'.

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manioc

another name for the plant cassava.

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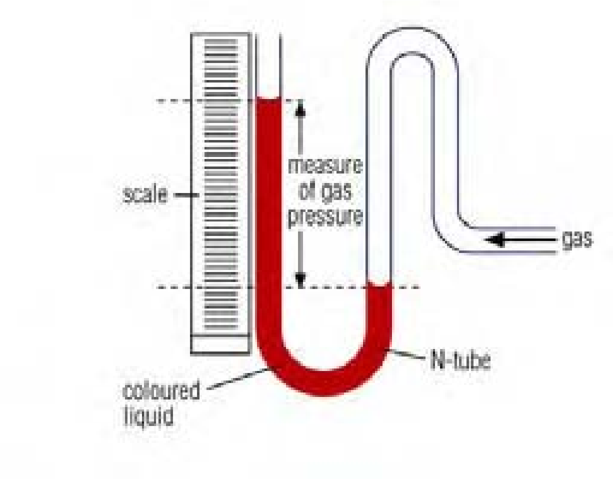
manometer

instrument for measuring the pressure of liquids (including human blood pressure) or gases. In its basic form, it is a U-tube partly filled with coloured liquid. Greater pressure on the liquid surface in one arm will force the level of the liquid in the other arm to rise. A difference between the pressures in the two arms is therefore registered as a difference in the heights of the liquid in the arms.

manometer



(Image © Research Machines plc)

The manometer indicates gas pressure by the rise of liquid in the tube.

Man Ray

US photographer, painter, and sculptor; see Man Ray.

Manson, Patrick (1844-1922)

Scottish physician who showed that insects are responsible for the spread of diseases like elephantiasis and malaria. He was knighted in 1903.

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manta

another name for the devil ray, a large fish.

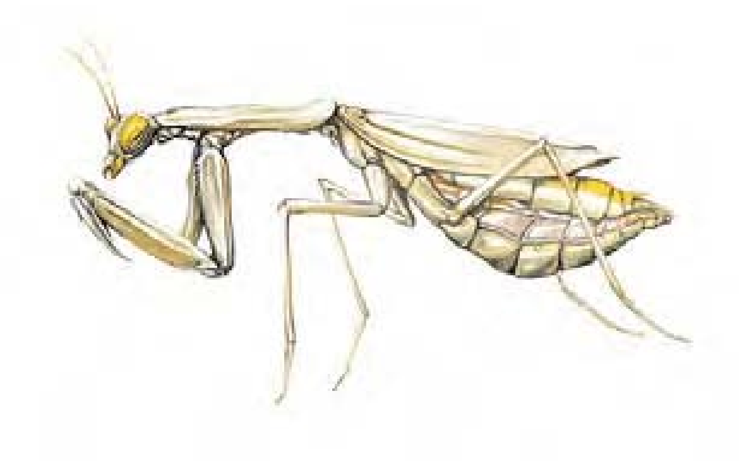
---

mantis

any of a group of carnivorous insects related to cockroaches. There are about 2,000 species of mantis, mainly tropical; some can reach a length of 20 cm/8 in. (Family Mantidae, order Dictyoptera.)

Mantises are often called 'praying mantises' because of the way they hold their front legs, adapted for grasping prey, when at rest. The eggs are laid in September and hatch early the following summer.

mantis



(Image © Research Machines plc)

The praying mantis is a superbly designed predator. It waits motionless or slightly swaying as if in a breeze until prey appears. Many species are effectively camouflaged to look like dead leaves. The female mantis is notorious for eating its mate during copulation (although this behaviour is relatively uncommon).

Praying Mantis

Go to site

Description of the carnivorous praying mantids (or Mantis) with information on their taxonomy, habitat, breeding habits, diet and peculiar characteristics; notably their uncanny use of camouflage to hide from predators and seduce prey. This illustrated site also includes information on a number of other insects and contains feature articles on some more quirky aspects of insect behaviour.

---

mantissa

in mathematics, the decimal part of a logarithm. For example, the logarithm of 347.6 is 2.5411; in this case, the 0.5411 is the mantissa, and the integral (whole number) part of the logarithm, the 2, is the characteristic.

---

mantle

intermediate zone of the Earth between the crust and the core, accounting for 82% of the Earth's volume. The crust, made up of separate tectonic plates, floats on the mantle which is made of dark semi-liquid rock that is rich in magnesium and silicon. The temperature of the mantle can be as high as 3,700°C/6,692°F. Heat generated in the core causes convection currents in the semi-liquid mantle; rock rises and then slowly sinks again as it cools, causing the movements of the tectonic plates. The boundary (junction) between the mantle and the crust is called the Mohorovicic discontinuity, which lies at an average depth of 32 km/20 mi. The boundary between the mantle and the core is called the Gutenburg discontinuity, and lies at an average depth of 2,900 km/1,813 mi.

The mantle is subdivided into **upper mantle**, **transition zone**, and **lower mantle**, based upon the different velocities with which seismic waves travel through these regions. The upper mantle includes a zone characterized by low velocities of seismic waves, called the **low-velocity zone**, at 72 km/45 mi to 250 km/155 mi depth. This zone corresponds to the asthenosphere upon which the Earth's lithospheric plates glide. Seismic velocities in the upper mantle are overall less than those in the transition zone, and those of the transition zone are in turn less than those of the lower mantle. Faster propagation of seismic waves in the lower mantle implies that the lower mantle is more dense than the upper mantle.

The mantle is composed primarily of magnesium, silicon, and oxygen in the form of silicate minerals. In the upper mantle, the silicon in silicate minerals, such as olivine, is surrounded by four oxygen atoms. Deeper in the transition zone greater pressures promote denser packing of oxygen such that some silicon is surrounded by six oxygen atoms, resulting in magnesium silicates with garnet and pyroxene structures. Deeper still, all silicon is surrounded by six oxygen atoms so that the mineral perovskite $MgSiO_3$ predominates.

---

map

diagrammatic representation of an area, for example part of the Earth's surface or the distribution of the stars. Modern maps of the Earth are made using satellites in low orbit to take a series of overlapping stereoscopic photographs from which a three-dimensional image can be prepared. The earliest accurate large-scale maps appeared about 1580 (see atlas).

Conventional aerial photography, laser beams, microwaves, and infrared equipment are also used for land surveying. Many different kinds of map projection (the means by which a three-dimensional body is shown in two dimensions) are used in map-making. Detailed maps requiring constant updating are kept in digital form on computer so that minor revisions can be made without redrafting.

Atlapedia

Go to site

Database of maps that allows the user to view a detailed political or physical map for almost any country in the world. Also included on this site are detailed facts about each of the countries.

Bodleian Library Map Room - The Map Case

Go to site

Broad selection of images from the historical map collection of the Bodleian library. Visitors can choose between rare maps of Oxfordshire, London, areas of Britain, New England, Canada and more. The maps can be viewed by thumbnail and then enlarged and downloaded in GIF format.

Graphic Map's World Atlas and Geography Facts

Go to site

Essential reference tool for geography students or anyone else interested in learning about the world. Presented as a gazetteer with facts and images, the site contains detailed maps for every country, island, territory, major island, lake, river, and mountain, together with its latitude and longitude, national flag, population, languages, international disputes, environment, and much more. There is a complete list of every country with its capital city, and even links to other sites focussing on the individual countries and cities.

History of Cartography

Go to site

A comprehensive directory of links to information on early mapping, including images, collections, and related projects available to view on the Web.

Mapquest

Go to site

Features interactive maps of more than 3 million cities worldwide. You can track down businesses and landmarks in Europe and zoom in on street maps. If you've lost your way, 'TripQuest' provides door-to-door driving directions.

Map Quiz Tutorial: Physical Geography

Go to site

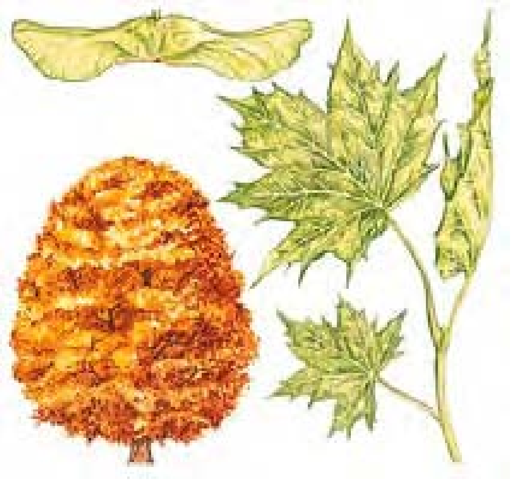
Interactive site that invites you to locate specific features on a physical map of the world. The answer frame at the bottom of the page tells you if you were correct.

---

maple

any of a group of deciduous trees with lobed leaves and green flowers, followed by two-winged fruits, or samaras. There are over 200 species, chiefly in northern temperate regions. (Genus *Acer*, family Aceraceae.)

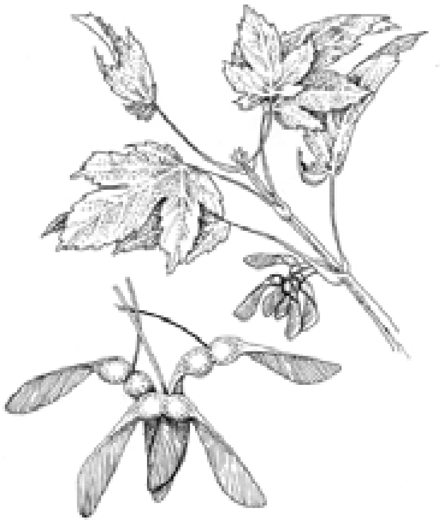
maple



(Image © Research Machines plc)

Maples are typically deciduous with lobed leaves and winged fruit, or keys. They grow throughout the north temperate regions of the world. The leaves are often strikingly coloured in the autumn.

maple



(Image © Research Machines plc)

Silver maple (*Acer saccharinum*), also known as the soft maple or white maple. The silver maple is one of 110 species of maple. Native to eastern North America, it has a short thick trunk and broad crown. The leaves of the silver maple are light green on top and silvery below, and the distinctive winged fruit is the largest of any maple.

maple

(Image © Photodisk)

The veins of a maple (*Acer*) leaf. As in most plants, the leaf is the primary food-manufacturing organ of the maple. The veins act as a skeletal structure and transport materials to and from the leaf tissue. In the autumn, the green chlorophyll breaks down, revealing the striking yellow, orange, and red pigments in the leaf.

Mapplethorpe, Robert (1946-1989)

US art photographer. He was known for his use of racial and homo-erotic imagery in chiefly fine platinum prints. He developed a style of polished elegance in his gallery art works, whose often culturally forbidden subject matter caused controversy.

---

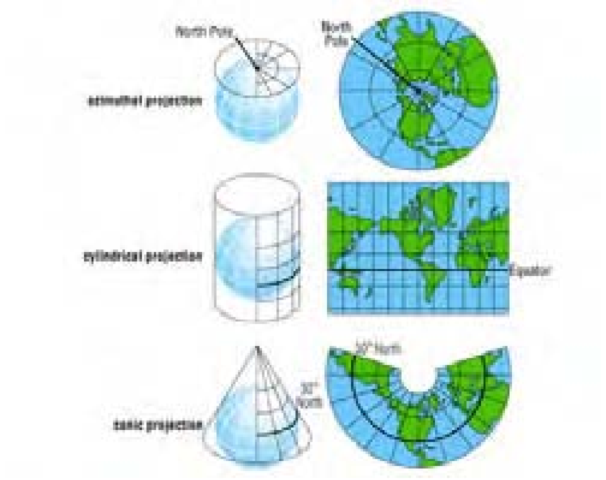
map projection

way of showing the Earth's spherical surface on a flat piece of paper. The most common approach has been to redraw the Earth's surface within a rectangular boundary. The main weakness of this is that countries in high latitudes are shown disproportionately large. The most famous cylindrical projection is the Mercator projection, which dates from 1569. Although it gives an exaggerated view of the size of northern continents, it is the best map for navigation because a constant bearing appears as a straight line.

In 1973 German historian Arno Peters devised the **Peters projection** in which the countries of the world retain their relative areas. In other projections, lines of longitude and latitude appear distorted, or the Earth's surface is shown as a series of segments joined along the Equator. In 1992 the US physicist Mitchell Feigenbaum devised the **optimal conformal** projection, using a computer program designed to take data about the boundary of a given area and calculate the projection that produces the minimum of inaccuracies.

The theory behind traditional map projection is that, if a light were placed at the centre of a transparent Earth, the surface features could be thrown as shadows on a piece of paper close to the surface. This paper may be flat and placed on a pole (azimuthal or zenithal), or may be rolled around the Equator (cylindrical), or may be in the form of a tall cone resting on the Equator (conical). The resulting maps differ from one another, distorting either area or direction, and each is suitable for a particular purpose. For example, projections distorting area the least are used for distribution maps, and those with least distortion of direction are used for navigation charts.

map projection



(Image © Research Machines plc)

Three widely used map projections. If a light were placed at the centre of a transparent Earth, the shapes of the countries would be thrown as shadows on a sheet of paper. If the paper is flat, the azimuthal projection results; if it is wrapped around a cylinder or in the form of a cone, the cylindrical or conic projections result.

---

maquis

general term for a largely evergreen type of vegetation common in many Mediterranean countries, consisting of scrub woodland with many low-growing tangled bushes and shrubs, typically including species of broom, gorse, and heather.

---

marabou

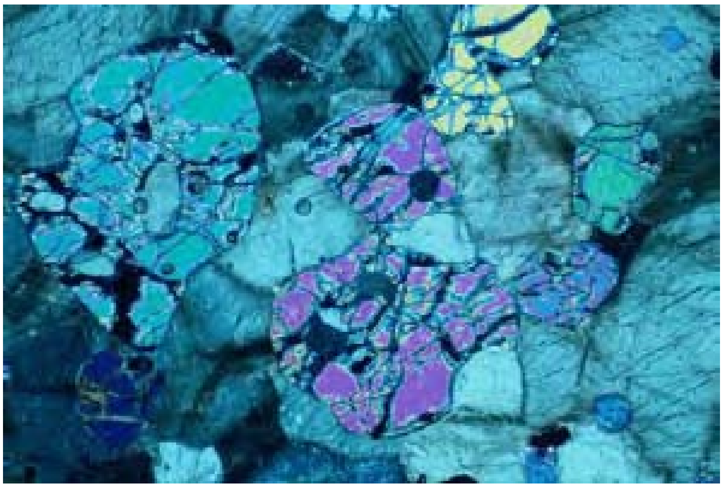
African stork, about 120 cm/4 ft tall, with a bald head, long heavy bill, black back and wings and white underparts, and an inflatable throat pouch. It eats snakes, lizards, insects, and carrion. The bald head avoids blood clogging the plumage when the stork feeds on carcasses left by predators such as lions. (Species *Leptoptilos crumeniferus*, family Ciconiidae, order Ciconiiformes.)

---

marble

rock formed by metamorphosis of sedimentary limestone. It takes and retains a good polish, and is used in building and sculpture. In its pure form it is white and consists almost entirely of calcite ($CaCO_3$). Mineral impurities give it various colours and patterns. Carrara, Italy, is known for white marble.

marble



(Image © Corel)

Marble through a polarized microscope. The coloured markings are caused by mineral impurities.

Marburg disease

or green monkey disease

viral disease of central Africa, first occurring in Europe 1967 among research workers in Germany working with African green monkeys. Caused by a filovirus, it is characterized by haemorrhage of the mucous membranes, fever, vomiting, headache, and diarrhoea; mortality is high. It is a haemorrhagic fever similar to Ebola virus disease.

An outbreak of Marburg disease in the Democratic Republic of Congo killed 52 miners in 1999. Bats were believed to be the vectors for the disease.

Marconi, Guglielmo (1874-1937)

Italian electrical engineer and pioneer in the invention and development of radio. In 1895 he achieved radio communication over more than a mile, and in England in 1896 he conducted successful experiments that led to the formation of the company that became Marconi's Wireless Telegraph Company Ltd. He shared the Nobel Prize for Physics in 1909 for the development of wireless telegraphy.

After reading about radio waves, Marconi built a device to transmit these electromagnetic waves and receive them as electrical signals. He then tried to transmit and receive radio waves over increasing distances. In 1898 he successfully transmitted signals across the English Channel, and in 1901 established communication with St John's, Newfoundland, from Poldhu in Cornwall, and in 1918 with Australia.

Marconi

(Image © Research Machines plc)

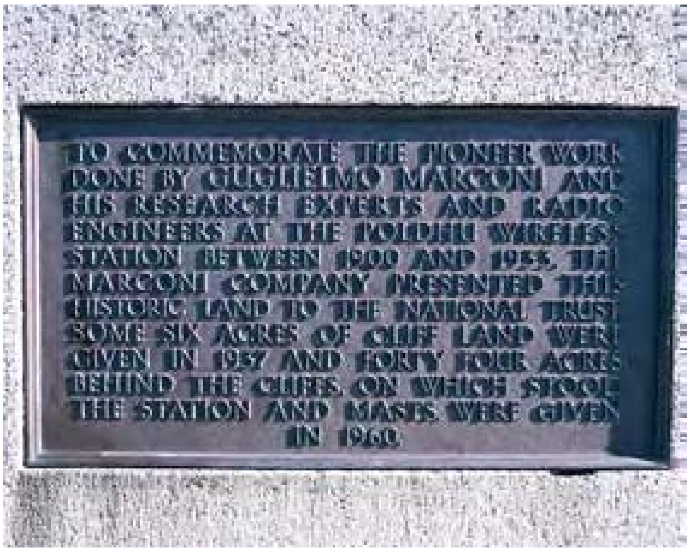
The bungalow at Lizard Point in Cornwall where the Italian inventor Guglielmo Marconi (1874-1937) lived around 1900. Just along the coast is the site of the Poldhu Wireless Station from where, on 12 December 1901, Marconi transmitted the first radio signal, a letter 'S,' across the Atlantic to St John's in Nova Scotia.

Marconi

(Image © Billie Love)

The Italian pioneer of radio telegraphy Guglielmo Marconi, speaking from his 700-ton yacht, *Elettra* in Genoa, Italy, to an audience in Sydney, Australia. The yacht, purchased in 1919, was converted into a floating laboratory where he tested short-wave reception and transmission. By the end of the 1920s he had set up a worldwide system of short-wave stations.

Marconi



TO COMMEMORATE THE PIONEER WORK
DONE BY GUGLIELMO MARCONI AND
HIS RESEARCH EXPERTS AND RADIO
ENGINEERS AT THE POLDHU WIRELESS
STATION BETWEEN 1900 AND 1933, THE
MARCONI COMPANY PRESENTED THIS
HISTORIC LAND TO THE NATIONAL TRUST
SOME SIX ACRES OF CLIFF LAND WERE
GIVEN IN 1937 AND FORTY FOUR ACRES
BEHIND THE CLIFFS, ON WHICH STOOD
THE STATION AND MASTS WERE GIVEN
IN 1960.

(Image © Research Machines plc)

A plaque commemorating the work of the Italian inventor Guglielmo Marconi (1874-1937) at the Poldhu Wireless Station, near Lizard Point in Cornwall. Lizard Point is the most southerly point on mainland Britain.

Biography of G Marconi

Go to site

Presentation of the life and discoveries of Guglielmo Marconi. The site includes sections on his early years and education, and the many patents that he established in the course of his scientific career. Central emphasis is of course given to his development of wireless telegraphy, from the first attempt to send a signal one and a half miles away, up to his successful wireless transmission across the Atlantic in 1901.

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mare

plural maria

dark lowland plain on the Moon. The name comes from the Latin word for 'sea', because these areas were once wrongly thought to be water.

---

margay

small wild cat living in forested areas from the southern USA to South America, where it hunts birds and small mammals. It is about 60 cm/2 ft long with a 40 cm/1.3 ft tail, and has a rounded head and yellowish-brown fur marked with black spots and blotches. (Species *Felis wiedi*, family Felidae.)

---

marginal land

in farming, poor-quality land that is likely to yield a poor return. It is the last land to be brought into production and the first land to be abandoned. Examples are desert fringes in Africa and mountain areas in the UK.

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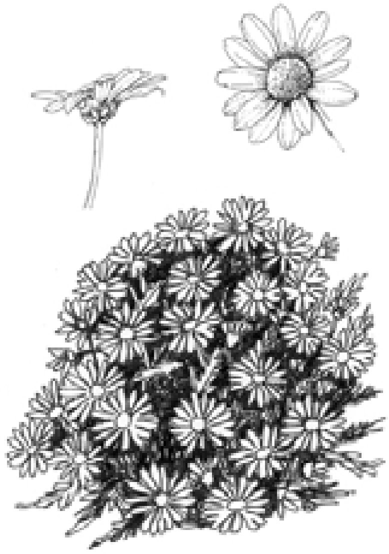
marguerite

European plant belonging to the daisy family. It is a shrubby perennial with white daisylike flowers. Marguerite is also the name of a cultivated variety of chrysanthemum. (*Leucanthemum vulgare*, family Compositae.)

marguerite



(Image © Research Machines plc)

Marguerite (*Argyranthemum frutescens*), also known as the Paris daisy or Boston daisy, or chrysanthemum grandiflorum. The marguerite is a short, bushy perennial, popular in gardens and as cut flowers. It grows up to 90 cm/35 in tall and its daisylike flowers bloom throughout the summer.

Mariana Trench

lowest region on the Earth's surface; the deepest part of the sea floor. The trench is 2,400 km/1,500 mi long and is situated 300 km/200 mi east of the Mariana Islands, in the northwestern Pacific Ocean. Its deepest part is the gorge known as the Challenger Deep, which extends 11,034 m/36,210 ft below sea level.

Mariana Trench

A column of 10,000 tonnes of sea water presses down on every square metre of the ocean floor in the Mariana Trench.

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marigold

any of several plants belonging to the daisy family, including pot marigold (*C. officinalis*) and the tropical American *T. patula*, commonly known as French marigold. (Genera *Calendula* and *Tagetes*, family Compositae.)

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marijuana

dried leaves and flowers of the hemp plant cannabis, used as a drug; it is illegal in most countries. It is eaten or inhaled and causes euphoria, distortion of time, and heightened sensations of sight and sound. Mexico is the world's largest producer.

Mariner

series of US space probes that explored the planets Mercury, Venus, and Mars 1962-75.

Mariner 1 (to Venus) had a failed launch. Mariner 2 (1962) made the first fly-by of Venus, at 34,000 km/21,000 mi, confirmed the existence of solar wind, and measured Venusian temperature. Mariner 3 (launched 4 November 1964) did not achieve its intended trajectory to Mars. Mariner 4 (launched 25 November 1964) passed Mars at a distance of 9,800 km/6,100 mi, and took photographs revealing a dry, cratered surface. Mariner 5 (1967) passed Venus at 4,000 km/2,500 mi and measured Venusian temperature, atmosphere, mass, and diameter. Mariner 6 and Mariner 7 (1969) photographed Mars's equator and southern hemisphere respectively, and also measured temperature, atmospheric pressure and composition, and diameter. Mariner 8 (to Mars, in 1971) had a failed launch. Mariner 9 (1971) mapped the entire Martian surface, and photographed Mars's moons. Its photographs revealed the changing of the polar caps, and the extent of volcanism, canyons, and features, which suggested that there might once have been water on Mars. Mariner 10 (1974-75) took close-up photographs of Mercury and Venus, and measured temperature, radiation, and magnetic fields.

Mariner

(Image © NASA)

The Mariner 1 spacecraft bound for Venus is launched atop an Atlas-Agena 5 rocket from Cape Kennedy, in 1962. Unfortunately the spacecraft had to be destroyed by the range safety officer when it veered off course.

Mariner Mars Missions

Go to site

Profiling the Mariner 4, Mariner 6, Mariner 7, and Mariner 9 missions to Mars. The site includes introductory text, technical information about the spacecraft and their experiments, and access to the Mariner imagery.

Mariotte, Edme (1620-1684)

French physicist and priest known for his recognition in 1676 of Boyle's law about the inverse relationship of volume and pressure in gases, formulated by Irish physicist Robert Boyle in 1672. He had earlier, in 1660, discovered the eye's blind spot.

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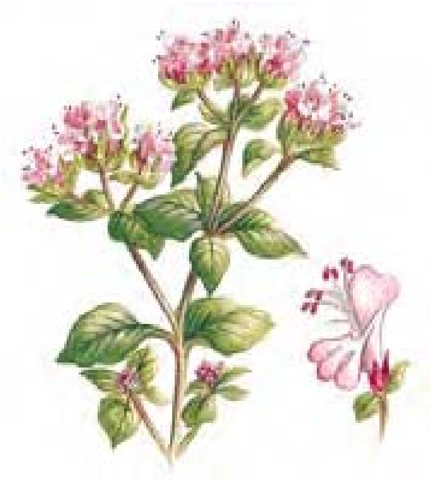
marjoram

aromatic herb belonging to the mint family. Wild marjoram (*O. vulgare*) is found in both Europe and Asia and has become naturalized in the Americas; the sweet marjoram (*O. majorana*) used in cooking is widely cultivated. (Genus *Origanum* or *Marjorana*, family Labiatae.)

marjoram



(Image © Research Machines plc)

Wild marjoram is a perennial growing up to 70 cm/2 ft 4 in high. When grown in warmer countries it has a stronger flavour, and is dried and sold as the herb oregano. Sweet marjoram is also a popular herb.

Markov, Andrei Andreyevich (1856-1922)

Russian mathematician, formulator of the Markov chain, an example of a stochastic (random) process.

Markov, Andrei Andreyevich

Go to site

Devoted to the life and contributions of Andrei Markov. In addition to biographical information, you will find a list of references about Markov and links to essays that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Markov. You will also find a map of his birthplace.

Markov chain

in statistics, an ordered sequence of discrete states (random variables) $x_1, x_2, \ldots, x_i, \ldots, x_n$ such that the probability of x_i depends only on n and/or the state x_{i-1} which has preceded it. If independent of n, the chain is said to be homogeneous.

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mark sensing

in computing, a technique that enables pencil marks made in predetermined positions on specially prepared forms to be rapidly read and input to a computer. The technique makes use of the fact that pencil marks contain graphite and therefore conduct electricity. A **mark sense reader** scans the form by passing small metal brushes over the paper surface. Whenever a brush touches a pencil mark a circuit is completed and the mark is detected.

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marl

crumbling sedimentary rock, sometimes called **clayey limestone**, including various types of calcareous clays and fine-grained limestones. Marls are often laid down in freshwater lakes and are usually soft, earthy, and of a white, grey, or brownish colour. They are used in cement-making and as fertilizer.

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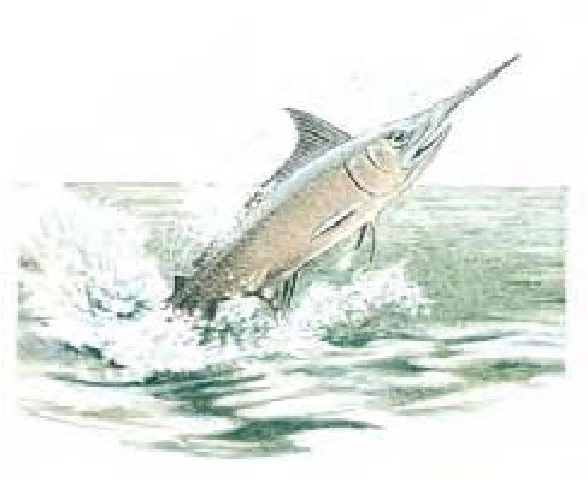
marlin

or spearfish

any of several open-sea fishes known as billfishes. Some 2.5 m/7 ft long, they are found in warmer waters and have elongated snouts and high-standing dorsal (back) fins. Members of the family include the **sailfish** (*Istiophorus platypterus*), the fastest of all fishes over short distances - reaching speeds of 100 kph/62 mph - and the **blue marlin** (*Makaira nigricans*), highly prized as a 'game' fish. (Family Istiophoridae, order Perciformes.)

marlin



(Image © Research Machines plc)

The blue marlin is a very large, deep-shouldered seafish with a streamlined body. Its upper jaw is elongated into a distinct, spikelike snout. It may reach weights of as much as 900 kg/2,000 lb and is prized by game fishers. It is found throughout the warm and temperate seas and oceans of the world.

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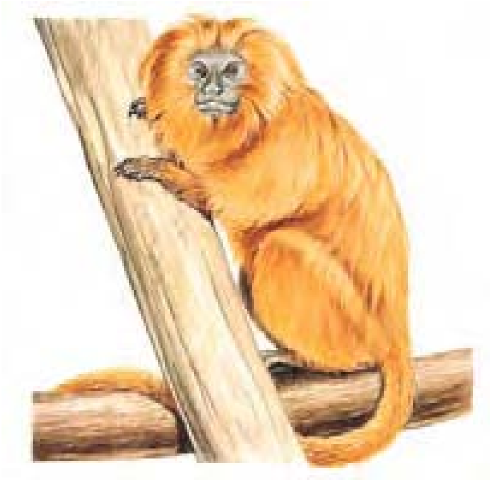
marmoset

any of a group of small tree-dwelling monkeys found in South and Central America; some reach a body length of only 15 cm/6 in. Most species have characteristic tufted ears, clawlike nails, and a handsome tail, which is not prehensile (it cannot be used to grip branches in the same way as the arms and legs). Some marmosets are known as tamarins. (Genus *Callithrix* and related genera, family Callithricidae.)

Best-known is the **common marmoset** *C. jacchus* of Brazil, often kept there as a pet. The discovery of a new species of Brazilian marmoset, *C. saterei*, was announced in 1996. The black-capped dwarf marmoset was discovered in Brazil in 1997. Another new species was discovered in Brazil in 1998. It is the world's second smallest monkey and weighs 160 g/5.6 oz with a body length of 15 cm/6 in (excluding tail) and has been named dwarf marmoset *Callithrix humilis*. Two new species of marmoset were discovered in northwestern Brazil in 2000: the Manicore marmoset *Callithrix manicorensis* and the Acari marmoset *C. acariensis*.

marmoset



(Image © Research Machines plc)

The golden lion tamarin, a member of the marmoset family, is one of three species of tamarin found in the rainforests of southeast Brazil. Tamarins live in family groups, in dense vegetation, 3–10 m/10–33 ft above the ground. They are gravely endangered by the loss of primary tropical forest.

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marmot

any of several large burrowing rodents belonging to the squirrel family. There are about 15 species, distributed throughout Canada and the USA, and from the Alps to the Himalayas. They eat plants and some insects, and live in colonies, make burrows (one to each family), and hibernate in winter (alpine marmots hibernate for six months of the year). In North America they are called **woodchucks** or **groundhogs**. (Genus *Marmota*, family Sciuridae.)

The rarest marmot is the Vancouver Island marmot which is found only in a limited area on Vancouver Island. The marmots are threatened by logging, and fewer than 100 remain.

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marram grass

coarse perennial grass that flourishes in sandy areas. Because of its tough, creeping roots, it is widely used to hold coastal dunes in place. (*Ammophila arenaria*, family Gramineae.)

Mars

fourth planet from the Sun. It is much smaller than Venus or Earth, with a mass 0.11 that of Earth. Mars is slightly pear-shaped, with a low, level northern hemisphere, which is comparatively uncratered and geologically 'young', and a heavily cratered 'ancient' southern hemisphere.

mean distance from the Sun

227.9 million km/141.6 million mi

equatorial diameter

6,780 km/4,210 mi

rotation period

24 hours 37 minutes

year

687 Earth days

atmosphere

95% carbon dioxide, 3% nitrogen, 1.5% argon, and 0.15% oxygen. Red atmospheric dust from the surface whipped up by winds of up to 450 kph/280 mph accounts for the light pink sky. The surface pressure is less than 1% of the Earth's atmospheric pressure at sea level

surface

the landscape is a dusty, red, eroded lava plain. Mars has white polar caps (water ice and frozen carbon dioxide) that advance and retreat with the seasons

satellites

two small satellites: Phobos and Deimos

Life on Mars?

a network of canals

A century after the American astronomer Percival Lowell mapped what he claimed was a network of artificial canals criss-crossing the surface of Mars, the possibility of life on other planets still exercises the imagination of public and scientists alike. Lowell's vision of an inhabited Mars spawned a genre of science fiction stories, most notably H G Wells's *War of the Worlds*. Other astronomers, though, failed to see the canals and dismissed them as optical illusions.

The twin Viking space probes that landed on Mars in 1976 analysed the soil and reported it lifeless. Conditions on the planet are too harsh for life to exist today. So there was considerable surprise when, in August 1996, a team of American scientists announced that they had at last found what had eluded all previous searches - evidence of life on Mars, albeit long-dead.

rocks in ice

The evidence lay in a 1.9 kg/4.2 lb rock from space which was found in the Allan Hills region of Antarctica in 1984; it was catalogued as sample ALH84001. Antarctica is a rich hunting ground for meteorites, because the extraterrestrial rocks lie preserved in deep freeze on the surface of the ice for many thousands of years after they fall.

Most meteorites are fragments from asteroids, but a dozen of them found at various places around the world are now identified as having come from Mars, on the basis of their composition. This one showed evidence of having been blasted off the surface of Mars by a giant impact 16 million years ago, and aimlessly circling the Sun before it encountered the Earth 13,000 years ago.

Meteorite ALH84001 was once part of the original crust of Mars. Detailed analysis shows that it formed 4,500 million years ago and was subsequently immersed under water when the climate on Mars was warmer and wetter than it is today. Hence it is a prime sample in which to find evidence of ancient life on Mars, should there have been any.

PAHs and microfossils

A team headed by David S McKay of NASA's Johnson Space Center in Houston, analysed the meteorite and found that it contained certain compounds, particularly complex molecules known as polycyclic aromatic hydrocarbons (PAHs), which are associated with life. On their own, these compounds would not be strong evidence for life on Mars, since they can be synthesized by normal chemical processes, too.

What tipped the balance was the discovery of wormlike structures, only a few millionths of an inch long, that the team interpreted as fossils of microscopic bacteria that once lived on Mars, probably about 3,600 million years ago.

However, the NASA team were unable to analyse the chemical composition of these supposed microfossils because they were so small, and so the team could not rule out the possibility that they are in fact composed of minerals that happen to have taken up a bacteriumlike shape. One argument against the microfossil interpretation is that the structures are 'too' small – 100 times smaller than microfossils found in Earth rocks.

too soon to say

Not surprisingly, the announcement of the discovery caused controversy in scientific circles. Even an optimist about the possibility of life on other worlds, Carl Sagan, called it 'not proven', while John F Kerridge, a planetary scientist at the University of California, San Diego, said, 'The conclusion is at best premature and more probably wrong'.

'We don't claim that we have conclusively proven it,' said team member Dr Everett Gibson. 'We are putting this evidence out to the scientific community for other investigators to verify, enhance, attack – disprove if they can – as part of the scientific process. Then, within a year or two, we hope to resolve the question one way or the other.'

back to the source

The findings came at a good time for NASA, which was renewing its Mars exploration programme with the launch of two probes in late 1996: Mars Global Surveyor, an orbiter, and Mars Pathfinder, which landed a small rover on the surface in July 1997. Possible target areas for future missions would be two unnamed craters, photographed 20 years ago by the Viking orbiter spacecraft, where meteorite ALH84001 could have been ejected from Mars. One crater is 20 km/12.4 mi across and the other is half that size, both in the planet's southern highlands. Both craters have the right age to be the source of ALH84001.

2003, 'the year of Mars'

In 2003, the Earth was at its closest to Mars for thousands of years and three separate missions headed off from Europe, Japan, and the USA.

The Japanese Nozomi mission orbited and mapped the planet without landing. The European Space Agency mission's British-made Beagle 2 Lander, scheduled to land on Mars on Christmas Day, disappeared, leaving NASA's Mars Exploration Rover, the first mission to land safely in early 2004. The six-wheeled vehicle searched the Martian landscape and, in March 2004, NASA announced that the Rover had discovered the first direct chemical and geological evidence showing that water once flowed on Mars.

The Quest for the Red Planet

introduction

If there is one major goal left in space exploration that really whets the appetite, it is the quest to find life on the Red Planet, Mars. The loss of NASA's Mars Climate Orbiter and the Mars Polar Lander in 1999 was a devastating blow to everyone who was hoping to learn more about the Red Planet, especially the scientists who had spent years devising and preparing the mission and its experiments.

Mars

Mars, named after the Roman god of war, is called the Red Planet because of its distinctive ruddy colour when seen in the night sky. This is the result of much iron oxide or rust in the soil and rocks. Mars has long been seen as a tantalizing world, especially since early observations by telescopes revealed fascinating features. Parts of Mars seemed to change shape and colour and lines were seen on its surface. Some scientists became over-excited and, based on a mistranslation of the Italian word *canali*, claimed that the linear channels were canals and that these were used for irrigation to grow vegetation using water from the melting poles of the planet. This led to speculation that the planet was inhabited by intelligent beings.

could there be life on Mars?

The 'life on Mars' idea still intrigues people today, although at least the fear of Mars aliens has been quashed, largely owing to the first explorations of the planet by various spacecraft that flew past, orbited, and landed on the Red Planet. Some spacecraft, however, sent back images that suggested that water had indeed once flowed over the Martian surface. Like those early telescope observations, this has led to wild assumptions by scientists and the media alike that, simply if there is water, there is life. There is absolutely no evidence that life exists anywhere other than the Earth. But the quest to find life elsewhere seems unstoppable and appears to have almost become the *raison d'être* for space exploration. There is no water on Mars now but there are still many who, despite the extreme conditions that exist on the surface, believe that there may be primitive Martian lifeforms, or that these existed in the planet's early history when conditions, including lots of running water, may have been more acceptable. The first evidence of water on Mars was announced by NASA in 2004.

explorations of Mars

The first astronauts could possibly travel to Mars in about 2015, if funds allow. Their voyage will have been made possible by the unmanned precursor explorations of Mars. These began in earnest very early in the space age, which was born on 4 October 1957 with the launch of the first Earth satellite, Sputnik 1 by the former Soviet Union. At first Mars proved to be an elusive target. Six attempts to fly a craft to Mars – five by the Soviet Union starting in November 1960 and one by the USA – failed between 1960 and 1964 before the US Mariner 4 was launched. It flew past Mars in July 1965, taking a series of grainy pictures, the best of which showed that Mars was covered in craters.

orbiting Mars

Mariner 9 became the first craft to orbit Mars in 1971 but the Soviet Union continued to have a miserable time trying to explore the Red Planet. It had suffered a total of 13 failures before its first relatively successful Mars 5 orbiter flight in 1973. One spacecraft, Mars 6, appears to have landed safely in 1974 but may have been covered by its parachute before it had a chance to send back data and pictures to Earth! Subsequent Russian Mars attempts have also ended in failure. Two Russian spacecraft were launched in 1988 to especially explore Phobos, one of Mars's two moons. Both failed just as they were approaching the planet and the Mars 96 probe never left Earth orbit and crashed in South America!

US attempts to explore Mars

The USA has been a little more successful. Three US spacecraft, Viking 1 and Viking 2 and the Mars Pathfinder and its little rover, the Sojourner, have made landfall on the Red Planet in 1976 and 1977 respectively. These craft found what seems to be a barren, sterile world. The Viking 1 and Viking 2 spacecraft consisted of orbiters and landers. The Viking landers touched down safely in July and September 1976. Two Viking orbiters also conducted a systematic survey of the planet, including its polar caps, and plotted giant dust storms which regularly blow across the Martian surface. The Viking landers were equipped to analyse soil using a robot arm with a scoop. Two Viking landers scooped up soil but found no indications of life. The Viking craft were also equipped with several instruments to study the Martian environment. Temperatures ranged from about - 86°C/186.8°F before dawn to - 33°C/91.4°F in the mid-afternoon. Pictures showed a pink sky, caused by airborne reddish dust scattering sunlight, and spectacular sunsets, which created a number of haloes. Gusts of wind reached 50 km/31 mi per hr. Carbon dioxide ice-frost was also photographed on rocks. NASA's Mars Exploration Rover landed on Mars in January 2004.

Pathfinder

The Mars Pathfinder's landing area in Arres Valis in 1997 created much worldwide excitement with millions of people logging on to NASA Web sites to see the images returned 'live'. A new fleet of US-led uncrewed landing and orbiting expeditions was planned, with the Mars Climate Orbiter due to arrive in October 1999 and the Mars Polar Lander in December 1999. They were to have been followed every two years by more spacecraft. It was hoped that by 2007, bits of Mars rock would be brought back to Earth. Sadly, both the Mars Climate Orbiter and the Mars Polar Lander failed, much to the embarrassment of NASA, and later Mars trips must now be in doubt. Earlier, NASA had lost the Mars Observer which exploded just before it entered orbit around Mars in 1990.

Mars Express

The European Space Agency's (ESA) Mars Express was given the go-ahead in November 1998 and was launched in 2003. Its lander, Beagle 2, was lost on arrival.

mapping Mars

The highly successful US Mars Global Surveyor has been orbiting Mars since 1997, returning spectacular close-ups of many features – and clearing up one puzzle. What had seemed to be a huge 'Mars face' in an earlier Viking spacecraft image was due to the angle of the Sun and shadows. The Surveyor showed that the feature was a mesa, a natural rock formation, and there was no 'face'. Mars has now been almost mapped entirely. Especially tantalizing is the fact that without these spacecraft we would not have known that much of Mars seemed to have once had water flowing over its surface. This serves as the main attraction for sending people to Mars. Apart from watching the first men walking on the Moon, nothing has captured the imagination of the public more than Mars landings. However, overcoming the technological hurdles of sending people to Mars will be extremely expensive. If there is going to be a crewed Mars mission, it will likely be a very modest affair.

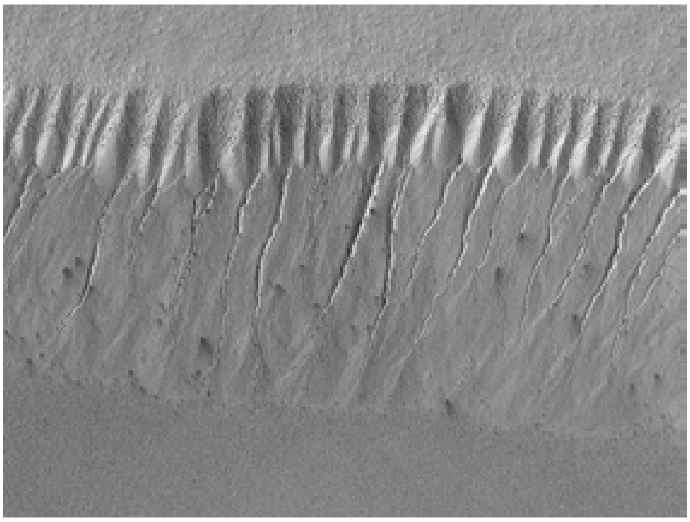
humans on Mars?

In 1994, NASA had developed a strategy for a possible expedition to Mars to begin in 2011 involving three launches of a huge new booster. Even this plan was considered too ambitious technically and financially and NASA scaled down the proposed baseline mission. The new plan involved the use of smaller boosters but double the number of launches to assemble the components in Earth orbit for despatch to Mars. An inflatable TransHab module would be launched to Mars with the Cargo 1 craft to make landfall in the prime landing zone. This would serve as a living and experiment quarters for the Mars crew after their arrival – assuming a safe and accurate landing. The crew would land in a separate spacecraft which would then be connected to TransHab. The upper part of the manned Cargo vehicle would later take off after the proposed 500-day Mars surface exploration mission and dock with return craft which would have been placed in Mars orbit earlier.

a dangerous quest

There is another important issue in human Mars exploration. The *Apollo* astronauts were three days away from the Earth but a Mars crew would face hazards with no immediate return to Earth in prospect. The quest for Mars is as dangerous and uncertain as the earliest ocean voyages. Whether the public is prepared to lose costly spacecraft, and even face the loss of the lives of astronauts in order to reach the Red Planet remains to be seen.

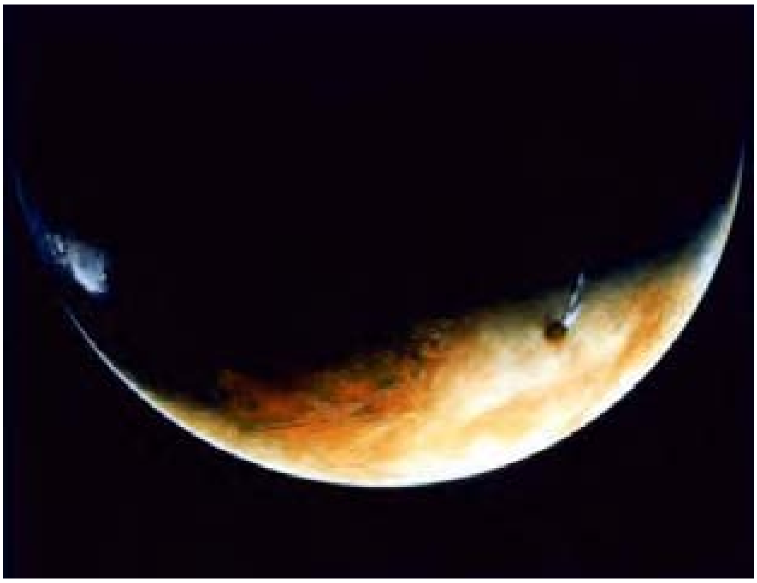
Mars



(Image © NASA)

Martian gullies that astronomers think may have been caused by water erosion. The gullies are found in colder areas on slopes facing away from sunlight. This region spends much of the six-month Martian winter in darkness and has temperatures cold enough to freeze carbon dioxide (-130°C/-200°F).

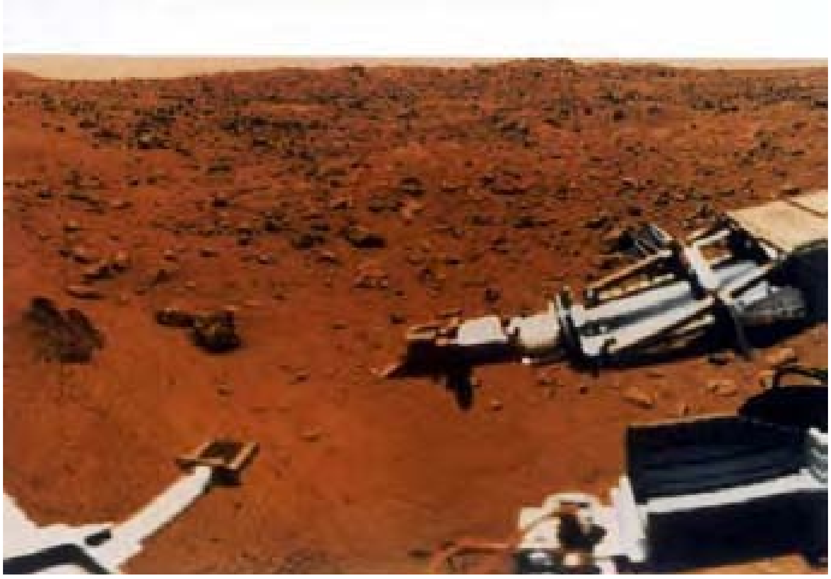
Mars



(Image © NASA)

A computer-enhanced photograph of Mars taken by Viking 2 in August 1976. On the left, with ice cloud plumes on its western flank, is Ascreaus Mons, one of the giant Martian volcanoes. In the centre is the great rift canyon Valles Marineris, and on the right the frosty crater basin Argyre.

Mars



(Image © NASA)

The surface of Mars, the 'Red Planet', is a stony desert. The colouring comes from hydrated iron oxide, the same chemical that gives deserts on Earth a reddish hue. This photograph was taken by the Viking 1 space probe in 1976 and shows the spacecraft's sampler scoop.

European Martian Climate Database

Go to site

This Web interface allows the user to access climate data about the planet Mars, produced by numerical simulations of the Martian atmosphere using a computerized weather forecasting model.

Mars Exploration

Go to site

Well-presented NASA site with comprehensive information on current and future missions to Mars. There are fascinating and well-written accounts of Pathfinder and Global Surveyor, and large numbers of images of the planet.

Mars Introduction

Go to site

Detailed description of the planet Mars, including statistics and information about its surface, volcanoes, satellites, and clouds, supported by a good selection of images.

Virtual Mars

Go to site

View a three-dimensional image of Mars. Clicking on a land feature centres your view at that spot and allows you to rotate the planet. Click on the button below the image to toggle the names of surface features and landing sites, including the Pathfinder and Viking 2 landing sites. Night and day areas are recalculated every five minutes to adjust to rotation.

Whole Mars Catalog

Go to site

Regularly updated with links to breaking stories of Mars research and events. There are links to other major Mars sites, and to pages that deal with certain key topics such as Mars meteorites and missions to Mars.

Mars Global Surveyor

MGS

US spacecraft, launched in November 1996, that went into orbit around Mars in September 1997 to conduct a detailed photographic survey of the planet, commencing in March 1998. The spacecraft used a previously untried technique called **aerobraking** to turn its initially highly elongated orbit into a 400 km/249 mi circular orbit by dipping into the outer atmosphere of the planet. The Global Surveyor established its correct orbit for mapping the surface of Mars in February 1999, a year later than planned.

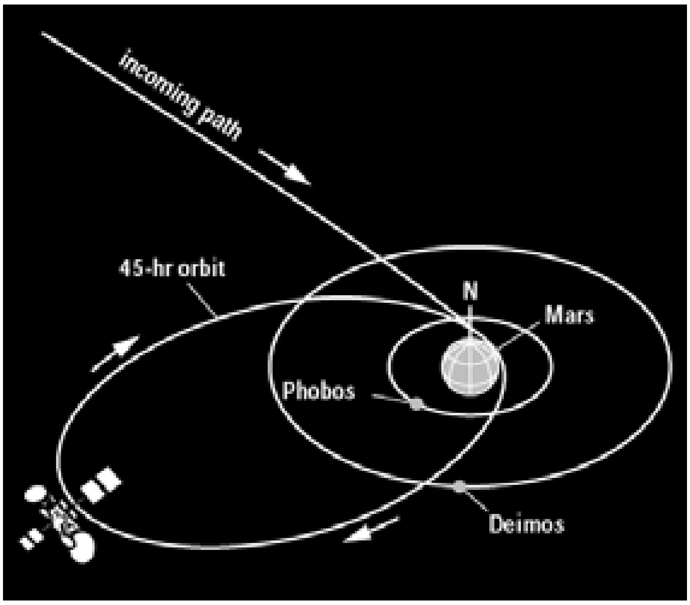
In June 2000, US astronomers announced that photographs from the Mars Global Surveyor showed channels that seemed to have been formed by large amounts of water seeping to the surface and causing landslides. Around 65,000 images taken in the previous year were examined, and were thought to be evidence of a ground-water supply. In 2001, the Global Surveyor located two regions on the surface rich in haematite, providing further evidence for the existence of water at some time in the planet's history. On 31 January 2001, Mars Global Surveyor completed its primary mission and then went into an extended mission phase, continuing to transmit data back to Earth.

Mars Global Surveyor

(Image © NASA)

Technicians at the Jet Propulsion Laboratory fitting the Mars Global Surveyor spacecraft in a protective canister for its transfer from the payload hazardous servicing facility (PHSF) to the launch pad.

Mars Global Surveyor



(Image © Research Machines plc)

The Mars Global Surveyor (MGS) arrived at Mars after a ten-month flight from Earth. MGS used the planet's atmosphere to decrease its speed (aerobraking), so that it could be captured by Martian gravity into a 45-hour circular orbit.

Mars Global Surveyor

Go to site

Regularly updated with images from the cameras of Mars Global Surveyor (MGS), this site is now home to a huge collection of high-resolution images of the planet. There are also results from the thermal emission spectrometer and Mars Orbiter laser altimeter. A graphical simulation shows Mars's position with respect to the Earth, and the position of the MGS spacecraft relative to Mars.

marsh

low-lying wetland. Freshwater marshes are common wherever groundwater, surface springs, streams, or run-off cause frequent flooding, or more or less permanent shallow water. A marsh is alkaline whereas a bog is acid. Marshes develop on inorganic silt or clay soils. Rushes are typical marsh plants. Large marshes dominated by papyrus, cattail, and reeds, with standing water throughout the year, are commonly called swamps. Near the sea, salt marshes may form.

marsh

(Image © Garret Nagle)

Lakes and marshy moorland at Thingvellir, Iceland. This is a typical periglacial landscape, which in winter becomes coated in snow and ice.

Marshall Space Flight Center

MSFC

NASA field centre at Huntsville, Alabama, established in 1960, where the series of Saturn rockets and the space shuttle engines were developed. It also manages missions, such as the Gravity Probe B, as well as the propulsion for the space shuttle and various payloads, including microgravity experiments. The *Destiny* science laboratory for the *International Space Station* was built by the Boeing Company using the centre's facilities.

The centre's first director was German rocket engineer Wernher von Braun.

Marshall Space Flight Center

Go to site

Outlining the activities of the centre, this well-designed site has pages introducing their science projects and describing the spacecraft missions with which it is involved. Animations and video clips accompany many of its news releases. The Marshall image exchange allows easy access to image galleries of its space flight and science projects past and present.

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marsh gas

gas consisting mostly of methane. It is produced in swamps and marshes by the action of bacteria on dead vegetation.

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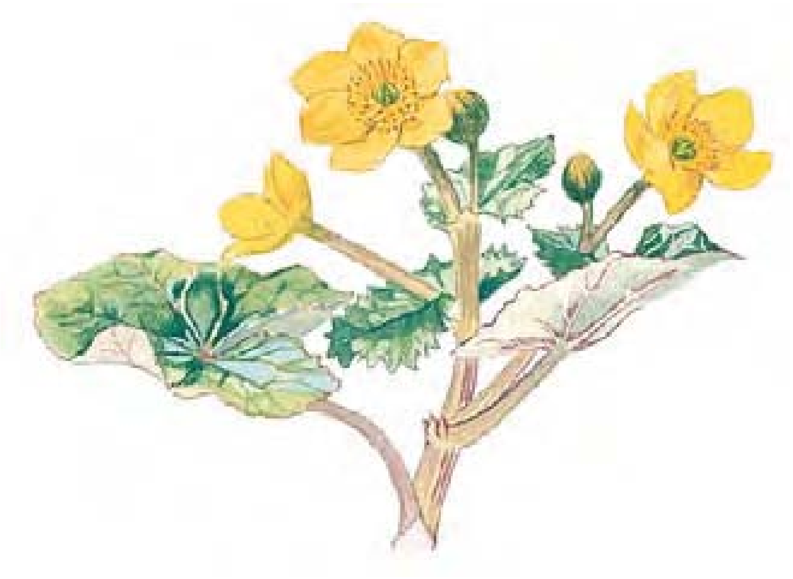
marsh marigold

plant belonging to the buttercup family, known as the kingcup in the UK and as the cowslip in the USA. It grows in moist, sheltered places and has brilliant yellow five-sepalled flowers. (*Caltha palustris*, family Ranunculaceae.)

marsh marigold



(Image © Research Machines plc)

The marsh marigold, or kingcup, has large yellow flowers. It is widely found by streams and water meadows in Europe, Asia, and the USA.

marsh marigold

(Image © Corel)

Marsh marigold *Caltha palustris* growing wild in the Austrian Alps.

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marsh rose

shrub native to South Africa, which grows to 1-4 m/3-13 ft high. It is under threat, partly because its beautiful flowers are frequently picked, but also because of fungi, probably introduced by footwear or equipment, and by changes in management practice that have prevented periodic fires which are necessary for seed germination. Ironically, numbers of the shrub are now so low that uncontrolled fires could wipe out the remaining adult specimens. Although protected, they remain highly threatened. (*Orothamnus zeyheri*.)

Mars Observer

NASA space probe launched in 1992 to orbit Mars and survey the planet, its atmosphere, and the polar caps over two years. The probe was also scheduled to communicate information from the robot vehicles delivered by Russia's Mars 94 mission. The US$980 million project miscarried, however, when the probe stopped transmitting in August 1993 after a suspected explosion in its orbital insertion engine.

Mars Pathfinder

NASA spacecraft launched on 4 December 1996, landing on the planet Mars on 4 July 1997. It carried a small six-wheeled roving vehicle called Sojourner to examine rock and soil samples around the landing site.

Mars Pathfinder was the first to use air bags instead of retrorockets to cushion the landing.

Pathfinder sent its last data transmission on 27 September 1997. It sent over 23 million bits of information back to Earth, including over 16,500 images from the landing site, 15 chemical analyses of the surrounding soil, and previously unknown data on the Martian wind and weather.

Mars Pathfinder

Go to site

Features galleries of both Pathfinder (lander) and Sojourner (rover) images. The scientific findings directory has chapters on geology, mineralogy, and meteorology, and interpretation of the Pathfinder data and images. There are high-resolution pictures and images viewable with red/green glasses.

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marsupial

(Greek marsupion 'little purse')

mammal in which the female has a pouch where young (born tiny and immature) are carried for a considerable time after birth. Marsupials include omnivorous, herbivorous, and carnivorous species, among them the kangaroo, wombat, opossum, phalanger, bandicoot, dasyure, and wallaby.

The Australian marsupial anteater known as the numbat is an exception to the rule in that it has no pouch.

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marten

small bushy-tailed carnivorous mammal belonging to the weasel family. Martens live in North America, Europe, and temperate regions of Asia, and are agile tree climbers. (Genus *Martes*, family Mustelidae.)

The **sable** (*M. zibellina*) lives in eastern Siberia, and provides the most valued fur. The largest marten is the **fisher** (*M. pennanti*) of North America, with black fur and reaching 125 cm/4 ft in length.

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martin

any of several species of birds belonging to the swallow family. (Family Hirundinidae, order Passeriformes.)

Martin, Archer John Porter (1910-2002)

English biochemist who shared the Nobel Prize for Chemistry in 1952 for work with Richard Synge on partition chromatography in 1944.

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maser

acronym for microwave amplification by stimulated emission of radiation

in physics, a high-frequency microwave amplifier or oscillator in which the signal to be amplified is used to stimulate excited atoms into emitting energy at the same frequency. Atoms or molecules are raised to a higher energy level and then allowed to lose this energy by radiation emitted at a precise frequency. The principle has been extended to other parts of the electromagnetic spectrum as, for example, in the laser.

The two-level ammonia-gas maser was first suggested in 1954 by US physicist Charles Townes at Columbia University, New York, and independently the same year by Nikolai Basov and Aleksandr Prokhorov in Russia. The solid-state three-level maser, the most sensitive amplifier known, was envisaged by Nicolaas Bloembergen at Harvard in 1956. The ammonia maser is used as a frequency standard oscillator (see clock), and the three-level maser as a receiver for satellite communications and radio astronomy.

Maskelyne, Nevil (1732-1811)

English astronomer. He made observations to investigate the reliability of the lunar distance method for determining longitude at sea. In 1774 he estimated the mass of the Earth by noting the deflection of a plumb line near Mount Schiehallion in Perthshire, Scotland.

Maskelyne was appointed Astronomer Royal in 1765 and held that office until his death. He began publication in 1766 of the *Nautical Almanac*. This contained astronomical tables and navigational aids, and was probably his most enduring contribution to astronomy.

Maskelyne, Nevil

Go to site

Devoted to the life and contributions of Nevil Maskelyne. In addition to biographical information, you will find a list of references about Maskelyne and links to essays that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Maskelyne. You will also find an image of him, which you can click on to enlarge, and a map of his birthplace.

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masochism

desire to subject oneself to physical or mental pain, humiliation, or punishment, for erotic pleasure, to alleviate guilt, or out of destructive impulses turned inward. The term is derived from Leopold von Sacher-Masoch.

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mass

in physics, quantity of matter in a body as measured by its inertia, including all the particles of which the body is made up. Mass determines the acceleration produced in a body by a given force acting on it, the acceleration being inversely proportional to the mass of the body. The mass also determines the force exerted on a body by gravity on Earth, although this attraction varies slightly from place to place (the mass itself will remain the same). In the SI system, the base unit of mass is the kilogram.

At a given place, equal masses experience equal gravitational forces, which are known as the weights of the bodies. Masses may, therefore, be compared by comparing the weights of bodies at the same place. The standard unit of mass to which all other masses are compared is a platinum-iridium cylinder of 1 kg, which is kept at the International Bureau of Weights and Measures in Sèvres, France.

mass and volume

To remember that if an object floats, it displaces water equal to its mass, but if it sinks, it displaces water equal to its volume

Think of a pebble, made of neutronium. It is small, but it weighs a lot. If it were to displace water equal to its mass, then when you threw this little pebble into a swimming pool, all the water would have to jump out of the swimming pool. So it must only displace water equal to its volume

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mass action, law of

in chemistry, a law stating that at a given temperature the rate at which a chemical reaction takes place is proportional to the product of the active masses of the reactants. The active mass is taken to be the molar concentration of each reactant.

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massage

manipulation of the soft tissues of the body, the muscles, ligaments, and tendons, either to encourage the healing of specific injuries or to produce the general beneficial effects of relaxing muscular tension, stimulating blood circulation, and improving the tone and strength of the skin and muscles.

The benefits of massage were known to the ancient Chinese, Egyptian, and Greek cultures. The techniques most widely practised today were developed by the Swedish physician Per Henrik Ling (1776-1838).

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mass-energy equation

German-Swiss-US physicist Albert Einstein's equation $E = mc^2$, denoting the equivalence of mass and energy. In SI units, E is the energy in joules, m is the mass in kilograms, and c, the speed of light in a vacuum, is in metres per second.

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mass extinction

event that produces the extinction of many species at about the same time. One notable example is the boundary between the Cretaceous and Tertiary periods (known as the K-T boundary) that saw the extinction of the dinosaurs and other large reptiles, and many of the marine invertebrates as well. Mass extinctions have taken place frequently during Earth's history.

There have been five major mass extinctions, in which 75% or more of the world's species have been wiped out: End Ordovician period (440 million years ago) in which about 85% of species were destroyed (second most severe); Late Devonian period (365 million years ago) which took place in two waves a million years apart, and was the third most severe, with marine species particularly badly hit; Late Permian period (251 million years ago), the gravest mass Late Triassic (205 million years ago), in which about 76% of species were destroyed, mainly marine; Late Cretaceous period (65 million years ago), in which 75-80 of species became extinct, including dinosaurs.

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mass number

or nucleon number; symbol A

sum of the numbers of protons and neutrons in the nucleus of an atom. It is used along with the atomic number (the number of protons) in nuclear notation: in symbols that represent nuclear isotopes, such as $^{14}_{6}\text{C}$, the lower number is the atomic number, and the upper number is the mass number. Since the mass of the electrons in an atom are negligible, the total number of protons is neutrons (mass number) in an atom determines its mass.

mass production

manufacture of goods on a large scale, a technique that aims for low unit cost and high output. In factories mass production is achieved by a variety of means, such as division and specialization of labour and mechanization. These speed up production and allow the manufacture of near-identical, interchangeable parts. Such parts can then be assembled quickly into a finished product on an assembly line. The technique was first implemented by US automobile pioneer Henry Ford in 1908, for the manufacture of the Model T Ford automobile.

Division of labour means that a job is divided into a number of steps, and then groups of workers are employed to carry each step out, specializing and therefore doing the job in a routine way, producing more than if each individually had to carry out all the stages of manufacture. However, the system has been criticized for neglecting the skills of workers and removing their involvement with the end product.

Many of the machines now used in factories are robots (for example, on car-assembly lines): they work automatically under computer control. Such automation further streamlines production and raises output.

mass spectrograph

or mass spectrometer

in physics, an apparatus for analysing chemical composition. Positive ions (charged particles) of a substance are separated by an electromagnetic system, designed to focus particles of equal mass to a point where they can be detected. This permits accurate measurement of the relative concentrations of the various ionic masses present, particularly isotopes.

mastiff

breed of powerful dog, usually fawn in colour, that was originally bred in Britain for hunting purposes. It has a large head, wide-set eyes, and broad muzzle. It can grow up to 90 cm/36 in at the shoulder, and weigh 100 kg/220 lb.

mastodon

any of an extinct family of mammals belonging to the elephant order. They differed from elephants and mammoths in the structure of their grinding teeth. There were numerous species, among which the **American mastodon** (*Mastodon americanum*), about 3 m/10 ft high, of the Pleistocene era, is well known. They were hunted by humans for food. (Family Mastodontidae, order Proboscidae.)

match

small strip of wood or paper, tipped with combustible material for producing fire. Friction matches containing phosphorus were first made in 1816 in France by François Derosne.

A **safety match** is one in which the oxidizing agent and the combustible body are kept apart, the former being incorporated into the striking surface on the side of the box, the latter into the match. Safety matches were patented by a Swede, J E Lundström in1855. Book matches were invented in the USA in 1892 by Joshua Pusey.

maté

dried leaves of the Brazilian holly (*Ilex paraguayensis*), an evergreen shrub that grows in Paraguay and Brazil. The roasted, powdered leaves are made into a tea. (Family Aquifoliaceae.)

mathematical induction

formal method of proof in which the proposition $P(n + 1)$ is proved true on the hypothesis that the proposition $P(n)$ is true. The proposition is then shown to be true for a particular value of n, say k, and therefore by induction the proposition must be true for $n = k + 1, k + 2, k + 3, \ldots$. In many cases $k = 1$, so then the proposition is true for all positive integers.

mathematics

science of relationships between numbers, between spatial configurations, and abstract structures. The main divisions of **pure mathematics** include geometry, arithmetic, algebra, calculus, and trigonometry. Mechanics, statistics, numerical analysis, computing, the mathematical theories of astronomy, electricity, optics, thermodynamics, and atomic studies come under the heading of **applied mathematics**.

early history

Prehistoric humans probably learned to count at least up to ten on their fingers. The ancient Egyptians (3rd millennium BC), Sumerians (2000-1500 BC), and Chinese (1500 BC) had systems for writing down numbers and could perform calculations using various types of abacus. They used some fractions. Mathematicians in ancient Egypt could solve simple problems which involved finding a quantity that satisfied a given linear relationship. Sumerian mathematicians knew how to solve problems that involved quadratic equations. The fact that, in a right-angled triangle, the square of the longest side is equal to the sum of the squares of the other two sides (Pythagoras' theorem) was known in various forms in these cultures and also in Vedic India (1500 BC).

The first theoretical mathematician is held to be Thales of Miletus (*c.* 580 BC) who is believed to have proposed the first theorems in plane geometry. His disciple Pythagoras established geometry as a recognized science among the Greeks. Pythagoras began to insist that mathematical statements must be proved using a logical chain of reasoning starting from acceptable assumptions. Undoubtedly the impetus for this demand for logical proof came from the discovery by this group of the surprising fact that the square root of 2 is a number which cannot be expressed as the ratio of two whole numbers. The use of logical reasoning, the methods of which were summarized by Aristotle, enabled Greek mathematicians to make general statements instead of merely solving individual problems as earlier mathematicians had done.

The spirit of Greek mathematics is typified in one of its most lasting achievements, the *Elements* by Euclid. This is a complete treatise on geometry in which the entire subject is logically deduced from a handful of simple assumptions. The ancient Greeks lacked a simple notation for numbers and nearly always relied on expressing problems geometrically. Although the Greeks were extremely successful with their geometrical methods they never developed a general theory of equations or any algebraic ideas of structure. However, they made considerable advances in techniques for solving particular kinds of equations and these techniques were summarized by Diophantus of Alexandria.

medieval period

When the Hellenic civilization declined, Greek mathematics (and the rest of Greek science) was kept alive by the Arabs, especially in the scientific academy at the court of the caliphs of Baghdad. The Arabs also learned of the considerable scientific achievements of the Indians, including the invention of a system of numerals (now called 'arabic' numerals) which could be used to write down calculations instead of having to resort to an abacus. One mathematician can be singled out as a bridge between the ancient and medieval worlds: al-Khwarizmi summarized Greek and Indian methods for solving equations and wrote the first treatise on the Indian numerals and calculating with them. Al-Khwarizmi's books and other Arabic works were translated into Latin and interest in mathematics in Western Europe began to increase in the 12th century. It was the demands of commerce which gave the major impetus to mathematical development and north Italy, the centre of trade at the time, produced a succession of important mathematicians beginning with Italian mathematician Leonardo Fibonacci who introduced Arabic numerals. The Italians made considerable advances in elementary arithmetic which was needed for money-changing and for the technique of double-entry bookkeeping invented in Venice. Italian mathematicians began to express equations in symbols instead of words. This algebraic notation made it possible to shift attention from solving individual equations to investigating the relationship between equations and their solutions, and led eventually to the discovery of methods of solving cubic equations (about 1515) and quartic equations. They began to use the square roots of negative numbers (complex numbers) in their solutions to equations.

early modern period

In the 17th century the focus of mathematical activity moved to France and Britain though continuing with the major themes of Italian mathematics: improvements in methods of calculation, development of algebraic symbolism, and the development of mathematical methods for use in physics and astronomy. Geometry was revitalized by the invention of coordinate geometry by René Descartes in 1637; Blaise Pascal and Pierre de Fermat developed probability theory; John Napier invented logarithms; and Isaac Newton and Gottfried Leibniz invented calculus, later put on a more rigorous footing by Augustin Cauchy. In Russia, Nikolai Lobachevsky rejected Euclid's parallelism and developed a non-Euclidean geometry; this was subsequently generalized by Bernhard Riemann and later utilized by Einstein in his theory of relativity. In the mid-19th century a new major theme emerged: investigation of the logical foundations of mathematics. George Boole showed how logical arguments could be expressed in algebraic symbolism. Friedrich Frege and Giuseppe Peano considerably developed this symbolic logic.

the present

In the 20th century, mathematics became much more diversified. Each specialist subject is being studied in far greater depth and advanced work in some fields may be unintelligible to researchers in other fields. Mathematicians working in universities have had the economic freedom to pursue the subject for its own sake. Nevertheless, new branches of mathematics have been developed which are of great practical importance and which have basic ideas simple enough to be taught in secondary schools. Probably the most important of these is the mathematical theory of statistics in which much pioneering work was done by Karl Pearson. Another new development is operations research, which is concerned with finding optimum courses of action in practical situations, particularly in economics and management. As in the late medieval period, commerce began to emerge again as a major impetus for the development of mathematics.

Higher mathematics has a powerful tool in the high-speed electronic computer, which can create and manipulate mathematical 'models' of various systems in science, technology, and commerce.

Modern additions to school syllabuses such as sets, group theory, matrices, and graph theory are sometimes referred to as 'new' or 'modern' mathematics.

Mathematics

the beginnings of maths

Most ancient civilizations had the means to make accurate measurements, to record them in writing, and to use them in calculations involving elementary addition and subtraction. Apparently for many of them that was sufficient. It seems, for example, that the ancient Egyptians relied on simple addition and subtraction even for calculations of area and volume, although their number system was founded upon base 10, as ours is today. They certainly never thought of mathematics as a subject of potential interest or study for its own sake.

Not so the Babylonians. Contemporaries of the Egyptians, they nevertheless had a more practical form of numerical notation and were genuinely interested in improving their mathematical knowledge. (Perversely, however, their system used base 10 up to 59, after which 60 became a new base; one result of this is the way we now measure time and angles.) By about 1700 BC the Babylonians not only had the four elementary algorithms – the rules for addition, subtraction, multiplication, and division – but also had made some progress in geometry. They knew what we now call Pythagoras' theorem, and had formulated further theorems concerning chords in circles. This even led to a rudimentary understanding of algebraic functions.

the ancient Greeks

Until the very end of their own civilization, the ancient Greeks had little use for algebra other than within a study of logic. After all, to them learning was as interdisciplinary as possible. Even the philosopher Thales of Miletus (lived *c.* 585 BC), regarded as the first named mathematician, considered himself a philosopher in a school of philosophers; mathematics was peripheral. The Greeks' attitude of scientific curiosity was, however, to result in some notable advances in mathematics, especially in the endeavour to understand why and how algorithms worked, theorems were consistent, and calculations could be relied on. It led in particular to the notion of mathematical proof, in an elementary but no less factual way. Mathematician and philosopher Pythagoras (lived *c.*530 BC), having proved the theorem now called after him, imbued mathematics with a kind of religious mystique on the basis of which he became a rather unsuccessful social reformer. Others became fascinated by solving problems using a ruler and compass, in which an outline of the concept of an irrational number (such as π) inevitably appeared. Further investigations of curves followed, and resulted in the first suggestions of what we now call integration. Such geometrical studies were often applied to astronomy. A corpus of various kinds of mathematical knowledge was beginning to accumulate.

The person who recorded much of it was the mathematician Euclid (*c.* 330–260 BC). His work *The Elements* is intended as much as a history of mathematics as a compendium of knowledge, and was massive therefore in both scope and production. It contained many philosophical elements (as we would now define them) and astronomical hypotheses, but the exposition of the mathematical work was masterly, and became the style of presentation emulated virtually to this day. Euclid's geometry, especially, became the standard for millennia: mathematicians still distinguish between Euclidean and non-Euclidean geometry. He even included discussion and ideas on spherical geometry. Unfortunately, some of *The Elements* was lost, including the work on conic sections.

Conic sections seem to have been a source of fascination to many ancient Greek mathematicians. Archimedes (*c.* 287–212 BC), one of the most practical men of all time, used the principle of conic sections in an investigation into how to solve problems of an algebraic nature. A little later, Apollonius of Perga (lived *c.* 230 BC), wrote definitively of the subject, adducing a considerable number of associated theorems and including relevant proofs. The significance of part of this extra material was established only at the end of the 19th century.

the Romans

After about 150 BC, the study of astronomy dominated the scientific world. Consequently, for a while, little mathematical progress was made except in the context of the cosmological theories of the time. (There was accordingly some significant research into spherical geometry and spherical trigonometry.) It was then too that Roman civilization briefly flourished and began to recede – again with little effect on the status of mathematics. Surprisingly, however, after about 400 years, the Alexandrian Diophantus (lived *c.* AD 270–280) devised something of extreme originality: the algebraic variable, in which a symbol stands for an unknown quantity. Equations involving such indeterminates – Diophantus included one indeterminate per equation, needing thus only one symbol – are now commonly called Diophantine equations.

Alexandria thus became the centre for mathematical thought at the time. Very shortly afterwards, the mathematician, astronomer, and geographer Pappus (lived *c.* 320) deemed it time again for a compilation of all known mathematical knowledge. In *The Collection* he revised, edited, and expanded the works of all the classic writers and added many of his own proofs and theorems, including some well-known problems that he left unsolved. It is this work more than any other that ensured the survival of the mathematics of the Greeks until the Renaissance about a thousand years later.

the Arabs

In the meantime the initiative was taken by the Arabs, whose main sphere of influence was, significantly, farther east. They were thus in contact with Persian and Indian scientific schools, and accustomed to translating learned texts. Both Greek and Babylonian precepts were assimilated and practised – the best known proponent was Al-Khwarizmi (lived *c.*840), whose work was historically important to later mathematicians in Europe. The Arabs devised accurate trigonometrical tables (primarily for astronomical research) and continued the development of spherical trigonometry; they also made advances in descriptive geometry.

mathematical knowledge returns to Europe

It was through his learning in the Arab markets of Algeria that the medieval merchant from Pisa Leonardo Fibonacci (or Leonardo Pisano, *c.* 1180–1250), brought much of contemporary mathematics back to Europe. It included - only then - the use of the 'Arabic' numerals 1 to 9 and the 'zephirum' (0), the innovation of partial numbers or fractions, and many other features of both geometry and algebra. From that time, hundreds of translators throughout Europe (especially in Spain) worked on Latin versions of Arab works and transcriptions. Only when Europe had regained all the knowledge and, so to speak, updated itself could genuine development take place. The effort took nearly 400 years before any truly outstanding advances were made - but may be said to be directly responsible for the overall updating and advance in science that then came about, known as the Renaissance.

the 16th century

One of the first instances of genuine progress in mathematics was the means of solving cubic equations, although acrimonious recriminations over priority surrounded its initial publication. One particularly charismatic contender - Italian mathematician and physicist Niccolo Fontana (*c.* 1499-1557), usually known as Tartaglia - besides being a military physicist, was also an inspirational figure in the propagation of mathematics. The means of solving quartic equations was discovered soon afterwards.

Within another 20 years, the French mathematician François Vieta (1540-1603) was improving on the systematization of algebra in symbolic terms and expounding on mathematical (as opposed to astronomical) applications of trigonometry. It was he, if anyone, who initiated the study of number theory as an independent branch of mathematics. At the time of Vieta's death, Henry Briggs (1561-1630) in England was already professor of geometry; a decade later he combined with Scottish mathematician John Napier (1550-1617), the deviser of 'Napier's bones', to produce the first logarithm tables using the number 10 as its base, a means of calculation commonly used until the late 1960s but now outmoded by the computer and pocket calculator. Simultaneously, the German astronomer Johannes Kepler was publishing one of the first works to consider infinitesimals, a concept that would lead later to the formulation of the differential calculus.

the 17th century

It was in France that the scope of mathematics was then widened by a group of great mathematicians. Most of them met at the scientific discussions run by the director of the convent of Place Royale in Paris, Fr Marin Mersenne (1588-1648). To these discussions sometimes came the philosopher-mathematician René Descartes (1596-1675), the lawyer and magistrate Pierre de Fermat (1601-1675), the physicist and mathematician Blaise Pascal (1623-1662), and the architect and mathematician Gérard Desargues (1591-1661). Descartes was probably the foremost of these in terms of mathematical innovation, although it is thought that Fermat - for whom mathematics was an absorbing but part-time hobby - had a profound influence upon him. His greatest contribution to science was in virtually founding the discipline of analytical (coordinate) geometry, in which geometrical figures can be described by algebraic expressions. He applied the tenets of geometry to algebra, and was the first to do so, although the converse was not uncommon. Unfortunately, Descartes so much enjoyed the reputation his mathematical discoveries afforded him that he began to envy anyone who then also achieved any kind of mathematical distinction. He therefore regarded Desargues - who published a well-received work on conics - not only as competition but actually as retrogressive. When Pascal then publicly championed Desargues (whom Descartes had openly ridiculed), putting forward an equally accepted form of geometry now known as projective geometry, matters became more than merely unfriendly.

In the meantime, Fermat took no sides, studied both types of geometry, and was in contact with several other European mathematicians. In particular, he used Descartes' geometry to derive an evaluation of the slope of a tangent, finding a method by which to compute the derivative and thus being considered by many the actual formulator of the differential calculus. Part of his study was of tangents as limits of secants. With Pascal he investigated probability theory, and in number theory he independently devised many theorems, one of them now famous as Fermat's Last Theorem.

It is now known that at about this time in Japan, a mathematician called Seki Kowa (*c.* 1642-1708) was independently discovering many of the mathematical innovations also being formulated in the West. Even more remarkably, he managed to change the social order of his time in order to popularize the subject.

the discovery of calculus

Three years after Pascal died, a religious recluse haunted by self-doubt, English physicist and mathematician Isaac Newton (1642-1727), was obliged by the spread of the plague to his university college in Cambridge to return home to Woolsthorpe in Lincolnshire and there spend the next year and a half in scientific contemplation. One of his first discoveries was what is now called the binomial theorem, which led Newton to an investigation of infinite series, which in turn led to a study of integration and the notion that it might be achieved as the opposite of differentiation. He arrived at this conclusion in 1666, but did not publish it. More than seven years later, in Germany, philosopher, and mathematician Gottfried Leibniz (1646-1716) - who had possibly read the works of Pascal - arrived at exactly the same conclusion, and did publish it. He received considerable acclaim in Europe, much to Newton's annoyance, and a priority argument was very quickly in process. Naively, Leibniz submitted his claim for priority to a committee on which Newton was sitting, so the outcome was a surprise to no one else, but it was in fact Leibniz's notation system that was eventually universally adopted. It was not until 1687 that Newton's studies on calculus were published within his massive *Principia Mathematica*, which also included much of his investigations into physics and optics. Leibniz went on to try to develop a mathematical notation symbolizing logic, but although he made good initial progress it met with little general interest, and despite his energy and status he died a somewhat lonely and forlorn figure.

Another who died in even worse straits was an acquaintance of both Newton and Leibniz: French mathematician Abraham de Moivre (1667-1754), a Huguenot persecuted for his religious background to the extent that he could find no professional position despite being a first-class and innovative mathematician. He met his end broken by poverty and drink - but not before he had formulated game theory, reconstituted probability theory, and set the business of life insurance on a firm statistical basis.

Leibniz's work on calculus was greatly admired in Europe, and particularly by the great Swiss mathematician family domiciled in Basle: the Bernoullis. The eldest of three brothers, Jakob (or Jacques, 1654-1705), actually corresponded with Leibniz; the youngest, Johan (or Jean, 1667-1748), was recommended by the Dutch physicist Christiaan Huygens to a professorship at Groningen. Both brothers were fascinated by investigating possible applications of the new calculus. Unhappily, their study of special curves (particularly cycloids) using polar coordinates proceeded independently along identical lines and resulted in considerable animosity between them. When Jakob died, however, Johan succeeded him at Basle, where he educated his son Daniel - also a brilliant mathematician - whose great friends were Swiss mathematicians Leonhard Euler (1707-1783) and Gabriel Cramer (1704-1752).

the 18th century

Euler may have been the most prolific mathematical author ever. He had amazing energy, a virtually photographic memory and a gift for mental calculation that stood him in good stead late in life when he became totally blind. Not since Descartes had anyone contributed so innovatively to mathematical analysis - Euler's *Introduction* (1748) is considered practically to define in textbook fashion the modern understanding of analytical methodology, including especially the concept of a function. Other works introduced the calculus of variations and the now familiar symbols π, e, and i, and systematized differential geometry. He also popularized the use of polar coordinates, and explained the use of graphs to represent elementary functions.

It was his friend Swiss natural philosopher and mathematician Daniel Bernoulli (1700-1782) who had originally managed to secure a position for him in St Petersburg. When, in 1766, Euler returned there from a post at the Prussian Academy, his place in Berlin was taken by the Italian-born French mathematician Joseph Lagrange (1736-1813) whose ideas ran almost parallel with Euler's. In many ways Lagrange was equally as formative in the popularizing of mathematical analysis, for although he might not have been as energetic or outrightly creative as Euler, he was far more concerned with exactitude and axiomatic rigour, and combined with this a strong desire to generalize. The publication of his studies of number theory and algebra were thus models of precise presentation, and his mathematical research into mechanics began a process of creative thought that has not ceased since. One immediate result of the latter was to inspire his friend and fellow-Frenchman the mathematician and theoretical physicist Jean le Rond d'Alembert (1717-1783) to great achievements in dynamics and celestial mechanics. It was d'Alembert who first devised the theory of partial differential equations.

Towards the end of Lagrange's life, when he was already ailing, he became professor of mathematics at the institution which for the next 50 years at least was to exercise considerable influence over the progress of mathematics; the newly-established École Polytechnique in Paris. Two of his contemporaries there were French astronomer Pierre Laplace (1749-1827) and French mathematician Gaspard Monge (1746-1818). Laplace became famous for his astronomical calculations, Monge for his textbook on geometry; both were acquaintances of Napoleon Bonaparte - as was Joseph Fourier (1768-1830), the physicist who demonstrated that a function could be expanded in sines and cosines through a series now known as the Fourier series.

It was one of Gaspard Monge's pupils - French military engineer Jean-Victor Poncelet (1788-1867) - who first popularized the notion of continuity and outlined contemporary thinking on the principle of duality. And it was one of Laplace's colleagues (whom he disliked), French mathematician Adrien Legendre (1752-1833), who took over where Lagrange left off, and researched into elliptic functions for more than 40 years, eventually deriving the law of quadratic reciprocity and, in number theory, proving that π is irrational.

the 19th century

Legendre's investigations into elliptic integrals were outdated almost as soon as they were published by the work of the Norwegian mathematician Niels Abel (1802-1829) and the mathematician and mathematical physicist German Karl Jacobi (1804-1851). Jacobi went on to make important discoveries in the theory of determinants: he was a great interdisciplinarian. The tragically short-lived Abel has probably had the longer-lasting influence, in that he devised the functions now named after him. He was also unlucky in that his proof, that in general roots cannot be expressed in radicals, was discovered simultaneously and independently by the equally tragic French mathematician Evariste Galois (1811-1832), who only just had time before his violent death to initiate the theory of groups. Further progress in function theory was made by the French mathematician Augustin Cauchy (1789-1857), a prolific mathematical writer who in his works pioneered many modern mathematical methods, developing in particular the use of limits and continuity. He also originated the theory of complex variables, based at least partly on the work of Swiss mathematician Jean Argand (1767-1822), who had succeeded in representing complex numbers by means of a graph.

By this time, however, the centre of mathematics in Europe was undoubtedly Göttingen, where the great German mathematician Karl Gauss (1777-1855) had long presided. Sometimes compared with Archimedes and Newton, Gauss was indisputably not only a mathematical genius who made a multitude of far-reaching discoveries - particularly in geometry and statistical probability - but was also an exceptionally inspirational teacher who inculcated in his pupils the need for meticulous attention to proofs. Late in his tenure at Göttingen, three of his pupils/colleagues were German mathematicians Lejeune Dirichlet (1805-1859), Bernhard Riemann (1826-1866), and Julius Dedekind (1831-1916). There could not have been a more influential quartet in the history of mathematics: the work of all four provides the basis for a major part of modern mathematical knowledge.

non-Euclidean geometry

Gauss himself was most interested in geometry. Swiss mathematician Jakob Steiner (1796-1863) in Germany was trying to remove geometry from the 'taint' of analysis as propounded by the French, but Gauss went further and decided to investigate geometry outside the scope of that described by Euclid. It was a momentous decision - made almost simultaneously and quite independently by Russian mathematician Nikolai Lobachevsky (1792-1856) and Hungarian mathematician János Bolyai (1802-1860). Between them they thus derived non-Euclidean geometry. The ramifications of this were widespread and fast-moving. In Ireland, mathematician William Hamilton (1805-1865) suggested the concept of *n*-dimensional space; in Germany, mathematician Hermann Grassmann (1809-1877) not only defined it but went on to use a form of calculus based on it. But it was Gauss's own pupil, Riemann, who really became the arch-apostle of the subject. He invented elliptical hyperbolic geometries, introduced 'Riemann surfaces' and redefined conformal mapping (transformations) explaining his innovations with such enthusiasm and accuracy that the modern understanding of time and space now owes much to his work.

Boolean algebra

Meanwhile Dirichlet - who succeeded Gauss when the great man died and himself became an influential teacher - and Dedekind concentrated more on number theory. Dirichlet slanted his teaching of mathematics towards applications in physics, whereas Dedekind was determined to arrive at a philosophical interpretation of the concept of numbers. Such an interpretation was thought likely to be of use in the contemporary search for a mathematical basis for logic. English mathematician George Boole (1815-1864) had already attempted to create a form of algebra intended to represent logic that, although not entirely successful, was stimulating to others.

topology

As the study of geometry expanded rapidly, the importance of algebra also increased accordingly. Riemann was influential; German mathematician Karl Weierstrass (1815-1897) provided important redefinitions in function theory; but in algebraic terms development was next most instigated by the English mathematician Arthur Cayley (1821-1895) who discovered the theory of algebraic invariants even as he carried out research into *n*-dimensional geometry. The principles of topology were being established one by one even though the branch itself was not yet complete. Norwegian mathematician Sophus Lie (1842-1899) made important contributions to geometry and to algebra - and indirectly to topology - with the concept of continuous groups and contact transformations, and Cayley went on to invent the theory of matrices. French geometrician Gaston Darboux (1842-1917) revised popular thinking about surfaces.
German mathematician Felix Klein (1849-1925) - an influential figure in his time - unified all the geometries within his *Erlangen Programme* (1872). But it is German mathematician Felix Hausdorff (1868-1942) who is actually credited with the formulation of topology.

Dedekind finally achieved his goal and axiomatized the concept of numbers - only for his axioms to be (albeit apologetically and acknowledgedly) 'stolen' from him by Italian mathematician Giuseppe Peano (1858-1932). The axioms, however, may have inspired - among others - Hausdorff to conceive the idea of point sets in topology, and Danish-born German mathematician Georg Cantor (1843-1918) to define set theory (the basis on which most mathematics is taught in schools today) and transfinite numbers, and certainly caused a revival of interest in number theory generally. German mathematician Immanuel Fuchs (1833-1902) reformulated much of function theory while attempting to refine Riemann's method for solving differential equations. His pupil, French mathematician Henri Poincaré (1854-1912) - similarly fascinated by Riemann's work - made many conjectures that were later useful in the investigation of topology and of space and time, but less successfully spent years researching into what are now called integral equations, only to discover after they were finally axiomatized by Swedish mathematician Ivar Fredholm (1866-1927) that he had done all the work without perceiving the answer.

the 20th century

It has been claimed that more professional mathematicians lived in the 20th century than had lived in all of recorded time. Certainly the enterprise of mathematics has grown remarkably, so much so that two figures active around the turn of the 20th century, Poincaré and the German mathematician, philosopher, and physicist David Hilbert (1862-1943), are claimed to be among the last mathematicians who had a broad and deep knowledge of the whole of the field.

A genuine polymath and an enthusiastic teacher, Hilbert expanded virtually all branches of mathematics, especially in the interpretation of geometric structures implied by infinite-dimensional space. Hilbert's plenary address to one of the very early International Congress of Mathematicians conferences (held in Paris in 1900) consisted of presenting 23 problems which he believed would occupy the world's mathematicians for the coming century. His predictions proved very generative of future work, and to solve a 'Hilbert problem', as they became known, was a guarantee of professional accolades of the highest order. The types of problems he proposed ranged from the quite specific to the sort 'develop a general theory of ...'. During the 20th century mathematics became gradually either more theoretical or more practical. Theoretically interest swung towards finding features in common between disparate mathematical structures. French mathematician Henri Lebesgue (1875-1941) devised a concept of measure that contributed greatly to the theory of abstract spaces. Andrei Kolmogorov (1903-1987) and others not only related this to probability theory but thereby to problems of statistical mechanics and the clarification of the ergodic theorems provided by US mathematician George Birkhoff (1884-1944) in 1932.

The 20th century was the century of generalization and abstraction, and of the study of structure by means of its systematization and classification. In an important sense, the 20th century was the century of algebra, not only as an ever-growing subject matter but also as the very language of much of pure mathematical proof (in much the same way that geometry was both subject and language for proof for the ancient Greeks). It is also a story of the development of very general and abstract theories, rather than the solution of individual problems, and the provision of very abstract settings for such theoretical accounts.

Such theories often developed as hybrids of earlier areas of study as the methods, concepts and techniques of abstract algebra were successfully deployed against previously resistant problems in a range of different mathematical domains. Systematic work of this sort was done in a variety of rapidly developing fields: algebraic geometry, algebraic number theory, algebraic topology, and even algebraic algebra (category theory).

Modern mathematics (as it became known) has concerned itself with such abstract mathematical structures, drawing on algebraic concepts that have become almost hegemonic, including groups, rings, and fields. As an example of some of these trends, one of the key problems in group theory (a branch of abstract algebra) became the classification of all finite simple groups. In 1980 mathematicians completed the classification, a problem which had taken over a 100 mathematicians more than 35 years, covering over 14,000 pages in mathematical journals.

In consequence of this broadening of scope and scale, an increasing amount of mathematical work has moved away from being that of an individual mathematician to teams of collaborators in the same or different institutions. One notable exception to this came with the announcement in October 1994 by Andrew Wiles (1953-), an English mathematician working at Princeton University, New Jersey, USA, that he had solved Fermat's Last Theorem, an unproven central result in number theory, working in complete secrecy for seven years. The theorem's proof had eluded mathematicians for over 300 years, and Wiles's proof drew heavily on a wide range of mathematical results and ideas, particularly from algebraic number theory. Starting in the 1930s and subsequently, the Bourbaki group of mathematicians, (comprising some of the most renowned European mathematicians of the period, such as the French algebraic geometer André Weil (1906-1998) commenced publishing a very influential set of books, entitled *Elements of Mathematics*. They saw it as the encyclopedia of mathematics, starting with set theory and abstract algebra, rather than geometry as Euclid had with his *Elements* some 2,300 years earlier. A whole generation of pure mathematicians in a number of countries gained their mathematical training using these works.

They helped to shape and orientate mathematics towards the pure, the abstract, and the detached from the problems and phenomena of the material world, which had served since time immemorial as one key source of mathematical challenge.

Yet, as in previous generations, pure mathematical work, developed from queries and curiosity from within mathematics itself, found unexpected applications. In algebraic topology, work in knot theory was used to work on problems arising from the physical folding of the DNA molecule in space. And in the 1950s French mathematician René Thom (1923-) categorized abstract geometric surfaces called manifolds using the notion of cobordism (for which he won a Fields medal, the mathematical equivalent of a Nobel prize). It was during the 1970s that Thom and English mathematician Christopher Zeeman (1925-) produced applications of this work in what became known as catastrophe theory. In particular, they looked at notions of stability, continuity and discontinuity in physical phenomena and human systems, emerging from an area called non-linear dynamics.

Chaos theory

A modern computer-based relative to this work is chaos theory. The central discovery, actually made in 1961 by US meteorologist Edward Lorenz (1917-), is that random behaviour can arise in systems whose mathematical description contains no hint whatever of randomness. The geometry of chaos can be explored using theoretical techniques of topology, but the most vivid images are obtained using computer graphics. The geometric structures of chaos are called fractals; they have the same detailed form on all scales of magnification, a phenomenon called self-similarity.

Polish-born French mathematician Benoit Mandelbrot (1924-) produced the first fractal images in 1962, using a computer that repeated the same mathematical pattern over and over again. He wrote of investigating 'the geometry of nature', in some ways harking back to Galileo's claim over 300 years earlier that 'the book of the universe is written in the language of geometry.' In 1975, US mathematician Mitchell Feigenbaum (1945-) discovered a new universal constant (approximately 4.669201609103) that is important in chaos theory. Order and chaos, traditionally seen as opposites, are now viewed as two aspects of the same basic process, that is the evolution of a system over time.

The study of statistics and probability was also taken up with new enthusiasm for more practical applications. English mathematician and biometrician Karl Pearson (1857-1936) refined Gauss's ideas to derive the notion of standard deviation. Danish mathematician Agner Erlang (1878-1929) used probability theory in a highly practical way to aid the efficiency of the circuitry of his capital's telephone system. US mathematician Alonzo Church (1903-1995) defined a 'calculable function' and by so doing clarified the nature of algorithms. Following this, another US mathematician George Dantzig (1914-) was able to set up complex linear programmes for computers. Such progress is being maintained, sometimes now as a result of using the machines themselves to devise further advances.

Computer scientists have devised symbolic computation systems which manipulate algebraic expressions in the same way that a human mathematician would do, only faster and more accurately. The result might be called 'computer-assisted mathematics'. A good example is the proof in 1972 of the four-colour theorem by US mathematicians Kenneth Appel and Wolfgang Haken. In 1852 English mathematician Francis Guthrie conjectured that no more than four colours need be used in order to ensure that no two adjacent colours on a map share the same colour. Mathematicians quickly proved that five colours would suffice, but had no success whatsoever in reducing the number to four. A direct attack by computer would not be possible, for how could a computer consider all possible maps? But Appel and Haken came up with a list of around 2,000 particular maps, and showed that if each had a rather complicated property, then the conjecture must be true. The computer then checked this property, case by case.

The boundaries around the edge of mathematics are not completely clear, and computer incursions are only one such instance. The 20th century saw a resurgence of work in philosophical issues, in particular a renewal of the quest to find a relationship between mathematics and logic. German logical philosopher and mathematician Gottlob Frege (1848-1925) had devised a system of symbolic logic. However, his pride turned to ashes when English philosopher and mathematician Bertrand Russell (1872-1970) pointed out to him an internal, and fundamental, inconsistency. Russell, with his teacher and friend English mathematician and philosopher Alfred North Whitehead (1861-1947), attended lectures on this topic given by given by Peano; together Russell and Whitehead then published a large work on the foundations of mathematics, entitled *Principia Mathematica*. It had an immediate impact, and remained influential. And several different philosophical theories were dealt a heavy blow by the theorem formulated in 1930 by Austrian-born US philosopher and mathematician Kurt Gödel (1906-1978). This stated that the overall consistency (completeness) of a mathematics that contained the arithmetic of whole numbers cannot itself be proved mathematically. Thus, mathematical concepts and techniques could not be deployed to prove the consistency of mathematics itself. In some sense, paradox is a fundamental aspect of mathematics.

Mathematics and Computing

the electronic mathematician

Mathematicians have always dreamed of possessing machines that would remove the drudgery from their work. The inventor of logarithms, John Napier, also invented a system of carved ivory rods for doing multiplication, known as Napier's bones. Blaise Pascal built the first mechanical calculator in 1642. In 1835 Charles Babbage designed a calculating machine that could modify its own instructions, a forerunner of today's computers. Two of the true parents of the computer, John Von Neumann and Alan Turing, were mathematicians.

Until the 1970s, computers were used as glorified calculators, for 'number crunching' - performing what were essentially just long and complicated calculations in arithmetic. Many mathematical problems, however, require understanding, not just a numerical answer. More and more, computers are being used by mathematicians as 'experimental' tools: to investigate aspects of mathematical problems, test predictions, and prove the correctness of theories. Computer scientists have also responded to mathematicians' needs by devising symbolic computation systems. These manipulate algebraic expressions in the same way that a human mathematician would - only faster and more accurately. The result might be called 'computer-assisted mathematics': the computer does not make mathematicians obsolete, but it adds enormously to their power, bringing within their range problems that had hitherto seemed impossible.

examples of the use of symbolic computation systems

A good example is the proof in 1972 of the Four Colour Theorem by Kenneth Appel and Wolfgang Haken. In 1850 Francis Guthrie conjectured that no more than four colours need be used in colouring a map in order to ensure that no two adjacent countries share the same colour. Mathematicians quickly proved that five colours would suffice, but had no success whatsoever in reducing that number to four. A direct attack by computer would not be possible, for how could a computer consider all possible maps? But Appel and Haken came up with a list of 1,936 particular maps, and showed that if each had a rather complicated property, then the conjecture must be true. They then checked this property, case by case, on a computer, taking about 1,200 hours.

There are now many different symbolic computation systems, such as Macsyma, Reduce, Maple, and Mathematica. Their use is becoming almost routine among research mathematicians. Their power is immense. In 1847 the French mathematician Charles Delaunay spent 20 years calculating a formula for the position of the Moon, and the end result occupies an entire book. In 1970 three researchers at the Boeing Laboratories in Seattle checked his calculation by symbolic computation, taking only 20 hours. They found that Delaunay had made three errors, none serious.

Symbolic computation has been used to answer long-standing questions about dynamic systems, to help prove new results in number theory, to investigate questions in algebraic geometry, to devise new minimal surfaces, and even in the mathematics of games. In March 1991 Uri Zwick and Mike Patterson of Warwick University, England, used Mathematica to work out a winning strategy for the memory game pelmanism, in which pairs of identical cards are laid face down and players take turns to turn two of them over. If they match, the player removes them and takes an extra turn. The winner is whoever removes the most cards. The strategy is quite simple, but the proof that it works – and the experiments needed to discover it – would not have been possible without the computer.

the future

Computation and mathematics have always been closely related, and as the century draws to a close they are becoming intimately intertwined. This strong interaction between computing and mathematics will let the mathematician of the future spend more time thinking about concepts, and less time performing routine calculations. Computers, moreover, open up a whole new range of problems that mathematicians would not otherwise have thought of, and offer new perspectives from which to find answers.

The technology is not yet perfect. Symbolic computation programs seldom work well without a lot of careful structuring by their human user. Left to their own devices, the programs tend to suffer 'memory explosions', leaving copies of intermediate steps all over the computer's memory, filling it up, and grinding to an ignominious halt. But the technology is improving so fast that by the turn of the century there will be few mathematicians who do not 'collaborate' with a computer on a regular basis.

The Origins of Mathematics

first mathematics

It is often said that people first encountered mathematics when they began to count their livestock or tried to measure the size of a field. The two sides of the mathematical coin, discrete mathematics based on counting, and continuous mathematics that arises through measurement, still form the basis of modern mathematics.

inventing names for numbers

Counting and arithmetic did not come about easily for a variety of reasons. To count we just need tally marks; but in order to talk about counting, we need a name for each number we use. Every language combined names of small numbers as a way of expressing larger ones, as in the French word for 80, *quatre-vingt* (four twenties). The ancient Greeks used letters to represent numbers so that α was 1 while κ stood for 20 and in that way would write κα for 21. They could equally have written ακ to convey the same meaning, one-and-twenty.

Roman numerals were based on ten with the basic symbols being I, X, C, and M for 1, 10, 100, and 1,000 respectively, although they also introduced V to stand for 5, L for 50, and D for 500. The symbols were generally written in descending order, so that

1,944 = MDCCCCXXXXIIII.

Sometimes they made use of *position*: a smaller unit placed before a larger one indicated subtraction of the smaller from the larger – for instance 9 was written as IX instead of VIIII. So 1,944 = MCMXLIV. But this representation is not always as easy to understand or employ in arithmetic, which may be why the Romans did not always make use of it.

positional systems and '0'

In our number system, unlike the Greek system, order matters. Take 21. Swapping the places of the numerals 2 and 1 gives 12, a different number, for the 1 now represents 1 ten, while the 2 means two units.

No ancient European society devised a complete positional numbering system in which the meaning of a numeral depends on its position within the number and full use is made of a zero symbol. The idea of a zero symbol was used by the Mesopotamians and Babylonians, and was employed in the way that we do to distinguish between 74 and 704. The full potential of the system was not embraced, however, as the 0 was seldom used in the final place, the way we show the difference between 74 and 740.

There were nonetheless many practical and sophisticated counting systems in the ancient world. Commercial and trading societies often constructed good systems of arithmetic and the peoples of ancient Mesopotamia did have a sexagesimal positional system, one based on 60, over four thousand years ago. Numbers exceeding 60 were written according to the positional principle, while combinations of the symbols from one to ten were used to make the basic numbers of their system which ran from 1 to 59.

For instance, the ancient clay tablets reveal examples like:

$524{,}551 = 2 \times 60^3 + 25 \times 60^2 + 42 \times 60 + 31$.

The first complete positional system came into use in India around the 1st century AD. The symbol for 0 was called *sunya*, the Hindu word for 'empty'. It is the basis of our number system, called Hindu-Arabic, as it passed to Europe via medieval Arabic scholars. A positional system, complete with zero, was also invented by the Mayan civilization of Central America by the 6th century AD, based on multiples of powers of 20 instead of 10.

early computing

Throughout Asia and Europe, arithmetic was carried out on the calculator of the ancient world, the abacus (Greek 'sand tray'). The main obstacle to written arithmetic was lack of cheap writing materials. The first example of long division is by Calandri in 1491. The decimal system of fractions did not firmly take root until planted by force after the French Revolution of 1789.

A typical abacus consisted of a wooden rectangular frame in which a series of parallel rods were housed. Along each were a number of identical beads. Cutting across the rods was a counting bar. One rod represented the units column and the beads on rods to its left each represented multiples of 10, 100, 1,000, and so forth. Beads above the counting bar counted for five while those below represented one. Addition using an abacus is easy, as we need only count the number of each bead type and carry over to higher units as the need arises, although to carry out subtractions may require borrowing from the next highest rod.

A great advantage of the pen and paper methods that emerged in the Renaissance is one of communication, for they allow working to be shown and checked. The scribes of the ancient Babylonian tablets left descriptions of numerous problems and their answers, but we would need to see the clerks of the ancient world in action on their counting frames to appreciate exactly how they did their sums.

geometry and paradox

An early use of geometry and measurement arose in Egypt where the ancient Greek historian Herodotus tells us that the Nile's annual flood regularly washed away boundaries and landmarks so that a system of accurate surveying was needed in order to reaffirm who owned what: indeed the Greek word 'geometry' means 'Earth measure'. The founder of geometry was the Greek philosopher and scientist Thales of Miletus, who is said to have impressed the Egyptians by measuring the height of the Great Pyramid of Cheops through use of shadows.

His successor was the Greek mathematician and philosopher Pythagoras of Samos, best known for his theorem that says that the square on the longest side (hypotenuse) of a right-angled triangle has an area equal to the sum of the area of the squares of the other two sides. Pythagoras is also said to have discovered irrational numbers. If a right-angled triangle has two sides which are both 1 in length, the hypotenuse will be the square root of 2. Pythagoras proved this number was irrational, that is to say that it cannot be represented by any ordinary fraction a/b. Up to this point, it was taken as self-evident that, *in principle*, any constructed line could be measured *exactly* using a standard ruler, provided that we marked the ruler with a sufficiently fine scale. Pythagoras had proved this to be false.

This and some other paradoxes in classical mathematics were eventually resolved in the 4th century BC by the Greek mathematician and astronomer Eudoxus with his *Theory of Proportions*, an account of which is to be found in *The Elements*, the classical texts written by the Greek mathematician Euclid of Alexandria. Eudoxus introduced a theory that applied equally well to all lengths by making subtle use of inequalities to deal with equalities.

later achievements

Euclid's Alexandrian School remained the leading centre of thought during the later classical period. Its greatest genius was the Greek mathematician Archimedes, who took both geometry and mechanics to new heights. He died in 212 BC, probably killed by the Roman invaders of his home city of Syracuse, which he brilliantly defended through the use of devastating war machines that capsized the vessels of the invaders. In his tract, *The Method*, Archimedes allied mathematics and physics by insisting on rigorous standards of proof while emphasizing the importance of physical intuition as a guide to the truth.

The Greek mathematician Apollonius of Perga, a younger contemporary of Archimedes, gave the definitive description of curves arising from cones that proved to be a major ingredient of the theory devised by English physicist and mathematician Isaac Newton nearly two thousand years later to explain planetary orbits. The Greek mathematician and engineer Hero of Alexandria (lived AD 62) invented the first working steam engine, made a primitive thermometer, and proved the formula for the area of a triangle in terms of its three sides. Other outstanding figures were Greek geographer and mathematician Eratosthenes, who calculated the diameter of the earth in 230 BC through the difference in the sun's elevation at Syrene and Alexandria at the summer solstice, and Greek mathematician Diophantus, whose treatise on number theory inspired French mathematician Fermat's last theorem, while *The Collection* of Greek mathematician, astronomer, and geographer Pappus was the final great intellectual work of classical times.

decline and fall

Despite its success and staggering sophistication, Greek mathematics remained wedded to the geometric style of Euclid in which even common algebraic facts about numbers were demonstrated in what appears to us a strange and unnatural fashion through areas of geometrical figures. Even the Ancient Babylonians, one thousand years before the birth of Pythagoras, seemed more at home with algebra. Although they did not use symbols to stand for numbers as we would, they demonstrated how to solve quadratic equations (in which the unknown quantity x appears through its square, x^2) and compiled astonishingly extensive tables of number triples such as (3, 4, 5) and (4961, 6480, 8161) where the sum of the squares of the two smaller numbers equals the square of the larger. The precursors of modern algebraic methods are to be found in societies such as Mesopotamia, India, and China.

After the 4th century AD classical Greek mathematics entered terminal decline. Mathematics was not revived until the dawn of the modern age when the need to solve problems in navigation and the physical world ushered in a fresh and progressive epoch.

Fields Medal

This international prize for achievement in the field of mathematics is awarded every four years by the International Mathematical Union.

Year	Winner(s)
1936	Lars Ahlfors (Finland); Jesse Douglas (USA)
1950	Atle Selberg (USA); Laurent Schwartz (France)
1954	Kunihiko Kodaira (USA); Jean-Pierre Serre (France)
1958	Klaus Roth (UK); René Thom (France)
1962	Lars Hörmander (Sweden); John Milnor (USA)
1966	Michael Atiyah (UK); Paul J Cohen (USA); Alexander Grothendieck (France); Stephen Smale (USA)
1970	Alan Baker (UK); Heisuke Hironaka (USA); Sergei Novikov (USSR); John G Thompson (USA)
1974	Enrico Bombieri (Italy); David Mumford (USA)
1978	Pierre Deligne (Belgium); Charles Fefferman (USA); G A Margulis (USSR); Daniel Quillen (USA)
1982	Alain Connes (France); William Thurston (USA); S T Yau (USA)
1986	Simon Donaldson (UK); Gerd Faltings (West Germany); Michael Freedman (USA)
1990	Vladimir Drinfeld (USSR); Vaughan F R Jones (USA); Shigefumi Mori (Japan); Edward Witten (USA)
1994	L J Bourgain (USA/France); P-L Lions (France); J-C Yoccoz (France); E I Zelmanov (USA)
1998	Richard E Borcherds (UK); W Timothy Gowers (UK); Maxim Kontsevich (Russia); Curtis T McMullen (USA)
2002	Laurent Lafforgue (France); Vladimir Voevododsky (Russia)

Mathematical signs

Symbol	Meaning
a→b	a implies b
∞	infinity
lim	limiting value
a ≑b	a approximately equal to b
a=b	a equal to b
a>b	a greater than b
a<b	a smaller than b
a≠b	a not equal to b
b<a<c	a greater than b and smaller than c, that is a lies between b and c, but cannot equal either
a≥b	a equal to or greater than b, that is a at least as great as b
a≤b	a equal to or less than b, that is, a at most as great as b
b≤a≤c	a lies between the values of b and c and could take the values of b and c
$\lvert a\rvert$	absolute value of a; this is always positive, for example $\lvert -5\rvert=5$
+	addition sign, positive
-	subtraction sign, negative
×	multiplication sign, times
: or ÷ or /	division sign, divided by
a+b=c	a+b, read as 'a+b', denotes the addition of a and b. The result of the addition, c, is also known as the sum.
∫	indefinite integral
$_a\int^b f(x)dx$	definite integral, or integral between x=a and x=b
a-b=c	a-b, read as 'a minus b', denotes subtraction of b from a. a-b, or c, is the difference. Subtraction is the opposite of addition.
a×b=c	a×b, read as 'a multiplied by b', denotes multiplication of a by b. a×b, or c, is the product; a and b are factors of *c.*
ab=c	
a.b=c	
a:b=c	a:b, read as 'a divided by b', denotes division. a is the dividend, b is the divisor. a:b, or c, is the quotient. One aspect of division - repeated subtraction, is the opposite of multiplication - repeated addition.
a÷b=c	
a/b=c	
a^b	a^b, read as 'a to the power b'. a is the base, b the exponent
$^b\sqrt{a}=c$	$^b\sqrt{a}$ is the bth root of a, b being known as the root exponent. In the special case of $^2\sqrt{a}=c$, $^2\sqrt{a}$ or c is known as the square root of a, and the root exponent is usually omitted, that is $^2\sqrt{a}=\sqrt{a}$.
e	exponential constant and is the base of natural (napierian) logarithms = 2.7182818284..
π	ratio of the circumference of a circle to its diameter = 3.1415925535)

Mathematics: key events

BC	
c. 2500	The people of Mesopotamia (now Iraq) develop a positional numbering (place-value) system, in which the value of a digit depends on its position in a number.
c. 2000	Mesopotamian mathematicians solve quadratic equations (algebraic equations in which the highest power of a variable is 2).

876	A symbol for zero is used for the first time, in India.
c. 550	Greek mathematician Pythagoras formulates a theorem relating the lengths of the sides of a right-angled triangle. The theorem is already known by earlier mathematicians in China, Mesopotamia, and Egypt.
c. 450	Hipparcos of Metapontum discovers that some numbers are irrational (cannot be expressed as the ratio of two integers).
300	Euclid lays out the laws of geometry in his book *Elements*, which is to remain a standard text for 2,000 years.
c. 230	Eratosthenes develops a method for finding all prime numbers.
c. 100	Chinese mathematicians begin using negative numbers.
c. 190	Chinese mathematicians use powers of 10 to express magnitudes.
AD	
c. 210	Diophantus of Alexandria writes the first book on algebra.
c. 600	A decimal number system is developed in India.
829	Persian mathematician Muhammad ibn-Musa al-Khwarizmi publishes a work on algebra that makes use of the decimal number system.
1202	Italian mathematician Leonardo Fibonacci studies the sequence of numbers (1, 1, 2, 3, 5, 8, 13, 21,...) in which each number is the sum of the two proceedng ones.
1550	In Germany, Rheticus publishes trigonometrical tables that simplify calculations involving triangles.
1614	Scottish mathematician John Napier invents logarithms, which enable lengthy calculations involving multiplication and division to be carried out by addition and subtraction.
1623	Wilhelm Schickard invents the mechanical calculating machine.
1637	French mathematician and philosopher René Descartes introduces coordinate geometry.
1654	In France, Blaise Pascal and Pierre de Fermat develop probability theory.
1666	Isaac Newton develops differential calculus, a method of calculating rates of change.
1675	German mathematician Gottfried Wilhelm Leibniz introduces the modern notation for integral calculus, a method of calculating volumes.
1679	Leibniz introduces binary arithmetic, in which only two symbols are used to represent all numbers.
1684	Leibniz publishes the first account of differential calculus.
1718	Jakob Bernoulli in Switzerland publishes his work on the calculus of variations (the study of functions that are close to their minimum or maximum values).
1742	German mathematician Christian Goldbach conjectures that every even number greater than two can be written as the sum of two prime numbers. Goldbach's conjecture has still not been proven.
1746	In France, Jean le Rond d'Alembert develops the theory of complex numbers.
1747	D'Alembert uses partial differential equations in mathematical physics.
1798	Norwegian mathematician Caspar Wessel introduces the vector representation of complex numbers.
1799	Karl Friedrich Gauss of Germany proves the fundamental theorem of algebra: the number of solutions of an algebraic equation is the same as the exponent of the highest term.
1810	In France, Jean Baptiste Joseph Fourier publishes his method of representing functions by a series of trigonometric functions.
1812	French mathematician Pierre Simon Laplace publishes the first complete account of probability theory.
1822	In the UK, Charles Babbage begins construction of the first mechanical computer, the difference machine, a device for calculating logarithms and trigonometric functions.
1827	Gauss introduces differential geometry, in which small features of curves are described by analytical methods.
1829	In Russia, Nikolai Ivanonvich Lobachevsky develops hyperbolic geometry, in which a plane is regarded as part of a hyperbolic surface, shaped like a saddle. In France, Evariste Galois introduces the theory of groups (collections whose members obey certain simple rules of addition and multiplication).
1844	French mathematician Joseph Liouville finds the first transcendental number, which cannot be expressed as an algebraic equation with rational coefficients. In Germany, Hermann Grassmann studies vectors with more than three dimensions.
1854	George Boole in the UK publishes his system of symbolic logic, now called Boolean algebra.
1858	English mathematician Arthur Cayley develops calculations using ordered tables called matrices.
1865	August Ferdinand Möbius in Germany describes how a strip of paper can have only one side and one edge.
1892	German mathematician Georg Cantor shows that there are different kinds of infinity and studies transfinite numbers.
1895	Jules Henri Poincaré publishes the first paper on topology, often called 'the geometry of rubber sheets'.
1931	In the USA, Austrian-born mathematician Kurt Gödel proves that any formal system strong enough to include the laws of arithmetic is either incomplete or inconsistent.
1937	English mathematician Alan Turing publishes the mathematical theory of computing.
1944	John Von Neumann and Oscar Morgenstern develop game theory in the USA.
1945	The first general purpose, fully electronic digital computer, ENIAC (electronic numerator, integrator, analyser, and computer), is built at the University of Pennsylvania, USA.
1961	Meteorologist Edward Lorenz at the Massachusetts Institute of Technology, USA, discovers a mathematical system with chaotic behaviour, leading to a new branch of mathematics – chaos theory.
1962	Benoit Mandelbrot in the USA invents fractal images, using a computer that repeats the same mathematical pattern over and over again.
1975	US mathematician Mitchell Feigenbaum discovers a new fundamental constant (approximately 4.669201609103), which plays an important role in chaos theory.
1980	Mathematicians worldwide complete the classification of all finite and simple groups, a task that has taken over a hundred mathematicians more than 35 years to complete and whose results take up more than 14,000 pages in mathematical journals.
1989	A team of US computer mathematicians at Amdahl Corporation, California, discovers the highest known prime number (it contains 65,087 digits).

1993	British mathematician Andrew Wiles publishes a 1,000-page proof of Fermat's last theorem, one of the most baffling challenges in pure mathematics.
1995	Andrew Wiles proof of Fermat's Last Theorem is accepted.
1997	The largest number to be factorised to date has 167 digits: $(3^{349}-1)/2$ is split into its 80- and 87-digit factors by a team of US mathematicians after 100,000 hours of computing.
2000	Seven Millenium Problems are named by the Clay Mathematics Institute, with a prize of $1 million for the solution to each problem. The problems are the Birch and Swinnerton-Dyer Conjecture; the Hodge Conjecture; the Navier-Stokes Equations; P vs NP; the Poincaré Conjecture; the Riemann Hypothesis; Yang-Mills Theory.

Babylonian and Egyptian Mathematics

Go to site

Description of the mathematics of these two early civilizations. The site includes maps of the area at the time, images of tablets and scrolls dating back to that era, and also a list of publications for further reference. A short description of a scribe, Ahmes, who is credited with producing the Rhine scroll is also included.

History of Mathematics

Go to site

Overview of the history of mathematics with numerous links to important mathematicians from ancient times to the present day. The site includes sections on the problems of notation and communication, and on brilliant discoveries. There is also an extensive bibliography.

Mathematics Problem Solving Task Centre

Go to site

Australian site, updated monthly, containing not just one, but several problems each month. They are each designed for different levels of understanding. The main problems are divided into lower/middle primary, upper primary/lower secondary, and upper secondary levels. The site also includes a database of previous problems and a 'Challenging problem of the month'. Good maths practice!

NRICH: Mathematics Enrichment Club

Go to site

Online maths club developed jointly by the Royal Institution of Great Britain and the University of Cambridge. There are questions ranked by key stage, problems, puzzles, and articles, and students are encouraged to send in solutions.

What's New in Mathematics?

Go to site

Section of the American Mathematical Society's Web site aimed at the general public, with features on latest developments and buzz words.

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matrix

in biology, usually refers to the extracellular matrix.

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matrix

in mathematics, a square (*n* × *n*) or rectangular (*m* × *n*) array of elements (numbers or algebraic variables) used to facilitate the study of problems in which the relation between the elements is important. They are a means of condensing information about mathematical systems and can be used for, among other things, solving simultaneous linear equations (see simultaneous equations and transformation).

The advantage of matrices is that they can be studied algebraically by assigning a single symbol to a matrix rather than considering each element separately. The symbol used is usually a bold capital letter, but often a matrix is denoted by a symbol like $(a_{i\ j})$, meaning 'the matrix with element a in row i column j'.

The size of a matrix is described by stating the number of its rows and then the number of its columns so, for example, a matrix with three rows and two columns is a 3 × 2 matrix. A matrix with equal numbers of rows and columns is called a 'square matrix'.

Much early matrix theory was developed by the British mathematician Arthur Cayley, although the term was coined by his contemporary James Sylvester (1814-1897).

Matrices and Determinants

Go to site

History of the development and usage of matrices and determinants. This site also provides biographical background on the mathematicians responsible for the advancement of the topic, along with a description of the subject, and some examples.

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matter

in physics, anything that has mass. All matter is made up of atoms, which in turn are made up of elementary particles; it ordinarily exists in one of three physical states: solid, liquid, or gas.

states of matter

Whether matter exists as a solid, liquid, or gas depends on its temperature and the pressure on it. Kinetic theory describes how the state of a material depends on the movement and arrangement of its atoms or molecules. In a solid the atoms or molecules vibrate in a fixed position. In a liquid, they do not occupy fixed positions as in a solid, and yet neither do they have the freedom of random movement that occurs within a gas, so the atoms or molecules within a liquid will always follow the shape of their container. The transition between states takes place at definite temperatures, called melting point and boiling point.

conservation of matter

In chemical reactions matter is conserved, so no matter is lost or gained and the sum of the mass of the reactants will always equal the sum of the end products.

Matter and its Changes

Go to site

Detailed explanation of what matter is and how it undergoes physical and chemical changes. The site covers atoms and molecules; solids, liquids, and gases; and elements, compounds, and mixtures. It is supported by colourful images and diagrams.

States of Matter

Go to site

Summary of the various chemistry concepts associated with the states of matter. Part of a much larger chemistry site from the University of Akron, USA, this page explains kinetic molecular theory and the observed properties of the solid, liquid, and gaseous states. Other features include a set of key equations and an interactive practise exam.

Mauchly, John William (1907-1980)

US physicist and engineer who, in 1946, constructed the first general-purpose computer, the ENIAC, in collaboration with John Eckert. Their company was bought by Remington Rand in 1950, and they built the UNIVAC 1 computer in 1951 for the US census.

The work on ENIAC was carried out by the two during World War II, and was commissioned to automate the calculation of artillery firing tables for the US Army. In 1949 Mauchly and Eckert designed a small-scale binary computer, BINAC, which was faster and cheaper to use. Punched cards were replaced with magnetic tape, and the computer stored programs internally.

ENIAC's 50th Anniversary

Go to site

Account of John Mauchly and J Presper Eckert's construction of the first general-purpose electronic computer, ENIAC. This all-text site explains the importance of this 50-year-old innovation.

Mauna Kea

astronomical observatory in Hawaii, built on a dormant volcano of that name at 4,200 m/13,784 ft above sea level. Because of its elevation high above clouds, atmospheric moisture, and artificial lighting, Mauna Kea is ideal for infrared astronomy. The first telescope on the site was installed in 1970.

Telescopes include the 2.24-m/88-in University of Hawaii reflector (1970). In 1979 three telescopes were erected: the 3.8-m/150-in United Kingdom Infrared Telescope (UKIRT) (also used for optical observations); the 3-m/120-in NASA Infrared Telescope Facility (IRTF); and the 3.6-m/142-in Canada-France-Hawaii Telescope (CFHT), designed for optical and infrared work. The 15-m/600-in diameter UK/Netherlands James Clerk Maxwell Telescope (JCMT) is the world's largest telescope specifically designed to observe millimetre wave radiation from nebulae, stars, and galaxies. The JCMT is operated via satellite links by astronomers in Europe. The world's largest optical telescopes, the Keck Telescopes, are also situated on Mauna Kea. In 1999 the 8.1-m/319-in Gemini North reflector saw 'first light'. It is partnered with an identical telescope, Gemini South, at Cerro Pachón in the Chilean Andes.

In 1996 the capacity of the JCMT was enhanced by the addition of SCUBA (Submillimetre Common-User Bolometer Array). SCUBA is a camera comprising numerous detectors cooled to within a tenth of a degree of absolute zero (0 K) and is the world's most sensitive instrument at the 0.3-1.0-mm/0.01-0.04-in wavelength.

Mauna Kea Observatories

Go to site

Official site of the renowned observatories. A clickable image on the home page accesses information on the functions and findings of the group of telescopes atop Hawaii's highest peak. In addition to scientific data, there is information on access for visitors.

Maunder minimum

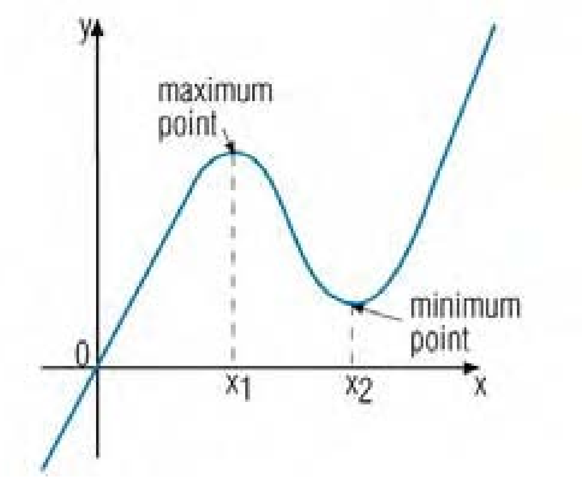
in astronomy, period 1645–1715 when sunspots were rarely seen and no auroras were recorded. The Maunder minimum coincided with a time of unusually low temperature on Earth, known as the Little Ice Age, and is often taken as evidence that changes in solar activity can affect the Earth's climate. The Maunder minimum is named after the English astronomer Edward Walter Maunder, who drew attention to it.

maximum and minimum

in coordinate geometry, points at which the slope of a curve representing a function changes from positive to negative (maximum), or from negative to positive (minimum). A tangent to the curve at a maximum or minimum has zero gradient.

Maxima and minima can be found by differentiating the function for the curve and setting the differential to zero (the value of the slope at the turning point). For example, differentiating the function for the parabola $y = 2x^2 - 8x$ gives $dy/dx = 4x - 8$. Setting this equal to zero gives $x = 2$, so that $y = -8$ (found by substituting $x = 2$ into the parabola equation). Thus the function has a minimum at the point (2, -8).

maximum and minimum



(Image © Research Machines plc)

A maximum point on a curve is higher than the points immediately on either side of it; it is not necessarily the highest point on the curve. Similarly, a minimum point is lower than the points immediately on either side.

maxwell

symbol Mx

c.g.s. unit of magnetic flux (the strength of a magnetic field in an area multiplied by the area). It is now replaced by the SI unit, the weber (one maxwell equals 10^{-8} weber).

The maxwell is a very small unit. It is equal to the flux through one square centimetre normal to a magnetic field with an intensity of one gauss.

Maxwell, James Clerk (1831–1879)

Scottish physicist. His main achievement was in the understanding of electromagnetic waves: **Maxwell's equations** bring together electricity, magnetism, and light in one set of relations. He studied gases, optics, and the sensation of colour, and his theoretical work in magnetism prepared the way for wireless telegraphy and telephony.

In developing the kinetic theory of gases, Maxwell gave the final proof that heat resides in the motion of molecules.

Studying colour vision, Maxwell explained how all colours could be built up from mixtures of the primary colours red, green, and blue. Maxwell confirmed English physicist Thomas Young's theory that the eye has three kinds of receptors sensitive to the primary colours, and showed that colour blindness is due to defects in the receptors. In 1861 he produced the first colour photograph to use a three-colour process.

Maxwell, James Clerk

Go to site

Extensive biography of the Scottish physicist and mathematician. The site contains a description of his contribution to physics, in particular his work on electricity and magnetism. Several literature references for further reading are also listed, and the Web site also features a photograph of Maxwell.

Visit to James Clerk Maxwell's House

Go to site

Biographical tour of the Edinburgh home of this famous Scottish physicist and mathematician. As well as chronicling Maxwell's life and works, this site, run by St Andrew's University, Scotland, examines his surroundings and family. The site also contains several pictures of Maxwell, his family, and the house.

Maxwell-Boltzmann distribution

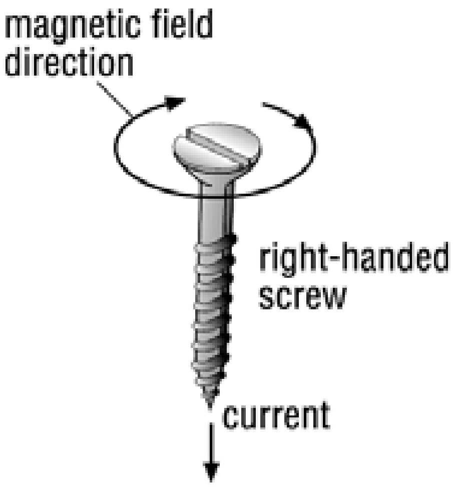
in physics, a statistical equation describing the distribution of velocities among the molecules of a gas. It is named after Scottish physicist James Maxwell and Austrian physicist Ludwig Boltzmann, who derived the equation, independently of each other, in the 1860s.

One form of the distribution is $n = N\exp(-E/RT)$, where N is the total number of molecules, n is the number of molecules with energy in excess of E, T is the absolute temperature (temperature in kelvin), R is the gas constant, and exp is the exponential function.

Maxwell's screw rule

in physics, a rule formulated by Scottish physicist James Maxwell that predicts the direction of the magnetic field produced around a wire carrying electric current. It states that if a right-handed screw is turned so that it moves forwards in the same direction as the conventional current, its direction of rotation will give the direction of the magnetic field.

Maxwell's screw rule



(Image © Research Machines plc)

Maxwell's screw rule, named after the physicist James Clerk Maxwell, predicts the direction of the magnetic field produced around a wire carrying electric current. If a right-handed screw is turned so that it moves forward in the same direction as the current, its direction of rotation will give the direction of the magnetic field.

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mayfly

any of a group of insects whose adult form lives only very briefly in the spring. The larval stage, which can last a year or more, is passed in water, the adult form developing gradually from the nymph through successive moults. The adult has transparent, net-veined wings. (Order Ephemerida.)

Mayo, William James (1861-1939)

US surgeon, founder, with his brother Charles Horace Mayo (1865-1939), of the **Mayo Clinic** for medical treatment in 1889 in Rochester, Minnesota.

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mayweed

any of several species of the daisy family native to Europe and Asia and naturalized elsewhere, including the European dog fennel or stinking daisy (*Anthemis cotula*), naturalized in North America, and the pineapple mayweed (*Matricaria matricarioides*), found in Europe and Asia. All have finely divided leaves. (Family Compositae.)

MD

abbreviation for **Doctor of Medicine**.

MDMA

(3,4-methylenedio-xymethamphetamine) psychedelic drug, also known as ecstasy.

ME

abbreviation for **myalgic encephalomyelitis**, a popular name for chronic fatigue syndrome.

meal-worm

any larva of the beetle genus *Tenebrio*, especially *T. molitor*. Meal-worms are slender and round, about 2.5 cm/1 in long, and tawny with bright rusty bands. They are pests of stored grain.

The adult of *T. molitor* is black, measures about 1.3 cm/0.5 in in length, has stout legs, and antennae with 11 joints,

classification

Meal-worms are in genus *Tenebrio* of the family Tenebrionidae, class Insecta, phylum Arthropoda.

mealy bug

kind of scale insect.

mean

in mathematics, a measure of the average of a number of terms or quantities. The simple **arithmetic mean** is the average value of the quantities, that is, the sum of the quantities divided by their number. The **weighted mean** takes into account the frequency of the terms that are summed; it is calculated by multiplying each term by the number of times it occurs, summing the results and dividing this total by the total number of occurrences. The **geometric mean** of *n* quantities is the *n*th root of their product. In statistics, it is a measure of central tendency of a set of data, that is one measure used to express the frequency distribution of a number of recorded events.

meander

loop-shaped curve in a river flowing sinuously across flat country. As a river flows, any curve in its course is accentuated (intensified) by the current. On the outside of the curve the velocity, and therefore the erosion, of the current is greatest. Here the river cuts into the outside bank, producing a **river cliff**. On the inside of the curve the current is slow and so it deposits any transported material, building up a gentle slip-off slope. As each meander migrates in the direction of its outer bank, the river gradually changes its course across the flood plain.

A loop in a river's flow may become so exaggerated that eventually it is cut off from the normal course and forms an oxbow lake. Meanders are common where the gradient is gentle, the discharge fairly steady (not subject to extremes), and the material that is carried is fine sediment. The word meander comes from the name of the River Menderes in Turkey.

mean deviation

in statistics, a measure of the spread of a population from the mean.

mean free path

in physics, the average distance travelled by a particle, atom, or molecule between successive collisions. It is of importance in the kinetic theory of gases.

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mean life

in nuclear physics, the average lifetime of a nucleus of a radioactive isotope; it is equal to 1.44 times the half-life. See radioactivity.

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measles

also known as rubeola

acute virus disease spread by airborne infection. Symptoms are fever, severe catarrh, small spots inside the mouth, and a raised, blotchy red rash appearing for about a week after two weeks' incubation. Prevention is by vaccination.

In 2003, 530,000 children died of measles worldwide. In industrialized countries measles is not usually a serious disease, but serious complications may develop, so most developed countries have a vaccination programme. Measles kills approximately one in 5,000 children who develop the disease in developed countries. It also has a one in 1,000 risk of causing encephalitis, which leaves half of those children who develop it brain-damaged.

Childhood Infections - Measles

Go to site

Educational page on measles, providing information on the signs, symptoms and progress of the disease. It also addresses issues such as possible complications, vaccination, home treatment, and contagiousness.

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mechanical advantage

MA

in physics, the ratio by which the load moved by a machine is greater than the effort applied to that machine. In equation terms: MA = load/effort.

The exact value of a working machine's MA is always less than its theoretical value because there will always be some frictional resistance that increases the effort necessary to do the work.

mechanical advantage

To remember the definition of mechanical advantage:

Men **a**lways **l**ike **e**ating

MA - **l**oad over **e**ffort (l/e)

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mechanical equivalent of heat

in physics, a constant factor relating the calorie (the c.g.s. unit of heat) to the joule (the unit of mechanical energy), equal to 4.1868 joules per calorie. It is redundant in the SI system of units, which measures heat and all forms of energy in joules.

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mechanics

branch of physics dealing with the motions of bodies and the forces causing these motions, and also with the forces acting on bodies in equilibrium. It is usually divided into dynamics and statics.

Quantum mechanics is the system based on quantum theory, which has superseded Newtonian mechanics in the interpretation of physical phenomena on the atomic scale.

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mechanization

the use of machines in place of manual labour or the use of animals. Until the 1700s there were few machines available to help people in the home, on the land, or in industry. There were no factories, only cottage industries, in which people carried out work, such as weaving, in their own homes for other people. The 1700s saw a long series of inventions, initially in the textile industry, that ushered in a machine age and brought about the Industrial Revolution.

Among the first inventions in the textile industry were those made by John Kay (flying shuttle, 1773), James Hargreaves (spinning jenny, 1764), and Richard Arkwright (water frame, 1769). Arkwright pioneered the mechanized factory system by installing many of his spinning machines in one building and employing people to work them.

Medawar, Peter Brian (1915-1987)

Brazilian-born British immunologist who was awarded a Nobel Prize for Physiology or Medicine in 1960 with Macfarlane Burnet for their work on acquired immunological tolerance of transplanted tissues. They discovered that the body's resistance to grafted tissue is undeveloped in the newborn child, and studied the way it is acquired. Medawar was knighted in 1965.

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media

singular medium

in computing, the collective name for materials on which data can be recorded. For example, paper is a medium that can be used to record printed data; a floppy disk is a medium for recording magnetic data.

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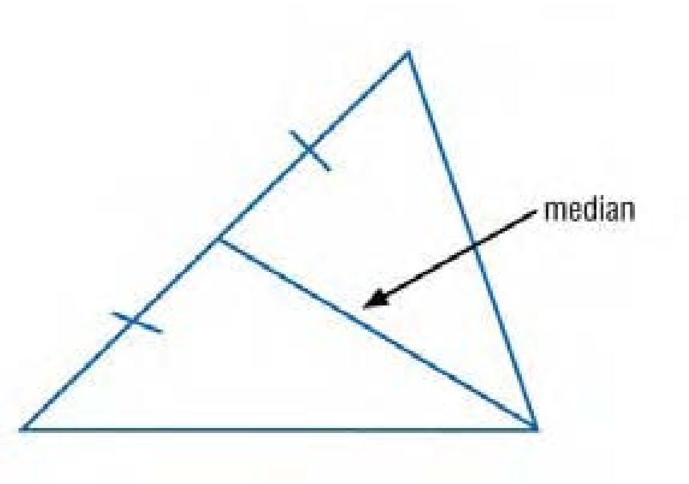
median

in mathematics and statistics, the middle number of an ordered group of numbers. If there is no middle number (because there is an even number of terms), the median is the mean (average) of the two middle numbers. For example, the median of the group 2, 3, 7, 11, 12 is 7; that of 3, 4, 7, 9, 11, 13 is 8 (the mean of 7 and 9). The median together with the mode and arithmetic mean make up the average of a set of data. In addition it is useful to know the range or spread of the data.

In geometry, the term refers to a line from the vertex of a triangle to the midpoint of the opposite side.

median



(Image © Research Machines plc)

The median is the line from the vertex (corner) of a triangle to the mid-point of the opposite side.

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medical ethics

moral guidelines for doctors governing good professional conduct. The basic aims are considered to be doing good, avoiding harm, preserving the patient's autonomy, telling the truth, and pursuing justice. Ethical issues provoke the most discussion in medicine where these five aims cannot be simultaneously achieved – for example, what is 'good' for a child may clash with his or her autonomy or that of the parents.

Traditionally these principles have been set out in the Hippocratic Oath (introduced by Greek physician Hippocrates and including such injunctions as the command to preserve confidentiality, to help the sick to the best of one's ability, and to refuse fatal draughts), but in the late 20th century rapidly advancing technology has raised the question of how far medicine should intervene in natural processes.

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medicine

the practice of preventing, diagnosing, and treating disease, both physical and mental; also any substance used in the treatment of disease. The basis of medicine is anatomy (the structure and form of the body) and physiology (the study of the body's functions).

In the West, medicine increasingly relies on new drugs and sophisticated surgical techniques, while diagnosis of disease is more and more by noninvasive procedures. The time and cost of Western-type medical training makes it inaccessible to many parts of the developing world; where health care of this kind is provided, it is often by auxiliary medical helpers trained in hygiene and the administration of a limited number of standard drugs for the prevalent diseases of a particular region.

Ethics in Medicine

the crossroads reached?

With advances in medical science, doctors often face agonizing moral decisions. Babies can now be kept alive with handicaps so severe that they would have died soon after birth a few years ago. What, for instance, should doctors do about a baby born with its brain outside its head? Many people would agree that it would be wrong to prolong the life of such a baby, but if a doctor lets the baby die, is this the same as killing it?

the moral dilemma

Similarly, some doctors have argued that nothing should be done to prolong the life of babies born with spina bifida, because such babies otherwise experience terrible suffering. (Adults with spina bifida often disagree, believing that their lives are worthwhile despite their suffering.) Yet the same doctors argue against infanticide for spina bifida babies, on the grounds that it would brutalize staff, traumatize parents, and reduce respect for human life.

handicap and the quality of life

With less severe forms of handicap, the issue is even less clear. The quality of the lives of Down's syndrome children is usually not unbearably awful, and they can live enjoyable and serene lives. But what about a Down's Syndrome baby born with a life-threatening condition, such as a serious intestinal blockage?

Some years ago, the parents of just such a child – baby Alexandra – wanted her to die, believing that nature had 'made its own arrangements to terminate a life which could not be fruitful'. The doctor would not operate without their consent. Eventually, the local social services department succeeded in persuading the courts to overturn the parents' decision.

the case of Dr Arthur

A rather different judgement was given in the case of Dr Arthur, a senior consultant paediatrician in Derby. He was asked to examine a newly born Down's Syndrome baby, whose parents were very distressed. Dr Arthur noted: 'Parents do not wish it to survive. Nursing care only.' He prescribed a sedative to alleviate the baby's distress, as and when it arose. Three days later, the baby died of broncho-pneumonia.

Dr Arthur was charged with murder; but the prosecution's case fell apart when it emerged that a post-mortem examination had shown that the baby had potentially fatal heart, lung, and brain defects. Dr Arthur was then charged with attempted murder, but was acquitted. The judge observed that it was lawful to treat a baby with sedation and nursing care only, if certain criteria were met – that the child was rejected by its parents and was irreversibly disabled.

dominant themes

There are, of course, many other issues in medical ethics, apart from whether severely handicapped babies should be allowed to die. Here, there is space to mention only the main themes:

1. *respect for life*: Since we generally accept that we may kill other people in war and in self-defence, is life absolutely sacred or not? Is it right to preserve life if the quality of that life is likely to be poor? Should doctors preserve life at all costs and by extraordinary means?

And if not, where should doctors draw the line? Is switching off a life-support machine the same as murder? In general, since we distinguish between an act and its omission, is there a difference between killing someone and letting someone die?

2. *patient autonomy*: This theme arises in a variety of medical contexts – such as medical confidentiality, voluntary euthanasia, or experimentation on humans. Since patients must give informed consent to an experimental procedure, how much information is the patient to be given, and how detailed should it be? The problem is particularly acute in the case of randomly controlled trials which require the patient's agreement to receiving at random alternative forms of treatment.

3. *resource allocation*: What are the ethical and rational principles of distribution for medical resources? Where expensive but life-saving treatments are available, how should they be rationed? When kidney dialysis machines were novel and scarce, some doctors treated patients on a 'first come, first served' basis, while others gave precedence to younger patients or those with dependents.

4. *reproductive technologies*: Should a doctor prescribe the Pill to a 12-year-old girl? Should post-coital 'contraceptives' – 'morning after' pills – be prescribed? Is abortion murder? If embryos resulting from in vitro fertilization are frozen in case the implanted embryo should miscarry, what is to be done with these embryos if both parents die, as happened in Australia in 1984? Should post-menopausal women have fertility treatment? Should surrogate mothers be permitted to rent their wombs to the highest bidder? If a surrogate mother changes her mind and decides to keep the baby, should she be entitled to do so? Should parents be able to choose the sex of their babies? If homosexuality has a genetic basis, should parents be able to abort a fetus carrying 'gay genes'? As genetic engineering and screening become available, what sort of people should there be? As we enter the 21st century, this is perhaps the most challenging ethical issue of all.

moral philosophy in medical ethics

Medical ethics has been described, rather unfairly, as an adventure playground for moral philosophers. To anyone unfamiliar with philosophy, the fact that different philosophers come to different conclusions about the same problems in medical ethics is frustrating. But, then, philosophers can often do little more than clarify the questions to be answered or considered by busy doctors who frequently have to make difficult decisions under stress.

no moral consensus

Moreover, in society at large, no single moral outlook currently prevails on matters of birth, of death, of suffering and of sexuality: there is moral pluralism, and a lack of moral consensus. However, by clarifying the issues, philosophers can help to build a consensus in medical ethics. Perhaps, though, such consensus is unlikely to emerge without consensus on not only an overall philosophy of medicine that clarifies what medicine is for, but also an overall moral philosophy that clarifies what human life is for and what its ends are.

Health in Ancient Rome

introduction

The ancient Romans suffered from numerous threats to health: war, food shortages, and many infectious diseases. They had no idea of the germ theory of disease, and instead believed that health was dependent on diet and life-style, with some conditions – in particular, epidemic diseases – coming from the gods. Pliny the Elder (*c.* AD 23–79) regarded the art of medicine as a Greek invention, writing that the Roman people had survived without medicine for more than six centuries; but there is evidence that a medicine without doctors was in fact more characteristic of Roman life.

traditional folk medicine

In the early Roman republic, preserving health and curing sickness were mainly a matter for the family. The head of household (the paterfamilias) was responsible for the well-being and fertility of his family members, slaves, and domestic animals. Remedies were based on easily available substances; in his handbook on agriculture, Cato (234-149 BC) recommended cabbage, with bruised leaves being applied to cure external conditions, and concoctions drunk for internal complaints. Pliny the Elder also advised readers of his encyclopedia to use cabbage, wool, and eggs to heal many diseases. Substances could be applied to the accompaniment of magic chants. In the first century AD Celsus (flourished AD 14-37) compiled an encyclopedia of information which every literate Roman should know; only the eight books on medicine survive. These cover a healthy diet, and outline the diseases which can affect the whole body and its constituent parts.

Greek medicine in Rome

By the mid-second century BC, Rome had conquered much of the Greek world, and in the process was being influenced in areas such as art, architecture, and medicine. Greek doctors believed in the importance of the individual regulating every aspect of life, keeping a balance between the constituent fluids of the body (the 'humours') by monitoring diet and exercise according to personal physique, the season, and the environment in which one lived. Some Romans were suspicious of Greek medicine, regarding it as too theoretical, particularly in its use of very complex drug recipes involving many ingredients. They could not understand how different doctors could hold such different beliefs about the causes of disease, and they were disturbed by the fact that these doctors expected a fee for their services. They feared that Greek doctors were out to poison their Roman conquerors; indeed, the first Greek doctor to be given citizen's rights in Rome, Archagathus, was colloquially known as 'The Executioner' (*carnifex*) because of his enthusiasm for surgery and cauterization. But, by the first century AD, about 90% of doctors in the Roman world were Greeks.

social status of doctors

Many Greek doctors in the western part of the Roman empire were of slave or freedman status. In the Greek-speaking East, doctors had higher status, and many served as local officials in their cities. Like other craftsmen, doctors belonged to trade guilds which acted as social clubs and looked after their members' welfare. Some learned their craft from family members, or by apprenticeship, but – in the absence of formal medical training – anyone could set up as a doctor. The best way to win a reputation as a good doctor was simply to score a success in treating a rich and famous patient.

Galen of Pergamum

Galen (129–216 AD) was the best-known, most prolific (writing about 350 books) and subsequently most influential doctor in the Roman world. After treating the gladiators at Pergamum from 157 onwards, he moved to Rome in 162 and went on to become personal physician to the emperor Marcus Aurelius and his family. His medical theories combined Aristotle's logic, Plato's notion of three body systems governed respectively by the liver, the heart and the brain, and the Hippocratic four humours: blood, black bile, yellow bile, and phlegm. He claimed that he carried out animal dissections every day, in order to understand the structure of the body.

cities and countryside

The city of Rome was famous for the aqueducts and sewers among its feats of civil engineering, but living conditions in most cities were poor; aqueducts were built predominantly to show the civic spirit of the person funding them, and as a way of boosting a town's image. By the first century BC, most Roman towns had a public bath, and villas and large town houses often had a private bath complex, but the primary purpose of baths was social; they provided a meeting place. Although aqueducts could supply street fountains, sewage systems were often inadequate, while water supply arrangements excluded the private citizen. Indeed, substances such as urine and faeces were considered to be effective substances in medical treatments. Doctors were largely an urban phenomenon; some cities appointed a public physician for their inhabitants. Traditional, cheap herbal remedies were not easily available to city dwellers, but in their place were many expensive imported drugs from all over the Roman empire.

the dangers of empire

Many Romans believed that conquest damaged their health, because it exposed them to a wide range of new exotic imports, including new foods and drinks, which they thought caused new diseases to arise in their bodies. Greek medicine, by offering drugs to produce vomiting in those who had overeaten, was condemned as treating the symptoms rather than the cause. Roman writers instead recommended a simple diet and a sensible lifestyle, taking responsibility for oneself and relying on Nature to provide healing.

hospitals and temples

In large households, sick slaves could be cared for in special buildings called *valetudinaria*. In the army, the general was responsible for the health of his soldiers; in permanent forts, purpose-built hospitals were set up, with a set of rooms opening off a square courtyard. For most people, however, care remained in the family, although it was also possible to visit the temple of a god or goddess associated with health. The most famous of these were dedicated to Asclepius, a god imported to Rome from Greece in 292 BC, and whose daughter Hygieia was the personification of good health.

Medicine in the 20th century

introduction

In the 20th century, biology came into its own; and medicine, the application of biology that the majority of us care most about, was transformed. This was no more than people at the turn of the 20th century expected. They had watched earlier sciences create new empires of energy and industry and they had seen a few glimpses of what science could do for medicine. Anaesthetics had quietened the screams of the operating room. Antisepsis helped keep the surgeon's patients alive. Most amazing, the germ theory of disease finally convinced people that lumbering humans could be felled by the tiniest organisms – and that we could do something about it. The great defenders of the germ theory such as the French chemist and microbiologist Louis Pasteur (1822–1896) and the German bacteriologist Robert Koch (1843–1910) were fêted around the world as scientific benefactors of humanity. Who could have foretold what would be achieved by building on their work?

But even the most optimistic would have been amazed anew by some of the medical technologies of the century to come. Visit a hospital today. This patient gets eye surgery by laser; that one sits in a machine which makes pictures of the inside of the brain; another wants to hear the results of a chemical readout from the DNA in their cells; or perhaps the appointment is to insert a tiny pacemaker to steady the beat of a faltering heart – all undreamt of a century before. What is more, the chances are that all of these patients have already evaded death from at least one of the scourges of the 19th century, simply through routine use of vaccines and antibiotics. As a group, they will live longer and be cared for more knowledgeably than any people in history.

Most likely they will worry more, too. A time-traveller from 1900 would be amazed by the turnaround in our attitudes to health and to doctors. We seem to have replaced fatalism with new fears and deference with doubt. Modern scientific medicine works wonders, but we are not happy just trusting the wonder-workers to do their stuff. We may benefit from the most successful medicine and health science ever developed but we still want more. Some diseases can be cured but we want cures for everything. So we pour billions of dollars every year into new research and in the meantime, we try elsewhere. More than 40% of Americans had tried an 'alternative' medical therapy in the late 1990s. Some were worried about side effects from prescribed drugs. Some were taking food supplements to ward off cancer. Some were simply seeking relief from symptoms regular physicians can do little about, such as allergies or back pain.

diagnosis

The first thing a doctor has to do when faced with a new patient is make a diagnosis. Disease is usually going on inside the body. Sometimes there are signs on the surface, but the key to diagnosis is getting information from the inside to the outside. You can ask the patient where it hurts. You can examine what comes out – by sniffing the urine, say. You can listen, maybe using a stethoscope to help. You can try looking inside by shining lights down tubes that have to be swallowed or inserted into the rectum. But unless you want to cut the patient open, anything more needs smarter technology. That began just before the beginning of the 20th century, with the discovery of X-rays by German physicist Wilhelm Röntgen (1845–1923).

Visualizing inside the body The use of X-rays in hospitals, and even on the battlefields of World War I, for diagnostic purposes was one of the most rapid disseminations of a new medical technique. Early medical X-rays were relatively crude by today's standards, and were in fact initially used for dubious purposes, such as the treatment of acne or heavy menstrual periods, in the years between the two world wars, but were quickly improved when the dangers of exposure were more fully documented and understood. Ever stricter regulation lead to exposure times coming down, until today's principle of ALARA (as low as reasonably attainable), and chemicals opaque to the rays were injected or swallowed to show up internal organs. A notable landmark was cardiac catheterization, first tried in 1929 in Germany, which allowed radio-opaque dye to be introduced directly into the heart.

With techniques like this, diagnostic X-rays were refined through the 20th century, reaching their peak with the technique of CAT (computerized axial tomography) scanning, which builds up a three-dimensional image from repeated cross-sectional X-rays. The first CAT scan was taken by the English engineer Godfrey Hounsfield (1919–2004) in 1972. By then X-rays had already been supplemented by ultrasound – bouncing high frequency sound waves off different tissues – developed in the 1950s by the Scottish obstetrician Ian Donald (1910–1987), and infrared imaging. CAT scans were followed by imaging techniques using more sophisticated physics, notably magnetic resonance imaging (MRI), which produces images of the body by beaming radio waves into a patient lying in a strong magnetic field, and positron emission tomography (PET). PET can take detailed pictures of which parts of the brain are active, and how the activity changes over time.

These are all ways of visualizing the inside of the body. Direct visualization has also been improved by use of fibre optics for endoscopes, which can be threaded into most body cavities fairly painlessly, and by 20th-century improvements in microscopy. Small tissue samples (biopsies) can give up lots of information when inspected under light, ultraviolet, or powerful electron microscopes, all now in clinical use. Without microscopy, there would be no smear tests for cervical cancer; no amniocentesis, in which fetal cells from a mother's amniotic fluid are examined; and no way to identify viruses recovered from body tissue or fluids. Nor would we understand nearly as much about what we find.

What about other kinds of information? The state of the brain and the heart can be assessed electrically. The first electrocardiograph (ECG) was built by the Dutch physiologist Willem Einthoven (1860-1927) around the turn of the 20th century. Like all of these instruments, it was and is used for research as well as diagnosis, and detailed electrical recordings are still used to test the latest theorizing about the rhythmic control of heart muscle cells, which draws on chaos theory and computer simulation. For the brain's internal electrical conversation, external recording relies on the electroencephalograph (EEG).

Understanding the body Then there are tests for things which cannot simply be identified by inspection. The more molecules with vital functions biologists identified - vitamins, hormones, enzymes, neurotransmitters - and the better their functions were understood, the more there was to test for. Specific antigens, usually protein molecules, and their complementary antibodies, may be found in the blood. This makes possible tests of varying reliability for conditions as diverse as prostate cancer (levels of the prostate specific antigen, PSA) or infection with the human immunodeficiency virus (HIV).

At the same time, deeper understanding of the information inside the cell has led to tests for inherited disorders - first examining the chromosomes, then looking for particular genes, nowadays often recording specific sequences of DNA bases in a gene. Here, diagnosis begins to shade into prediction, as genes associated with, say, breast cancer, only indicate an increased susceptibility to a common condition. As the information gets more detailed, so deciding what it means becomes more complicated.

However, not all DNA tests are ambiguous. At the beginning of the 21st century, we are starting to exploit DNA technology to improve on some of the older tests. It will be faster and more accurate to identify an organism taken, for example, from a blood sample, by reading its DNA than by growing it and peering down a microscope. Bacteria in a sample may not survive the journey from patient to laboratory via doctor but even dead bacteria will yield up their DNA. It may even be possible to spot telltale signs of cancer by recovering altered DNA. As with almost all the other tests already mentioned, these techniques can be applied to more people with the help of automated machines to do the chemistry and computers to analyse the results faster.

This enormous set of advances in knowledge and technique means that very few diagnoses are now made by classical history-taking and physical examination alone. Even when the doctor has a pretty good idea what the matter is, the likelihood is that a few tests will follow, to confirm the diagnosis and to rule out more exotic alternatives. There are still some conditions, like chronic fatigue syndrome, whose causes are elusive and which are difficult to diagnose. And however refined the scientific tests become there are always both false positives (an indication you have some condition when in fact you do not) and false negatives (getting the all-clear when you are really ill) to deal with. But doctors at the beginning of the 21st century have a rather better chance of knowing what ails you than their counterparts did 100 years ago.

treatment

There is something different about 21st-century medical treatments: they work. Not all treatments were ineffective before, but none were infallible and few indispensable. Fortunately, almost no diseases kill all-comers, so doctors' reputations could safely be built on a reliable incidence of spectacular recoveries. If the patient died, well that was what people mostly expected to happen. Now, we expect better results, and if we do not get them the threat of a lawsuit is always in the background.

This is one of the more remarkable historical shifts of the 20th century. As US physician and academic Lewis Thomas (1913-1993) relates in his medical memoir *The Youngest Science*, a doctor in training as late as the 1930s learnt mainly disease classification and diagnosis. Once you had identified the condition, you could tell the patient what was likely to happen, but there was little to be done to influence the outcome: 'the treatment of disease was the most minor part of the curriculum, almost left out altogether.'

early success Thomas and others say the turning point came in 1935, with the advent of the so-called sulfa drugs. The German chemist Gerhard Domagk (1895-1964) used the dye Prontosil that year to cure his daughter of a streptococcal infection, and others quickly found that the active part of the dye was the chemical sulphanilamide. It was the fruit of the dream of the Domagk's great compatriot German bacteriologist and immunologist Paul Ehrlich (1854-1915), who had searched for 'magic bullets' against particular pathogenic organisms. Ehrlich, inspired by his belief that the human immune system produced chemicals to kill invaders, synthesized hundreds of compounds and was finally rewarded with Salvarsan (announced in 1910) as a treatment for the sexually transmitted disease syphilis.

This success was not repeated until Domagk's discovery, which boosted the search for more synthetic drugs. At the same time, naturally occurring chemical killers - antibiotics - were nearing clinical use. First, and most famously, came penicillin, identified by Scottish bacteriologist Alexander Fleming (1885-1955) in 1928. This major discovery was made quite by accident, when some bacteria-containing petri dishes were set aside. He later noticed that specks of green mould had appeared on the nutrient agar and the bacterial colonies around the specks had disappeared. But Fleming found it hard to grow enough *Penicillium notatum*, the mould that normally makes penicillin to defend itself from bacteria. Penicillin was also proved unstable in use and so Fleming moved on to other things. Eleven years later, German-born British biochemist Ernst Chain (1906-1979) and Australian pathologist Howard Florey (1898-1968) in Oxford, managed to purify the drug and the war effort soon saw it in mass production in the USA.

Penicillin was highly effective against some but not all bacteria, and the post-war search for new antibiotics yielded a rich harvest. The range of antibacterial agents proliferated greatly in the second half of the 20th century, to the point where they were regarded as overused in many situations. This has increased the possibility of resistance among new strains of bacteria, and among patients who received antibiotics too frequently or for the wrong purposes. Hospitals saw outbreaks of MRSA (methicillin-resistant *Staphylococcus aureus*) and other 'superbugs' that were untreatable using antibiotics because the bacteria were resistant to all known medicines. The search for new ways of tackling these resistant bacteria will always continue but many old terrors are terrors no more. Pneumonia, meningitis, tuberculosis, diphtheria: all have become treatable by timely administration of the right drug.

viral attack That still left infectious diseases caused by viruses and the search for antiviral agents has been much less successful. Viruses hijack the machinery of human cells to reproduce themselves, and agents used to treat serious viral infections, such as AZT (trademark for azido-thymidine), which is prescribed for people infected with HIV, also have serious side effects. Acyclovir is now available over the counter for herpes infections - such as shingles and cold sores - but has few rivals.

treatment advances In other areas, though, the drug revolution was more productive, if not often delivering the miracle cures which antibacterials seemed to be. The first drug for a psychiatric condition was lithium, introduced for treatment of manic depression by Australian psychiatrist John Cade (1912–1980) in 1949. Others followed for use in depression or schizophrenia, though like most other things connected with psychiatry, their use remains controversial. A tradition that continued with the introduction of the selective serotonin-reuptake inhibitors (SSRIs), the drug family that includes Prozac, in the 1990s. By the beginning of the 21st century, court cases were being fought over whether or not Prozac is responsible for radical personality changes that may lead to crime.

Then there were a host of drugs to help manage other conditions – drugs to regulate blood pressure, heart rate, or urine production, to relieve symptoms of arthritis or asthma, to reduce cholesterol or prevent blood clotting. And the way such drugs are developed changed, too. Where Ehrlich or Domagk made new chemicals and tried them out, increasing understanding of our metabolism and of immunology, endocrinology, and especially, cell biology, meant that drugs could, at least in theory, be designed for particular targets. Alternatively, natural body chemicals could be identified and used in treatment.

The most obvious examples of this strategy are the hormones. When the Canadian physician Frederick Banting (1891–1941) and physiologist Charles Best (1899–1978) discovered in 1922 that diabetic symptoms were induced by lack of insulin, it was logical to work towards treating the disease by purifying the hormone and giving it by injection. Insulin is only one of many of the body's chemical messengers, both hormones and neurotransmitters, that have been isolated in the 20th century, and many have found clinical uses. There are probably more to come. Chemicals which activate cells in the immune system, for example, like interleukin 2 discovered in 1985, is being pioneered in the treatment of cancer, HIV, and multiple sclerosis.

Another hormone-based treatment was the development of the contraceptive pill by Gregory Pincus (1903–1967) and others in the 1950s, and the freedom it gave women to time their reproduction. Various forms of birth control were disseminated in an effort to stem the growth of the world's population. In the last third of the 20th century the understanding of the menstrual cycle and menopause led to the development of hormone replacement therapy and other modifiers of the side effects of hormonal imbalances. Trials of a contraceptive pill for men began in 2004.

transfusions and transplants This chemical revolution certainly accounts for many of the advances in treatment seen in the last century. However, not all treatments operate at the molecular level, though even those that have benefited from improvements in understanding about the minute details of biological systems. Blood transfusion, for example, is a fairly simple undertaking, but is only safe if blood of different types is kept apart. Otherwise, cross reaction makes red blood cells clump together and kills the recipient. This had been discovered in the early 19th century but was not fully understood till 1900, when Austrian-born US immunologist Karl Landsteiner (1868–1943) theorized that blood cells carry antigen molecules on their surfaces. The main types are A, B, AB, and O, the latter denoting the absence of either A or B.

This insight was not taken up to make transfusion normal practice for several decades, but Landsteiner spent the rest of his long career working on similar problems. In 1940, he helped discover the rhesus factor, a separate cell surface antigen in blood, which accounted for the intolerance some mothers' immune systems showed towards the blood of their unborn children.

The growth in understanding of the immune system also lay behind the rise of one of the best-publicized techniques of the 20th century, transplant surgery. French-born US surgeon Alexis Carrel (1873–1948) – who like Landsteiner went to the USA to work at the Rockefeller Institute in New York – pioneered the surgical joining of blood vessels to transferred organs as early as 1910. But this was little use because transplanted organs quickly degenerated.

Not until the 1940s did Brazilian-born British immunologist Peter Medawar (1915–1987) show that this was due to the new host's body making antibodies that attacked the foreign organ. Like the rhesus reaction, this confirmed that the body's defensive immune system reacts against anything which is recognized as 'not from here', not just against pathogens. On one hand, this theory helped in the recognition of autoimmune diseases, in which the patient's own tissues are attacked in error (conditions as diverse as arthritis and multiple sclerosis can be caused in this way); on the other hand, it finally paved the way for the new direction in surgery. The surgeon would no longer be restricted to finding more ingenious ways of cutting things out, or rejoining them. Now there was a possibility of replacement.

The first successes came through tissue-typing. If a new organ was immunologically compatible, it would escape rejection – and this was the basis for the first successful kidney transplants in the mid-1950s. A close relative willing to sacrifice a kidney was required for the operation. Transplanting unpaired organs (a kidney donor can live happily on their remaining kidney) took longer, but liver and lung transplants were soon tried. Finally, in 1967, the South African surgeon Christian Barnard (1922 –) took the heart of a young female car accident victim and used it to replace the diseased heart of 57-year-old Louis Washkansky.

Washkansky died 18 days later, and few of the 100 or so other heart recipients over the next year did much better. Again, the problem was immune reaction, and it was not until the introduction of the most effective immunosuppressive drug, cyclosporin, in the 1970s, that regular transplantation became possible. There were still great risks at this heroic end of medicine – suppressing the immune system saves the transplanted organ but lays the patient open to infection – but they were better than waiting to die. By the late 1990s, research was being carried out in the genetic modification of pig hearts so that they could fool the human immune system, to overcome a chronic shortfall of organ donors. The transplantation of animal organs to humans (xenotransplantation) carries the risk of the transmission of viruses from animals to humans as well as raising ethical complications.

Replacements do not have to come from living sources, of course. Separate lines of research have enabled many body parts and functions to be replaced artificially. This is most difficult for complex organs and surgeons cannot yet implant an artificial heart or kidney. Machines which operate externally are a different matter. The heart-lung machine, mainly developed by US surgeon John Gibbon (1903–1973) in the 1950s, ushered in the era of open-heart surgery as it enabled the surgeon to stop the heart during the operation, relying on the heart-lung machine to keep the blood pumping around the body. Kidney dialysis machines have been keeping patients with renal failure alive since the 1940s.

Simpler internal replacements have been spectacularly successful. Perhaps the most important for quality of life has been the artificial hip joint, pioneered by the British orthopaedic surgeon John Charnley (1911-1982) in the 1960s. Materials had to be found that could make a smoothly working joint, be attached to bone, and that would survive inside the body. Many thousands of arthritic hips are replaced every year and new techniques allow patients to leave hospital the next day.

genetic revolution? The next therapeutic revolution, based this time not on biochemistry or immunology but on genetics, may yield new improvements. The detailed understanding of the working of the genes elaborated in the last half of the 20th century has so far been mainly of diagnostic use. But gene therapy experiments are already under way. The idea is usually to make up for the absence of some vital protein by giving the patient the gene which contains the information to make it. The first proper experiment was as early as 1990, and involved the gene for adenosine deaminase being used to treat a child deficient in this important enzyme. Her condition improved, but as she was also taking powerful drugs this was not a perfect test. More recent trials, for example trying to replace the gene which is at fault in cystic fibrosis, have had mixed results. However, the late 20th-century's favourite method for encouraging biomedical innovation – venture capital investment in biotechnology companies – means that gene therapy is already a billion dollar industry, even if it is not yet clear what the product is. However, the industry received a major setback when US teenager Jesse Gelsinger died during a gene therapy trial in 1999.

In 1998, US gene therapy pioneer W French Anderson began to discuss a proposal to perform gene therapy on fetuses, by injecting them with genetically engineered viruses. The experiment would aim to correct adenosine deaminase deficiency in an unborn child. The possibility that some viruses could enter the fetus's germ cells, so that the engineered gene would be passed on to the next generation, sparked strong opposition to the proposal. Like heart transplants in their day, it seemed to some that medical goals might take science a step too far.

process of discovery This is just a selection from the vast range of innovation in treatments. New ones are constantly being tried, and a further essential development in 20th century medical science was the development of procedures for discovering which treatments are truly worthwhile. A stricken patient and a doctor with a bright idea remain a key way of advancing medical theory, but what turns a theory into an effective, workable treatment? The now grateful patient and the enthusiastic doctor may be convinced that their idea is a perfect treatment, but the only way to know for sure is by comparison. And the best way to make the comparison is in the form of a controlled trial.

The first modern clinical trial, with random assignment of patients to new or conventional therapy, was used by the English epidemiologist Austin Bradford Hill (1897-1991) in 1946 to test the use of streptomycin against tuberculosis. As drug licensing regulations tightened up in the decades after World War II, animal and then staged clinical trials became a major industry, trying to ensure that a new substance was better than existing drugs, and was safe to use. Nowadays, the 'gold standard' is the blind randomized trial, based upon those early tuberculosis trials, where those assessing the results do not know which patient is in which group. Many current medical controversies turn on interpretation of trial results in this and other areas. Do the tens of thousands of heart bypass operations carried out every year actually prolong lives, for example?

This approach to trials was refined with more powerful statistical techniques, including so-called 'meta-analysis' to combine the results of many different trials, but nowadays all this statistical power is usually deployed in pursuit of marginal improvements. Perhaps this is because the main fruits of the therapeutic revolutions of the 20th century have now been gathered, and researchers are doing more work for smaller gains. Certainly the results of the innumerable trials of cancer treatments – whether surgical, or using radiation, or cell-killing drugs – almost all make depressing reading.

The search for more powerful therapeutic technologies will continue, however. As infectious disease has largely succumbed to scientific medicine, doctors face intractable problems with conditions which many used not to live long enough to be troubled by – cancer, heart disease, and Alzheimer's disease all increased sharply in the 20th century. Their causes are complex, and their cures elusive. This is one reason for thinking hard about the third strand of medical practice after diagnosis and treatment: prevention.

prevention

The treatments which people remember are simple and effective. We would really like all therapies to be like the best antibiotics – pop a pill and watch your symptoms disappear. As we have said, fewer treatments are like that these days. But prevention is even more difficult to pin down, so, while there were some spectacular successes in the 20th century, preventive efforts nowadays often lose headway for two reasons: there may be many causes, not just one, of today's major diseases; and it may be the patient, not the doctor, who has to do something or, perhaps more difficult, stop doing something.

vaccination Some of the greatest successes come from vaccination. As pursuit of the germ theory revealed more and more pathogenic organisms, so more vaccines became available. Vaccine development may not work. We have known that malaria is caused by the parasitic organism *Plasmodium* since the work of the Indian-born British physician and bacteriologist Ronald Ross (1857-1932) in 1897, but there is still no effective vaccine (though we are quite good at killing the mosquitoes whose bites spread the disease). But there have been more successes than failure, with vaccines against viral diseases – including yellow fever, polio, measles, rubella, and mumps – a particularly important innovation. Smallpox, the target of a global campaign coordinated by the World Health Organization, was declared completely eradicated in 1980.

These advances also mean we can now hope to be better defended against new viral strains. To demonstrate this, look back at the global epidemic of influenza in 1918, which killed more people than World War I. Fifteen years later, US microbiologist Thomas Francis, Jr (1900-1969), pinned down the virus responsible for the flu, and the first effective vaccine was on offer by 1945. New vaccines can now be manufactured in quantity whenever a novel strain of flu is identified. Hitherto unknown viruses, like the AIDS virus HIV identified by French molecular biologist Luc Montagnier (1932-) and US biologist Robert Gallo (1937 -) in 1983-84, are a different matter.

diet and nutrition Also important for prevention were the biochemical discoveries of the early part of the 20th century, especially the increasingly long list of vitamins – substances only needed in small amounts but whose absence can be devastating. A key figure here was the English biochemist Frederick Gowland Hopkins (1861-1947), who started work on essential components of the diet in the early 1900s. Hopkins and others soon pinned down the dietary deficiencies behind a whole series of diseases – including beriberi (vitamin B), scurvy (vitamin C), and rickets (vitamin D).

The vitamins could, of course, be used to treat these conditions, often with startling results. But they were also an easy route to prevention. This and the discovery of other essential chemicals helped prompt renewed attention to diet and nutrition, and the Scottish nutritionist John Boyd Orr (1880–1971) led the way in defining minimum intake of different foodstuffs. These results in turn were used by campaigners fighting poverty and famine, trying to secure proper nutrition as the foundation of good health.

public health This helped reinforce earlier measures to establish standards of public health and hygiene which began to take effect in the 19th century. Indeed, the British epidemiologist and historian Thomas McKeown (1912-1988) argued that much of the reduction in infectious diseases such as tuberculosis was due to general improvements in hygiene, sanitation, and nutrition, rather than the medical advances that got so much attention. Tuberculosis, for example, started to decline before the tubercle bacillus was even discovered, and long before antibiotics were introduced. However, by the end of the 20th century, tuberculosis had returned and the World Health Organization declared its re-emergence a global emergency in 1993. It is estimated that between 2002 and 2020 about a billion people will be infected, more than 150 million will become ill, and 36 million will die of tuberculosis, if it is not brought under control.

This emphasis on the importance on public health as a way of improving survival rates and standards of living can be illustrated in the UK. At the beginning of the 20th century, the government took responsibility for public health, with an attempt to provide access to clean water and sanitation, as well as better housing. Thereafter, steps were taken to tackle the widespread poverty that made it impossible for millions of people to secure the basic necessities of a healthy lifestyle. Following the end of World War I in 1918, the British government adopted the phrase: 'A country fit for heroes' to describe the improvements that would be made to the lives of those who had fought for their country. The Housing and Town Planning Act of 1919 made money available to build new council houses to replace the slums of Britain's cities. Improvements were made in pensions, unemployment, and healthcare between World Wars I and II. However, the years after World War II saw the setting up of a national health service and the welfare state, representing the completion of the public health programme begun in the middle of the 19th century.

Computerization enabled the cause–effect relationships between different industries or occupations and particular illnesses to be established, thus enabling specific preventative measures to be taken to reduce risk to those exposed. Environmental health hazards too, were progressively identified. This field of medicine grew after the publication of *Silent Spring* by Rachel Carson (1907–1964), which alerted the world to the danger of chemical and radiation pollutants. One of the areas of contention at the end of the century concerned the hypothesis that male workers in nuclear plants may be exposed to radiation that could damage their sperm, resulting in birth defects among their children. New technologies, such as cellular telephones, also began to come under increasingly close inspection.

limits of prevention Modern medicine gave the final boost to the campaigns against many of the infectious and deficiency diseases. However, while vaccines provide a specific boost for the immune system, and vitamins guard against particular conditions, other preventive methods are less specific. In addition, as with diet campaigns, they depend on more than medical effort. Here, we begin to come up against the limits of prevention, and they tend to be economic and social, rather than strictly medical. Just as we now have the science to treat much of the infectious disease of the developing world, but lack the will to deliver it, so we know what to do to prevent a good deal of the current disease burden in the rich nations, but the follow up is hard to manage.

Cigarette smoking is the starkest example. The first clear evidence of a link between smoking and lung cancer was reported by the British English epidemiologist Austin Bradford Hill (1897-1991) and English physician Richard Doll (1912 –) in 1951. Half a century later, hundreds of millions of people across the globe still smoke heavily, and millions die from smoking-related cancer and heart and respiratory disease. The difficulties are many: people find it difficult to link a statistical finding to individual action; governments are reluctant to act because they take hefty tax revenues from tobacco companies; the companies themselves respond to antismoking campaigns by moving into new markets with aggressive advertising.

Progress is slow therefore, even when the science, and the risks, are reasonably clear. Things get more tangled when the preventive measures relate to actions that can have far-off consequences, such as diet or exercise, affecting cancers or heart disease, for example, or choice of sexual partners to AIDS. Good advice has to contend with our fondness of foods high in fat and sugar, to alcohol – and other recreational drugs – and with our ability to persuade ourselves that the person of our dreams is a 'low risk' sexual partner.

Here it becomes as important to try and understand what influences people's behaviour, and their personal notions about risk, as to mount ever-larger epidemiological studies to refine the data on which advice about healthy lifestyles is based. Why is it, for example, that in Great Britain people appear to accept a much higher risk of death from car crashes than from the new variant of Creuzfeldt–Jakob disease (vCJD), which is probably caused by eating beef from a cow with bovine spongiform encephalopathy (BSE or 'mad cow disease')?

The answers are not always clear, but these kinds of distinctions are an important part of the politics of health care and research – our final topic.

politics

By most measures, modern medical science has given us a lot. In the West we live longer and have more control over our lives than earlier generations but the powers of modern medical research and practice inevitably raise the political stakes around medicine. No one wants to be sick. Religion reconciles some to the facts of death, but few really want to die before old age. So medical science is the science that absolutely everyone is interested in, and as it has done more, so there is more to debate, discuss, and, perhaps, more to worry about as well as to welcome.

At the end of the 20th century, the successes of scientific medicine may have generated expectations that are hard to fulfil. Ever more is spent on research. The annual budget for the US National Institutes of Health stood at $81 million dollars in 1955. By the late 1990s it had risen to $15,000 million dollars. Researchers these days are careful not to promise too much. The poor results from US president Richard Nixon's lavishly funded 'war on cancer' in the 1970s saw to that. Nixon was influenced by confident pronouncements from researchers that 'with a billion dollars a year for ten years we could lick cancer'. That did not happen. However, all this new spending, together with billions of dollars more from the drug companies, is bound to produce some worthwhile results. But aside from how much gets spent on research and what it gets spent on, other questions have been heard more insistently as the 20th century has passed.

People outside the laboratories have become more interested in things like how the research gets done. Some question whether the methods used are acceptable. The growth of research means more animal experiments, and more work with human subjects. There must be safeguards before either animals or humans are shot full of new drugs, irradiated, operated on, or even assigned to a trial group destined *not* to receive the medicine under test. For animals, the safeguards focus on preventing unnecessary suffering and making sure that the information gained is of some use - a point often contested by opponents of such work. For humans, as well as passing those tests, subjects must understand what is going to happen and give their consent.

clinical trials Lest this seem obvious, consider just one celebrated case. In 1932 the US Public Health Service began an experiment in which black patients who thought they were being treated for syphilis in fact had no treatment. The supposed scientific benefit was to understand the effects of the disease in its last stages. One hundred of the 'patients' were dead before the study was finally halted in 1972. Another example concerns the testing of polio vaccines and many other medicines on US prison inmates who were not fully informed of the dangers to which they were being subjected.

Until studies like these came to light, most people believed that abuse of human subjects had been confined to medical experiments in German or Japanese concentration camps, but it seemed that scientific zeal could overcome humane impulses almost anywhere. This is why research hospitals now have ethics committees. They may also have to consider issues connected with use of human materials - is it alright to use fetal brain cells to treat Parkinson's disease, for example? And there is continuing concern about the whole area of reproductive and genetic research, as demonstrated resoundingly by the reaction to the cloning of an adult sheep by Scottish embryologist Ian Wilmut (1944-) and colleagues at the Roslin Institute in 1997. Within days, US president Bill Clinton had called for a special report from the US National Bioethics Advisory Commission on the prospects for producing cloned - therefore genetically identical - humans, a technique with conceivable benefits for medical research, and which one day might even enable tailor-made tissues to be cultured for patients with damaged organs.

Also of interest outside the laboratory is whether the work going on is safe. Aside from use of toxic chemicals or radiation, or work on lethal organisms, since the early 1970s there have been regulations in place to guard against any possible hazards from biomedical experiments which involve recombining DNA from different organisms.

fraud and forgery On top of this overlapping set of bureaucratic interests in research, the sheer amount money spent, and the competition to succeed in a high-pressure world where scientists must publish or perish, raised concerns from the 1970s onward about scientific fraud and misconduct. A few highly publicized cases of faked or fudged results - virtually all in biomedical research - led to calls for safeguards for whistleblowers and for tougher investigations of alleged wrongdoing. The most celebrated alleged fraud case, involving colleagues of Nobel laureate David Baltimore (1938-), dragged on for ten years from 1986 to 1996. Baltimore and his co-workers were eventually exonerated, but the feeling that something was amiss in biomedical research more generally was harder to dispel.

There was, however, much more to think about than the conduct of research. The way it was applied was increasingly seen as causing problems as well as solving them. For one thing, there were far more people in the world who might benefit. The increase in global population was at least partly due to the fruits of medical research, but the more populous world was also conspicuously divided when it came to the chances of a healthy life. Millions still died in the developing world from malnutrition and from common infectious and parasitic diseases while developed countries pressed ahead with heart transplants and drug therapies that cost thousands of dollars a month.

the health divide Even in the rich nations, the costs of new health technologies are more and more difficult to meet, and are one reason for inequalities in health care within countries as well as between them. All the affluent countries are troubled about paying the health bill, whether they have systems designed to provide universal care, like the National Health Service (NHS) in the UK, or rely mainly on health insurance as in the USA. It seems hard to credit now that the architects of the NHS in 1948 believed that demand for treatment would decline, after an initial rush. History has shown just the opposite. Visits to the doctor, hospital care, drug prescriptions, laboratory tests, and surgery all increase relentlessly.

At the same time, as people appear to grow more dependent on health professionals, they grow less inclined to take the doctor's word for anything. Patients are keenly aware of the potential hazards of treatment, as well as its benefits. Not all drugs were wonder drugs. Some were addictive or had serious side effects. Some, like the sleeping pill thalidomide, were disastrous. Thousands of pregnant women who took the drug in the late 1950s bore deformed children. So the mass consumption of drugs and hormones, boosted by the Food and Drugs Administration's licensing of first contraceptive pill, Searle's Enovid in 1960, went along with demands for better tests and for more information, in more understandable form. And the long series of epidemiological studies trying to show whether the pill did or did not increase risks of cancer or thrombosis, helped reinforce the feeling that every medical advance has its downside.

All this contributed to a late 20th century feeling that, as far as biomedicine went, we were 'doing better but feeling worse'. High technology medicine continued to offer new possibilities for patients, but also threw up troubling decisions. If the body was alive but the brain certified dead, could a transplant surgeon go ahead and remove other organs? How long should a patient in a coma be left on a life-support machine? Should a doctor tell a newly-tested patient's relatives that they might have inherited the same genetic disease? More work for the bioethicists.

challenges for the future

Despite the obvious advances of the 20th century, it seems that there will always be hurdles to overcome in the fight against ill health and disease. The obstacles that researchers face at the beginning of this century are different in many ways from those of the past. As medicine and society has succeeded in keeping many of us alive for longer, in more comfort, diseases of old age and inactivity now take their toll.

Alzheimer's disease is a prime example of a disease which has increased with an ageing population. Between 1990 and 2030 the proportion of people over 60 will grow by about 75% in OECD countries, with a dramatic rise of almost 100% in Japan. Alzheimer's disease (AD) was first described in a women in her 50s by Alois Alzheimer (1864-1915) in 1907. The causes of sporadic AD, the type that appears as dementia generally in those over 60, are now known to be multifactorial, which means that several factors have to come together in one person before the disease develops. A discovery by scientists at Duke University, North Carolina, in 1993 has transformed our understanding of AD; they found that people who carry the common variant (E4) in a particular gene have a fivefold greater risk of developing AD than people who do not carry this variant. This susceptibility gene only increases the risk of the disease developing, and a variety of non-genetic factors may influence our risk. A vaccine for preventing AD is in development. Meanwhile, Hyperazine A has been proven to lower neuronal cell death and the cloning of a human embryo holds out hope for a solution.

Another challenge for researchers is how to keep alive those increasing numbers of patients who desperately need organ transplants. One solution to the shortage of donor organs available is xenotransplantation - the use of live animal organs, tissues, or cells in human transplant operations. This includes the transplanting of bone marrow to assist AIDS patients and other immunosuppressed groups, and of pig fetal neural tissue to assist people with Parkinson's disease. The human immune system is primed to attack anything the body thinks is foreign. Ordinarily, a pig heart inside a human would be dead in five minutes - and so would the patient. But there has been a scientific breakthrough: pigs can be genetically engineered so that their hearts carry human signals. If such a heart were placed in a human, the immune system would not react, at least not strongly enough to cause rejection.

The challenge in the immediate future is to decide if this is ethical. A quick response to the question 'Do you have a problem with xenotransplantation?' might be 'Why? It's no different from eating bacon'. Yet, as usual with ethical issues, these matters are not straightforward. They concern animal as well as human rights. Apart from saving lives, the use of animal organs could help bring about an end to such practices as the selling of human organs, which is legal in India, and the use of organs of executed prisoners, which occurs in China. Xenotransplantation, however, requires that pigs be conceived by in vitro fertilization, born by hysterectomy during which the sow is killed, fed by white-gloved assistants, and quartered in a sterile environment with a mesh floor to prevent faecal build-up.

The debate is whether this sort of life is any worse than that of the average farm pig. Then there is the issue of how we feel about our own bodies. Is there a problem with a technology that will allow us to replace organs as if they were spare parts? At present it is predicted that the use of xenografts will help terminally ill patients - in other words save lives. Yet xenografts could be used as treatment - for instance, to assist those with a genetic disposition to heart disease. Uncomfortable scenarios rear up here: what about transplants for athletes, or for those who want to spend money on extending their life? Where new technology beckons, money follows not far behind. The money men are already licking their lips: Salomon Bros, a Wall Street investment company, has affirmed that the demand for organ transplants by the year 2010 could be worth $6 billion - tempting pickings if the scientists, the doctors, and the regulatory bodies give xenotransplantation the green light.

The role of people outside biomedicine, who ultimately pay for most of the research, is still changing. But there are some trends which seem well established. They want a say in many of these decisions, and they expect to be kept informed. They want the right to try unconventional treatments when they feel the scientifically sanctioned therapies are unpromising. And, they may want to get more involved in decisions about research itself. Political lobbying helps explain why funding for research on breast cancer is much higher than for work on prostate cancer - which kills roughly the same number of men as breast cancer claims female victims each year. More than this, the way the research is done may become a political issue, as has been seen in debates about the conduct of clinical trials of drugs that may help AIDS patients.

From the mid-1980s on, AIDS activists in the USA campaigned for faster approval of new drugs, while doctors and scientists argued that full safety testing and controlled trials were the best way forward, morally as well as scientifically. In the end, the view of those with the disease - that they had a right to decide what risks were worth taking - led to changes in the way trials were organized.

The management of AIDS, in fact, seemed to sum up very well where the biomedical enterprise stood at the 20th century's end. It was a new disease, and triggered ancient fears of a pandemic as well as tapping prejudices against homosexuals and other minority groups. HIV positive individuals tried to maintain their health with an assortment of self-help regimes and alternative remedies, as well as prescribed drugs. By the late 1990s, combined drug regimens were producing much improved survival rates, but at a cost far out of reach of the countries where the majority of HIV positive people are found. And the search for a vaccine went on, encouraged by the extraordinarily detailed knowledge of the virus which had been obtained from the work of thousands of researchers around the world.

Our understanding of AIDS draws on the biological and medical sciences, which have advanced so spectacularly in the last hundred years - on molecular biology, virology, cell biology, and immunology, in particular. The fact that the disease is still with us adds strength to the call which most often united patients, doctors, and scientists in the 20th century: more research!

Medical prefixes

a(n)-	lacking
ab-	away from
abdomin(o)-	abdominal
ad-	towards, near
andr(o)-	male
angi(o)-	blood or lymph vessel
ant(i)-	against, counteracting
ante-	before
arthr(o)-	joint
aut(o)-	self

bi-	twice, two
brachi(o)-	arm
brachy-	shortness
brady-	slowness
bronch(o)-	bronchial tube
carcin(o)-	cancer
cardi(o)-	heart
cerebr(o)-	brain
cholecyst-	gall bladder
circum-	surrounding
colp(o)-	vagina
contra-	against
crani(o)-	skull
cry(o)-	cold
crypt-	hidden, concealed
cyst(o)-	bladder
cyt(o)-	cell
dent-	tooth
derm-	skin
di-	double
dys-	difficult, painful, abnormal
end(o)-	within, inner
enter(o)-	intestine
epi-	above, upon
ex(o)-	outside, outer
extra-	outside, beyond
gastr(o)-	stomach
gyn-	female
haem-	blood
hepat(o)-	liver
hist(o)-	tissue
hyper-	above
hypno-	sleep
hypo-	below
hyster(o)-	uterus
immuno-	immunity
infra-	below
intra-	within
laryng(o)-	larynx
mal-	abnormal, diseased
mast-	breast
muco-	mucus
my(o)-	muscle
necro-	death
neo-	new
nephr(o)-	kidney
neur(o)-	nerve
noct-	night
oculo-	eye
olig(o)-	deficiency, few
ophthalm(o)-	eye
oro-	mouth
ortho-	straight, normal
osteo-	bone
ot(o)-	ear
paed-	children
path(o)-	disease
peri-	around, enclosing
pharmac(o)-	drugs
phleb(o)-	vein
phot(o)-	light
pneumon-	lung
poly-	many, excessive
post-	after
pre- (pro-)	before

ren-	kidney
retro-	behind
rhin-	nose
sclero-	thickening
ser(o)-	serum
spondyl-	vertebra, spine
supra-	above
syn-	together, union
tachy-	fast
tetra-	four
therm(o)-	heat, temperature
trache(o)-	trachea
uni-	one
urin-	urine, urinary system
utero-	uterus
vaso-	vessel
vesico-	bladder

Medical suffixes

suffix	meaning
-aemia	condition of blood
-algia	pain
-ase	enzyme
-blast	formative cell
-cele	tumour, swelling
-centesis	puncture
-cide	destructive, killing
-coccus	spherical bacterium
-cyte	cell
-derm	skin
-dynia	pain
-ectasis	dilation, extension
-ectomy	surgical removal of
-facient	making, causing
-fuge	expelling
-genesis	origin, development
-genic	causing, produced by
-gram	tracing, record
-iasis	diseased condition
-iatric	practice of healing
-itis	inflammation of
-kinesis	movement
-lith	calculus, stone
-lysis	breaking down, dissolution
-malacia	softening
-megaly	enlargement
-oid	likeness, resemblance
-oma	tumour
-opia	eye defect
-osis	disease, condition
-ostomy	surgical opening or outlet
-otomy	surgical incision into an organ or part
-pathy	disease
-penia	lack of, deficiency
-pexy	surgical fixation
-phage	ingesting
-philia	affinity for, morbid attraction
-phobia	fear
-plasty	reconstructive surgery
-plegia	paralysis
-pnoea	condition of breathing
-poiesis	formation
-ptosis	prolapse
-scopy	visual examination
-stasis	stagnation, stoppage of flow

-tome	cutting instrument
-uria	condition of urine

Medicine, Western: key events

c. 400 BC	The Greek physician Hippocrates of Cos recognizes that diseases have natural causes. The Hippocratic oath, still taken by doctors today, is attributed to him.
c. AD 200	The Greek physician Galen consolidates the work of the Alexandrian doctors and introduces the theory of the four humours, which remains the foundation of western medicine throughout the Middle Ages.
1530	The Swiss doctor and alchemist Paracelsus advocates the use of chemicals and minerals in the treatment of illness. In 1536 he publishes *Die grosse Wundartzney/Great Surgery Book*, challenging the precepts of Galen.
1543	Andreas Vesalius of Flanders gives the first accurate account of the human body.
1628	English doctor William Harvey discovers the circulation of the blood.
1768	Scottish surgeon John Hunter lays the foundation of experimental and surgical pathology.
1785	English doctor William Withering reports his discovery of the use of digitalis in treating heart disease; the active ingredient, derived from the foxglove, is isolated in 1904.
1798	English doctor Edward Jenner publishes his work on vaccination.
1877	Scottish doctor Patrick Manson studies animal carriers of infectious diseases.
1882	German bacteriologist Robert Koch isolates the bacillus responsible for tuberculosis.
1884	German doctor and bacteriologist Edwin Klebs isolates the diphtheria bacillus.
1885	French bacteriologist Louis Pasteur produces a vaccine against rabies.
1890	English surgeon Joseph Lister demonstrates antiseptic surgery.
1895	German physicist Wilhelm Röntgen discovers X-rays.
1897	Dutch botanist and chemist Martinus Beijerinck discovers viruses.
1899	Aspirin is introduced into general medical use as an analgesic.
1900	Austrian biochemist Karl Landsteiner identifies the first three blood groups, later designated A, B, and O; Sigmund Freud publishes *The Interpretation of Dreams* and profoundly influences modern psychiatry.
1905	US doctor George Washington Crile performs the first blood transfusion.
1910	German bacteriologist Paul Ehrlich develops the first specific antibacterial agent, Salvarsan, a cure for syphilis.
1922	Insulin is first used to treat diabetes.
1928	Scottish bacteriologist Alexander Fleming discovers penicillin.
1932	Gerhard Domagk of Germany discovers the first antibacterial sulphonamide drug, Prontosil.
1937	Electro-convulsive therapy (ECT) is developed by the Italian doctors Ugo Cerlutti and Lucio Bini.
1940s	Lithium treatment for manic-depressive illness is developed.
1950s	Antidepressant drugs and beta-blockers for heart disease are developed. Manipulation of the molecules of synthetic chemicals becomes the main source of new drugs. Peter Medawar studies the body's tolerance of transplanted organs and skin grafts. First kidney transplants.
1950	Proof of a link between cigarette smoking and lung cancer is established.
1953	Francis Crick of England and James Watson of the USA announce the structure of DNA. US microbiologist Jonas Salk develops a vaccine against polio.
1958	Scottish doctor Ian Donald pioneers diagnostic ultrasound.
1960s	A new generation of minor tranquillizers called benzodiazepines is developed.
1964	First pig heart valve transplant in the UK.
1967	South African surgeon Christiaan Barnard performs the world's first human heart transplant operation in Cape Town.
1971	Viroids, disease-causing organisms even smaller than viruses, are isolated outside the living body.
1972	The CAT scan, pioneered by Godfrey Hounsfield of England, is first used to image the human brain.
1975	French microbiologist César Milstein develops monoclonal antibodies.
1978	Louise Brown, the world's first 'test-tube baby' is born in the UK.
1980s	AIDS (acquired immune deficiency syndrome) is recognized in the USA (later research suggests that the first death from AIDS took place in Africa in 1959). US microbiologist Barbara McClintock's discovery of the transposable gene is recognized.
1980	The World Health Organization reports the eradication of smallpox.
1983	The virus responsible for AIDS, now known as human immunodeficiency virus (HIV), is identified by French microbiologist Luc Montagnier at the Institut Pasteur, Paris; A US scientist, Robert Gallo, at the National Cancer Institute, Maryland, USA, discovers the virus independently in 1984.
1984	The first vaccine against leprosy is developed.
1987	English microbiologist Walter Bodmer and others announce the discovery of a marker for the gene that causes cancer of the colon.
1989	Grafts of fetal brain tissue are first used to treat Parkinson's disease.
1990s	Cochlear implants for very young children achieve a success rate of more than 90% in alleviating profound deafness. Scientists discover that bovine spongiform encephalopathy (BSE), a fatal brain disease of cattle, can be transmitted to other species, including humans. The human form of BSE is believed to manifest itself as a variant form of Creutzfeldt-Jakob disease (CJD). Both these and other fatal brain-wasting disorders are thought to be caused by a self-replicating protein called a prion. A strain of typhoid fever that is resistant to all known antibiotics emerges in the late 1990s.
1990	The gene for maleness is discovered by UK researchers.
1991	First successful use of gene therapy (to treat severe combined immune deficiency) is reported in the USA.
1993	First trials of gene therapy against cystic fibrosis take place in the USA.
1996	An Australian man, Ben Dent, is the first person to end his life by legally sanctioned euthanasia.

1998	French surgeons at Lyons, France, perform the first arm transplant by sewing the hand and forearm of a brain-dead patient onto the arm stump of a living patient, New Zealand-born Clint Hallam.
1999	The UK Department of Health announces that all pregnant women in England and Wales will be offered an HIV test. HIV transmission to newborns can be cut from 15% to 2% by antiviral therapy, Caesarean section delivery, and bottle feeding but at present most infected mothers are unaware that they carry the virus.
2000	A UK study shows that women suffering from breast cancer are surviving longer than ever before because of improvements in treatment and especially the use of the drug tamoxifen.
2005	Huge advances in stem cell research in South Korea are admitted to be fabricated.

From Quackery to Bacteriology: the Emergence of Modern Medicine to 19th-Century America

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Online exhibit which traces the development of medicine through printed works: from heroic medicine at the beginning of the 19th century through to quackery movements, the experience of the Civil War, the improvements in medical education, and the formulation of the germ theory at the end of the 19th century. Other topics covered in the exhibit include women's health, mental health, public health, and preventative medicine as advocated through physical fitness and nutrition.

MedicineNet

Go to site

Immense US-based site dealing in plain language with all current aspects of medicine. There is a dictionary of diseases, cures, and medical terms. The site also includes an 'Ask the experts' section, lots of current medical news, and last, but not least, some important first aid advice.

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medicine, alternative

forms of medical treatment that do not use synthetic drugs or surgery in response to the symptoms of a disease, but aim to treat the patient as a whole (see holism). The emphasis is on maintaining health (with diet and exercise) and on dealing with the underlying causes rather than just the symptoms of illness. It may involve the use of herbal remedies and techniques like acupuncture, homeopathy, and chiropractic. Some alternative treatments are increasingly accepted by orthodox medicine, but the absence of enforceable standards in some fields has led to the proliferation of untrained practitioners.

Complementary Therapy

introduction

The term 'complementary therapy' is used to encompass any practice or system of beliefs about treatment that is not included in what is generally understood as Western scientific medicine. Science and much of Western medical practice is incompatible with many of the practices of complementary therapy, as such practices do not have a scientific basis, though this should not be seen as an obstacle to its understanding and acceptance. Practitioners of complementary therapy are seeing their role increasingly as offering something that Western scientific medicine does not, and something that adds to it without denying that scientific medicine has an essential role. Medical intervention is restricted to qualified medical practitioners in many Western countries and a significant proportion of them use complementary therapy. Not all complementary practitioners are regulated and this has caused concern as complementary therapy grows in popularity. However, organizations concerned with the training and registration of complementary practitioners have developed at a rapid rate recently to meet the growing demands of the public for a pluralist, holistic, effective, and safe approach to health care.

homeopathy

The roots of homeopathy lie in the work of Samuel Hahnemann, an 18th-century German physician. The brutalities of medical practice, which included purging, bleeding, and the use of poisons, were instrumental in his decision to explore other avenues in which he could use his skills. He was prompted to investigate the use of cinchona bark in the treatment of fever while he was working on a *Materia Medica*. Cinchona bark produced many of the symptoms associated with fever without inducing pyrexia. This led to him to speculate that a substance that was effective against a disease would produce symptoms resembling those of that disease if it was given to a healthy person. Homeopathy recognizes a need for balance and harmony. Disturbances in the harmony of the body due to illness can precede the appearance of symptoms as the body reacts to the illness. Symptoms of the same illness differ between individuals, and the establishment of a detailed profile of the patient and a complete symptom picture are an essential part of the diagnosis. Homeopathic remedies are intended to stimulate the resources of the body to restore its natural harmony, following Hahnemann's principle that the appropriate treatment is one that produces the same symptoms in a healthy person. Many of these principles pose a problem to the scientist, but the greatest obstacle to scientific acceptance is the observation that homeopathic remedies become more potent when subject to serial dilution and mechanical shock in the process known as 'succussion'. Theories have been developed in an attempt to explain why more dilute preparations are more powerful, but none of these have yet been proven.

herbal medicine

A wide range of medical practices that use unrefined and refined plant materials for treatment is encompassed by the term 'herbal medicine'. They do not necessarily have a common belief system and they range from traditional herbal medicine to many ethnic medical systems, such as Chinese and Ayurvedic medicine. Plants were used medicinally in China, Egypt, Greece, Rome, and other ancient civilizations up to 5,000 years ago. The central position of herbalism in health care was challenged by changes in medical thinking in Renaissance Europe, and by the consequent emphasis on the management of symptoms with specific remedies by the emerging medical establishment. Samuel Thomson, an

American physician, documented much of this early herbalist knowledge in the early 19th century, and he is now credited as the founder of Western herbal medicine. He developed a theory resembling that of the four humours, in which life and health were represented by heat; illness and death by cold; motion by air; and energy or life force by fire. He believed that the fever associated with infection was a healthy sign and, unlike his contemporaries, he wanted to facilitate it rather than to suppress it. He considered that coughing, vomiting, and diarrhoea were healthy signs of the body removing toxins. The underlying belief in herbalism is that health depends on maintaining the natural state of the body. The natural state of the body, or 'vital pulse', is represented by the rhythmic variation in tissue and cell activity, which protects, regulates, and renews the body. A herbal remedy is a preparation of the entire plant rather than an active ingredient extracted from it. The constituent components may have many different activities that restore the balance of the body, which is lost with the onset of illness. They are not specific for a particular symptom and they are thought to act by stimulating the natural defences of the body and enhancing the elimination of toxins. Attention to diet is often used as an adjunct to treatment by herbalists.

aromatherapy

The therapeutic use of volatile oils can be traced back to the ancient civilizations of India, China, Egypt, Babylon, and Greece, and their use in medicine survived until challenged by the advent of scientific chemistry in the 17th century. Aromatherapists believe that health depends on a balance of mental, emotional, and physical processes which is disturbed in illness. A holistic approach is taken to diagnosis and treatment. The volatile oils used in aromatherapy are complex mixtures of chemicals that occur naturally in plants. Specific disorders are treated with particular oils. They are believed to be absorbed through the skin or by inhalation before exerting their subtle effects on physical symptoms and emotional well being. The pleasant smell and application of the oils by massage can enhance the beneficial effects of aromatherapy through reduction of tension and pain, increased relaxation, and improved circulation. Aromatherapy is widely used as an adjunct to conventional care in patients who are terminally ill.

acupuncture

Traditional Chinese medicine is based on the fundamental principle that a life force known as *qi* flows around the body in 12 channels known as meridians. The flow of *qi* is important for good health. The balance between *yin* and *yang*, qualities possessed by all things including the internal functions and processes of the body and the meridians, is also vital to health. *Yin* is cold, dark, passive, and negative; *yin* organs include the heart, spleen, kidney, and liver. *Yang* is warm, light, active, and positive; *yang* organs include the small intestine, stomach, bladder, and gall bladder. Illness occurs when either *yin* or *yang* is dominant, and treatment helps to restore their balance. Acupuncture is one form of treatment used in traditional Chinese medicine. It involves the insertion of fine needles into the skin at particular points on the body to correct the imbalances between *yin* and *yang*. There are about 2,000 acupoints that lie on the meridians through which *qi* flows. The imbalance between *yin* and *yang* may be associated with many factors, such as stress, emotion, diet, or injury, and these are considered in conjunction with the medical history of the patient, and examination of the 12 pulses and the condition of the tongue before a diagnosis is made. The acupoints to be stimulated are then selected and needles are inserted to a depth of about 1/4 of an inch (6 mm) and rotated. The direction of insertion and rotation of the needles regulates the flow of *qi* and the collection or dispersion of energy. Acupuncture can be used to treat a wide range of acute and chronic illnesses, such as pain, anxiety, asthma, migraine, menstrual disorders, and gastrointestinal complaints. It can also be used as an aid to dieting and giving up smoking.

osteopathy

Osteopaths perceive the function of muscles and the skeletal system to be central to a range of health problems. Osteopathy was conceived as a system of diagnosis and treatment by Andrew Taylor Still in the USA in the 19th century. He believed that a lack of balance in the mechanical functioning of the body, such as muscle groups being too tense or joints moving incorrectly, may cause illness. He developed a range of manipulative techniques to correct the imbalances and claimed therapeutic success. These include massage, passive movement, and stretching of the limbs. Despite opposition from the medical profession, osteopathy has slowly achieved success because it can produce a dramatic improvement in disorders that are difficult to treat by conventional medicine, such as chronic back pain and sciatica. These are just a few of the more popular forms of complementary therapy that are available today. There are many others: chiropractic, reflexology, and relaxation techniques such as hypnotherapy, to name but a few.

Alternative Medicine Centre

Go to site

Guide to a range of disciplines within the field of alternative medicine, which also considers their relationship to mainstream medical treatment.

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medicine, history

medical science has developed by gradual steps from very early times. There is evidence of trepanning (cutting holes in the skull to relieve pressure) being practised in the prehistoric medicine of Stone Age peoples. In the earliest societies, medical practice was part of the duties of the priests; it relied more on the influence of the gods than on the value of the methods adopted. In ancient Greek medicine, even the priests of Asclepius, the god of healing, relied mainly on religious exercises to effect a cure. The main advances in medical practice came in the 1800s and 1900s, and today physicians and surgeons have a record of some success in treating and curing disease and injuries.

For a long time many people practised sympathetic medicine, in which plants were used to cure the organs they were thought to resemble. Others believed that herbs were under the influence of one or other of the planets. Great advances in medical practice came in the 1700s and 1800s, with a more scientific approach to the use of drugs. Surgery was difficult because of the lack of anaesthetics and the frequency with which wounds became septic and killed the patient. The advent of antiseptics, and of reliable anaesthetics, revolutionized surgery, and the development of the nursing profession improved patient care.

In the 1900s modern advances in drugs and surgical practices have revolutionized medicine, and as a result more people are able to enjoy good health and live longer.

Images from the History of Medicine

Go to site

Database of 60,000 images from the history of medicine. The collection includes portraits, pictures of institutions, caricatures, genre scenes, and graphic art, all of which illustrate social and historical aspects of medicine. The database may be browsed or searched by topic.

Medicine Through Time

Go to site

Fantastic site covering the history of medicine from prehistoric times through to the present day. The site is well presented, with lots of facts, interactive investigations, and stories.

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medlar

small shrub or tree native to southeastern Europe. It is widely cultivated for its fruits, resembling small brown-green pears or quinces. These are palatable when they have begun to decay. (*Mespilus germanica*, family Rosaceae.)

---

medulla

central part of an organ. In the mammalian kidney, the medulla lies beneath the outer cortex and is responsible for the reabsorption of water from the filtrate. In plants, it is a region of packing tissue in the centre of the stem. In the vertebrate brain, the medulla is the posterior region responsible for the coordination of basic activities, such as breathing and temperature control.

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medusa

free-swimming phase in the life cycle of a coelenterate, such as a jellyfish or coral. The other phase is the sedentary **polyp**.

---

meerkat

or suricate

small mammal with long soft grey fur, which is found in southern Africa, and belongs to the mongoose family. A third of its length of 35 cm/14 in is occupied by the tail. It feeds on succulent bulbs, insects, and small vertebrates, and is sociable, living in large extended family groups. Meerkat groups have a dominant breeding pair and up to 23 helpers to assist in the rearing of the babies. The dominant female produces 75% of the young.

The Madagascar cat and *Cynictis penicillata* are also termed meerkats.

classification

Meerkats *Suricata suricatta* are in family Viverridae, order Carnivora.

---

meerschaum

aggregate of minerals, usually the soft white clay mineral **sepiolite**, hydrous magnesium silicate. It floats on water and is used for making pipe bowls.

---

mega-

prefix denoting multiplication by a million. For example, a megawatt (MW) is equivalent to a million watts.

---

megabyte

MB

in computing, a unit of memory equal to 1,024 kilobytes. It is sometimes used, less precisely, to mean 1 million bytes.

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megalith

(Greek megas 'great', lithos 'stone')

prehistoric stone monument of the late Neolithic (New Stone Age) or early Bronze Age. Most common in Europe, megaliths include single, large uprights or menhirs; rows or alignments; stone circles (for example, Stonehenge, Wiltshire, England); and the hutlike remains of burial chambers after the covering earth has disappeared, known as dolmens.

A number of explanations have been put forward for the building of megaliths in areas including Denmark, Ireland, northeastern Scotland, England, western France, and Spain. These range from economic reasons to expressions of dominance and symbolism. The great stone monuments at Carnac in western Brittany, France; in Jersey, such as La Hougue Bie; and in western Britain and Ireland, suggest possible cultural links through trade among megalith builders whose rural economy encompassed arable farming, stockrearing, and the development of pottery and weaving.

Stone circles, alignments, and menhirs, along with henges (circular ditched earthworks), possibly performed astronomical and calendrical oriented ritual functions, linked to seasonal and agricultural practices, and matters of life and death. Little is known of the religious beliefs and observances associated with these monuments, but theories have included possible worship of an Earth mother combined with fertility ritual.

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megamouth

deep-sea shark that feeds on plankton. It has a bulbous head with protruding jaws and blubbery lips, is 4.5 m/15 ft long, and weighs 750 kg/1,650 lb. Although first discovered in 1976, the first live specimen was found in 1992 off the coast of Los Angeles. The first female was found in 1994 in Hakata Bay, Kyushu, Japan; she was 4.8 m/16 ft long and weighed 790 kg/1,740 lb. (Species *Megachasma pelagios*.)

---

megapode

or mound-builder

any of a group of chickenlike birds found in the Malay Archipelago and Australia. They pile up large mounds of vegetable matter, earth, and sand 4 m/13 ft across, in which to deposit their eggs, then cover the eggs and leave them to be incubated by the heat produced by the rotting vegetation. There are 19 species, all large birds, 50-70 cm/20-27.5 in in length, with very large feet. They include brush turkeys.
(Family Megapodiidae, order Galliformes.)

In some species the male bird feels the mound with his tongue and adds or takes away vegetation to provide the correct temperature.

megapode

The 'nests' in which scrub fowl lay their eggs are the largest structures created by any bird. These nests are in fact mounds of rotting vegetation, up to 5 m/16 ft in height and 12 m/40 ft in diameter. As the vegetation rots, it generates enough heat to incubate the eggs.

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megaton

one million (10^6) tons. Used with reference to the explosive power of a nuclear weapon, it is equivalent to the explosive force of one million tons of trinitrotoluene (TNT).

---

megavitamin therapy

the administration of large doses of vitamins to combat conditions considered wholly or in part due to their deficiency.

Developed by US chemist Linus Pauling in the 1960s, and alternatively known as 'orthomolecular psychiatry', the treatment has proved effective with addicts, schizophrenics, alcoholics, and depressives.

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meiosis

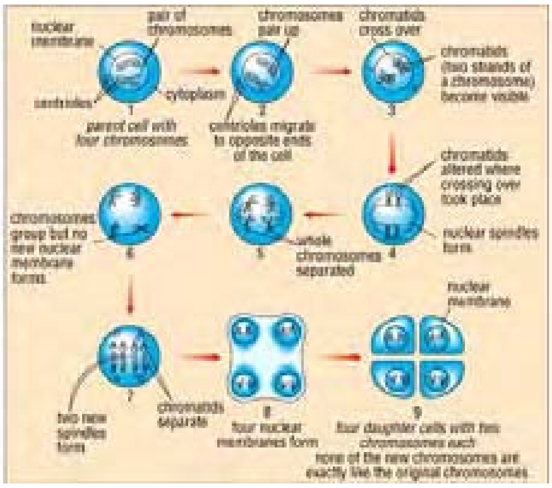
in biology, a process of cell division in which the number of chromosomes in the cell is halved. It only occurs in eukaryotic cells, and is part of a life cycle that involves sexual reproduction because it allows the genes of two parents to be combined without the total number of chromosomes increasing. Cells in reproductive organs - testes and ovaries in humans - divide to form sex cells (gametes) by meiosis.

In meiosis, the nucleus of a cell divides twice. A single cell produces four cells by the end of meiosis. In sexually reproducing diploid animals (having two sets of chromosomes per cell), meiosis occurs during formation of the gametes (sex cells), so that the gametes are haploid (having only one set of chromosomes - half the number of chromosomes of the parent cell). When the gametes unite during fertilization, the diploid condition is restored.

In plants, meiosis occurs just before spore formation. Thus the spores are haploid and in lower plants such as mosses they develop into a haploid plant called a gametophyte which produces the gametes (see alternation of generations). See also mitosis.

Meiosis gives rise to variation. This is an important part of sexual reproduction. The variation produced is inherited, which means that evolution can take place as a result of the natural selection of certain variants to suit a changing environment. The way that meiosis gives rise to variation is by recombining genes from chromosomes in new ways. When the number of chromosomes is halved, there is some randomness in the way parts of chromosomes are selected to go into the gametes.

meiosis


nuclear membrane
pair of chromosomes
chromosomes pair up
chromatids cross over
chromatids (two strands of a chromosome) become visible
centrioles
cytoplasm
1
parent cell with four chromosomes
2
centrioles migrate to opposite ends of the cell
3
chromatids altered where crossing over took place
nuclear spindles form
4
whole chromosomes separated
5
chromosomes group but no new nuclear membrane forms
6
nuclear membrane
7
two new spindles form
chromatids separate
8
four nuclear membranes form
9
four daughter cells with two chromosomes each
none of the new chromosomes are exactly like the original chromosomes

(Image © Research Machines plc)

Meiosis is a type of cell division that produces gametes (sex cells, sperm and egg). This sequence shows an animal cell but only four chromosomes are present in the parent cell (1). There are two stages in the division process. In the first stage (2-6), the chromosomes come together in pairs and exchange genetic material. This is called crossing over. In the second stage (7-9), the cell divides to produce four gamete cells, each with only one copy of each chromosome from the parent cell.

Meitner, Lise (1878-1968)

Austrian-born Swedish physicist who worked with the German radiochemist Otto Hahn and was the first to realize that they had inadvertently achieved the fission of uranium. They also discovered protactinium in 1918. She refused to work on the atom bomb.

---

meitnerium

chemical symbol Mt

synthesized radioactive element of the transactinide series, atomic number 109, relative atomic mass 266. It was first produced in 1982 at the Laboratory for Heavy-Ion Research in Darmstadt, Germany, by fusing bismuth and iron nuclei; it took a week to obtain a single new, fused nucleus. It was known by the temporary name unnilennium until 1997 when it was named after the Austrian-born Swedish physicist Lise Meitner.

---

melaleuca tree

or paperbark

tropical tree belonging to the myrtle family. The leaves produce **cajuput oil**, which is used in medicine. (*Melaleuca leucadendron*, family Myrtaceae.)

In favourable conditions, such as in the Florida Everglades, the tree reproduces rapidly. Attempts are being made to root out and destroy it because in a forest fire its crown becomes a ball of flame, rapidly spreading the blaze in all directions.

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melamine

$C_3H_6N_6$

thermosetting polymer based on urea-formaldehyde. It is extremely resistant to heat and is also scratch-resistant. Its uses include synthetic resins.

melanin

brown pigment that gives colour to the eyes, skin, hair, feathers, and scales of many vertebrates. In humans, melanin helps protect the skin against ultraviolet radiation from sunlight. Both genetic and environmental factors determine the amount of melanin in the skin.

---

melanism

black coloration of animal bodies caused by large amounts of the pigment melanin. Melanin is of significance in insects, because melanic ones warm more rapidly in sunshine than do pale ones, and can be more active in cool weather. A fall in temperature may stimulate such insects to produce more melanin. In industrial areas, dark insects and pigeons match sooty backgrounds and escape predation, but they are at a disadvantage in rural areas where they do not match their backgrounds. This is known as **industrial melanism**.

---

melanoma

highly malignant tumour of the melanin-forming cells (melanocytes) of the skin. It develops from an existing mole in up to two-thirds of cases, but can also arise in the eye or mucous membranes.

Malignant melanoma is the most dangerous of the skin cancers; it is associated with brief but excessive exposure to sunlight. It is easily treated if caught early but deadly once it has spread. There is a genetic factor in some cases.

Once rare, this disease is increasing at the rate of 7% in most countries with a predominantly fair-skinned population, owing to the increasing popularity of holidays in the sun. Most at risk are those with fair hair and light skin, and those who have had a severe sunburn in childhood. Cases of melanoma are increasing by 4% a year worldwide.

---

melon

any of several large, juicy (95% water), thick-skinned fruits of trailing plants of the gourd family. The muskmelon (*Cucumis melo*), of which the honeydew melon is a variety, and the large red watermelon (*Citrullus vulgaris*) are familiar edible varieties. (Family Cucurbitaceae.)

Thought to have originated in Asia, the melon became naturalized in the Nile Valley and was introduced to Europe at the end of the 15th century.

Cucumbers, Melons, and Squash

Go to site

Informative guide to melons, squash, and cucumbers from the Virginia Cooperative Extension. There is a guide to planting them, as well as the types of soil and sunlight that yield best results. This site also features solutions to common problems and information about harvesting and storage.

---

meltdown

the melting of the core of a nuclear reactor, due to overheating.

To prevent such accidents all reactors have equipment intended to flood the core with water in an emergency. The reactor is housed in a strong containment vessel, designed to prevent radiation escaping into the atmosphere. The result of a meltdown would be an area radioactively contaminated for 25,000 years or more.

At Three Mile Island, Pennsylvania, USA, in March 1979, a partial meltdown occurred caused by a combination of equipment failure and operator error, and some radiation was released into the air. In April 1986, a reactor at Chernobyl, near Kiev, Ukraine, exploded, causing a partial meltdown of the core. Radioactive fallout was detected as far away as Canada and Japan. Dozens of people died in the immediate aftermath of the disaster, and thousands more will probably die prematurely of radiation-induced cancers in the longer term, according to an IAEA estimate.

---

melting point

temperature at which a substance melts, or changes from solid to liquid form. A pure substance under standard conditions of pressure (usually one atmosphere) has a definite melting point. If heat is supplied to a solid at its melting point, the temperature does not change until the melting process is complete. The melting point of ice is 0°C or 32°F.

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membrane

in living things, a continuous layer, made up principally of fat molecules, that encloses a cell or organelles within a cell. Small molecules, such as water and sugars, can pass through the cell membrane by diffusion. Large molecules, such as proteins, are transported across the membrane via special channels, a process often involving energy input. The Golgi apparatus within the cell is thought to produce certain membranes.

In cell organelles, enzymes may be attached to the membrane at specific positions, often alongside other enzymes involved in the same process, like workers at a conveyor belt. Thus membranes help to make cellular processes more efficient.

memory

in computing, the part of a system used to store data and programs either permanently or temporarily. There are two main types: immediate access memory and backing storage. Memory capacity is measured in bytes or, more conveniently, in kilobytes (units of 1,024 bytes) or megabytes (units of 1,024 kilobytes).

memory

ability to store and recall observations and sensations. Memory does not seem to be based in any particular part of the brain; it may depend on changes to the pathways followed by nerve impulses as they move through the brain. Memory can be improved by regular use as the connections between nerve cells (neurons) become 'well-worn paths' in the brain. Events stored in **short-term memory** are forgotten quickly, whereas those in **long-term memory** can last for many years, enabling recall of information and recognition of people and places over long periods of time.

Short-term memory is the most likely to be impaired by illness or drugs whereas long-term memory is very resistant to such damage. Memory changes with age and otherwise healthy people may experience a natural decline after the age of about 40. Research is just beginning to uncover the biochemical and electrical bases of the human memory.

menagerie

small collection of wild animals kept in captivity for display. Rulers of early times used to bring back wild animals from abroad for public exhibition. Private collections later became common, and until the early 19th century one was maintained at the Tower of London, England. From these collections developed present-day zoos.

Mendel, Gregor Johann (1822-1884)

Austrian biologist who founded genetics. His experiments with successive generations of peas gave the basis for his theory of particulate inheritance rather than blending, involving dominant and recessive characters; see Mendelism. His results, published 1865-69, remained unrecognized until the early 20th century.

Mendel formulated two laws now recognized as fundamental laws of heredity: the law of segregation and the law of independent assortment of characters. Mendel concluded that each parent plant contributes a 'factor' to its offspring for determining a particular trait. These are what we now recognize as genes or alleles. He showed that the pairs of factors in the offspring do not give rise to a blend of traits.

Much of his work was performed on the edible pea *Pisum*, which he grew in the monastery garden. He carefully self-pollinated and wrapped (to prevent accidental pollination by insects) each individual plant, collected the seeds produced by the plants, and studied the offspring of these seeds. Seeing that some plants bred true and others not, he worked out the pattern of inheritance of various traits.

He reported his findings in 'Experiments with Plant Hybrids' (1866), but the importance of his work was not recognized at the time, even by the eminent botanist Karl Wilhelm von Naegeli, to whom Mendel sent a copy of his paper. It was not until 1900, when his work was rediscovered by Hugo De Vries, Carl Erich Correns, and Erich Tschermak von Seysenegg, that Mendel achieved fame - 16 years after his death.

mendelevium

chemical symbol Md

synthesized, radioactive metallic element of the actinide series, atomic number 101, relative atomic mass 258. It was first produced by bombardment of Es-253 with helium nuclei. Its longest-lived isotope, Md-258, has a half-life of about two months. The element is chemically similar to thulium. It was named by the US physicists at the University of California at Berkeley who first synthesized it in 1955 after the Russian chemist Dmitri Mendeleyev, who in 1869 devised the basis for the periodic table of the elements.

Mendeleyev, Dmitri Ivanovich (1834-1907)

Russian chemist who framed the periodic law in chemistry in 1869, which states that the chemical properties of the elements depend on their relative atomic masses. This law is the basis of the periodic table of the elements, in which the elements are arranged by atomic number and organized by their related groups.

Mendeleyev was the first chemist to understand that all elements are related members of a single ordered system. From his table he predicted the properties of elements then unknown, of which three (gallium, scandium, and germanium) were discovered in his lifetime. Meanwhile Lothar Meyer in Germany presented a similar but independent classification of the elements.

Mendeleyev, Dmitri Ivanovich

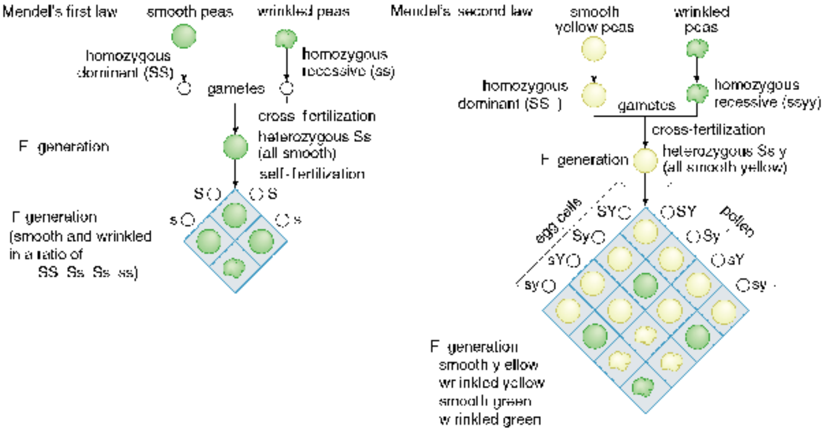
Go to site

Detailed biography of Dmitri Mendeleyev, the chemist who framed the periodic table of elements.

Mendelism

in genetics, the theory of inheritance originally outlined by Austrian biologist Gregor Mendel. He suggested that, in sexually reproducing species, all characteristics are inherited through indivisible 'factors' (now identified with genes) contributed by each parent to its offspring.

Mendelism


Mendel's first law
smooth peas
wrinkled peas
homozygous dominant (SS)
homozygous recessive (ss)
gametes
cross fertilization
F generation
heterozygous Ss (all smooth)
self-fertilization
S
S
s
s
F generation (smooth and wrinkled in a ratio of SS Ss Ss ss)
Mendel's second law
smooth yellow peas
wrinkled peas
homozygous dominant (SS)
homozygous recessive (ssyy)
gametes
cross-fertilization
F generation
heterozygous Ss y (all smooth yellow)
egg cells
pollen
SY
Sy
sY
sy
SY
Sy
sY
sy
F generation
smooth y ellow
wr inkled yellow
smooth green
w rinkled green

(Image © Research Machines plc)

Mendel's laws explain the proportion of offspring having various characteristics. When pea plants having smooth yellow peas are crossed with plants with wrinkled green peas, the first-generation offspring all have smooth yellow peas. The second-generation offspring, however, contain smooth yellow, wrinkled green, smooth green, and wrinkled yellow peas. This can be understood by tracing the passage of alleles Y, S, s, y throughout the generations. S and Y are dominant genes.

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menhaden

or hardhead or mossbunker

marine bony fish allied to shads and common on the Atlantic coast of North America. It is employed as bait, but is chiefly valuable for its rich oil. The residue remaining after extraction is used as a fertilizer.

classification

The menhaden *Brevoortia tyrannus* is in order Clupeiformes, class Osteichthyes.

---

menhir

(Breton 'long stone')

prehistoric tall, upright stone monument or megalith. Menhirs may be found singly as monoliths or in groups. They have a wide geographical distribution in the Americas (mainly as monoliths), and in Europe, Asia, and Africa, and belong to many different periods. Most European examples were erected in the late Neolithic (New Stone Age) or early Bronze Age.

The menhirs at Carnac in Brittany, northwestern France, are particularly impressive, one example standing about 10 m/39 ft high. In nearby Morbihan, Le Grand Menhir Brisé once stood almost 21 m/68 ft high.

In the British Isles, standing stones in England include the Devil's Arrows, Boroughbridge, West Yorkshire, and the Five Kings, Upper Coquerdale, Northumberland; and in Wales, Harold's Stones, Trelleck, Gwent. Numerous Irish examples, known as **goulaun**, **gallan**, **dallan**, or **liagan**, were built from the Neolithic to the early Christian period. In Scotland, groups of menhirs are often called **cat stones**, from Gaelic *cath* 'a battle'.

menhir

(Image © Research Machines plc)

One of a pair of standing stones sited in a field near Lamorna in Cornwall, jointly known as The Pipers. The function of standing stones in the prehistoric societies that erected them is unclear, although they may have had specific cultural or religious significance.

Ménière's disease

or Ménière's syndrome

recurring condition of the inner ear caused by an accumulation of fluid in the labyrinth of the ear that affects mechanisms of both hearing and balance. It usually develops in the middle or later years. Symptoms, which include deafness, ringing in the ears (tinnitus), nausea, vertigo, and loss of balance, may be eased by drugs, but there is no cure.

The vertigo and associated nausea of Menière's disease are often difficult to treat. Antihistamines, such as cinnarazine and betahistine, are effective in some patients. Surgical decompression of the fluid may relieve vertigo and prevent the condition worsening.

Ménière's Disease

Go to site

Information about symptoms, treatment, links to other contacts, and frequently asked questions about Ménière's Disease.

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meningitis

inflammation of the meninges (membranes) surrounding the brain, caused by bacterial or viral infection. Bacterial meningitis, though treatable by antibiotics, is the more serious threat. Diagnosis is by lumbar puncture.

Bacterial meningitis is caused by *Neisseria meningitidis*, a bacterium that colonizes the epithelial lining of the throat and is carried by 2-10% of the healthy population. Illness results if the bacteria enters the bloodstream, but this is rare.

Many common viruses can cause the occasional case of meningitis, although not usually in its more severe form. The treatment for viral meningitis is rest.

There are three strains of bacterial meningitis: serogroups A, B, and C. Vaccines exist for A and C, while clinical trials of candidate vaccines for meningitis B began in 2001. However, the existing vaccines do not provide long-term protection nor are they suitable for children under the age of two. B is the most prevalent of the groups, causing over 50% of cases in Europe and the USA. The severity of the disease varies from mild to lethal, and symptoms include fever, headache, nausea, neck stiffness, delirium, and (rarely) convulsions.

Childhood Infections - Meningitis

Go to site

Useful information on the signs and symptoms, and appropriate treatment of meningitis in children. The site also discusses the incubation, duration, and contagiousness of the illness, as well as the preventive measures that can be taken in certain cases.

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meningococcus

in medicine, the causative organism of meningococcal meningitis, *Neisseria meningitidis*.

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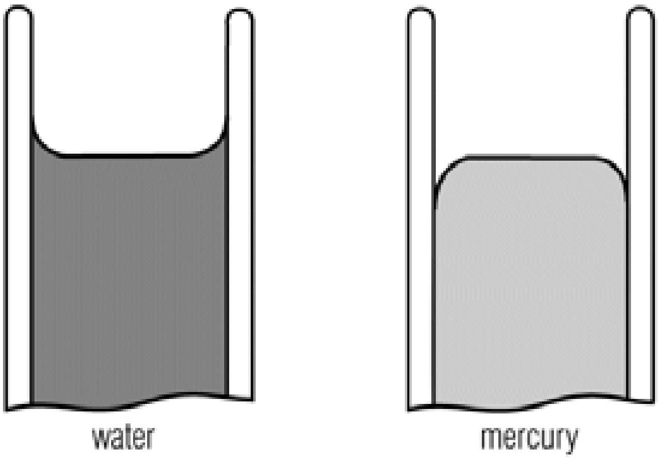
meniscus

in physics, the curved shape of the surface of a liquid in a thin tube, caused by the cohesive effects of surface tension (capillary action). When the walls of the container are made wet by the liquid, the meniscus is concave, but with highly viscous liquids (such as mercury) the meniscus is convex. Also, a meniscus lens is a concavo-convex or convexo-concave lens.

meniscus



(Image © Research Machines plc)

Comparison of the appearance of the meniscus in water and in mercury. When a liquid is placed in a thin tube, surface tension causes its surface to curve. A liquid, such as water, that wets the walls of the container has a concave meniscus, but a liquid that does not wet the walls, such as mercury, has a convex meniscus.

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meniscus

in biology, the fibro-cartilage in joints, such as the knee joint.

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menopause

in women, the cessation of reproductive ability, characterized by menstruation (see menstrual cycle) becoming irregular and eventually ceasing. The onset is at about the age of 50, but varies greatly. Menopause is usually uneventful, but some women suffer from complications such as flushing, excessive bleeding, and nervous disorders. Since the 1950s, hormone-replacement therapy (HRT), using oestrogen alone or with progestogen, a synthetic form of progesterone, has been developed to counteract such effects.

Long-term use of HRT was previously associated with an increased risk of cancer of the uterus, and of clot formation in the blood vessels, but newer formulations using natural oestrogens are not associated with these risks. Without HRT there is increased risk of osteoporosis (thinning of the bones) leading to broken bones, which may be indirectly fatal, particularly in the elderly.

The menopause is also known as the 'change of life'.

menopause

All female mammals undergo the menopause, not just humans.

Menopause Information and Resources

Go to site

Guide to the menopause, hormone-replacement therapy, and some other women's health issues. There are a whole host of recent medical reports and news, as well as basic facts and advice.

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menstrual cycle

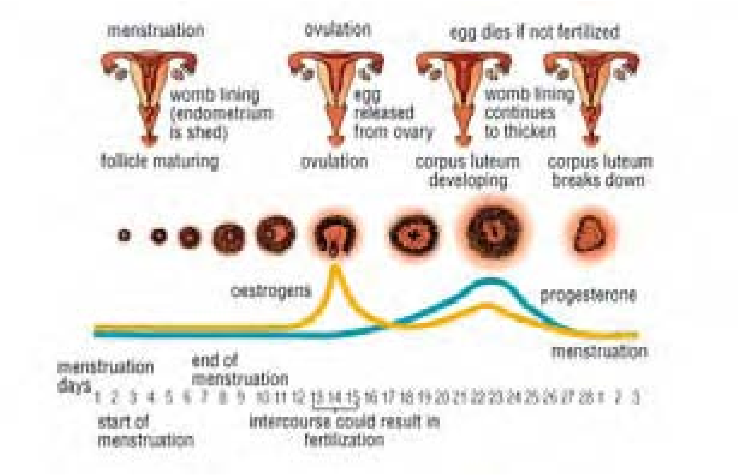
biological cycle occurring in female mammals of reproductive age that prepares the body for pregnancy. At the beginning of the cycle, a Graafian (egg) follicle develops in the ovary, and the inner wall of the uterus forms a soft spongy lining. The egg (ovum) is released from the ovary, and the uterus lining (endometrium) becomes vascularized (filled with blood vessels). At this stage fertilization can take place. If fertilization does not occur, the corpus luteum (remains of the Graafian follicle) degenerates, and the uterine lining breaks down, and is shed. This is what causes the loss of blood that marks menstruation. The cycle then begins again. Human menstruation takes place from puberty to menopause, except during pregnancy, occurring about every 28 days.

The monthly release of an egg from a woman's ovaries and the changes in the thickness of the lining of her womb (uterus) are controlled by hormones produced by the pituitary gland and by the ovaries. If fertilization occurs, the corpus luteum persists and goes on producing progesterone.

menstrual cycle

The menstrual cycles of women living in close proximity to each other become synchronized. This could be due to pheromones released in the sweat and may have evolved as means of thwarting male infidelity.

menstrual cycle


menstruation
ovulation
egg dies if not fertilized
womb lining (endometrium is shed)
egg released from ovary
womb lining continues to thicken
follicle maturing
ovulation
corpus luteum developing
corpus luteum breaks down
oestrogens
progesterone
menstruation
menstruation
days
end of menstruation
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 1 2 3
start of menstruation
intercourse could result in fertilization

(Image © Research Machines plc)

From puberty to the menopause, most women produce a regular rhythm of hormones that stimulate the various stages of the menstrual cycle. The change in hormone levels may cause premenstrual tension. This diagram shows an average menstrual cycle. The dates of each stage vary from woman to woman.

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mental disability

arrested or incomplete development of mental capacities. It can be very mild, but in more severe cases is associated with social problems and difficulties in living independently. A person may be born with a mental disability (for example, Down's syndrome) or may acquire it through brain damage. Between 90 and 130 million people in the world suffer from such disabilities.

Clinically, mental disability is graded as profound, severe, moderate, or mild, roughly according to IQ and the sufferer's ability to cope with everyday tasks. Among its many causes are genetic defect (phenylketonuria), chromosomal errors (Down's syndrome), infection before birth (rubella) or in infancy (meningitis), trauma (brain damage at birth or later), respiratory difficulties at the time of birth, toxins (lead poisoning), physical deprivation (lack of, or defective, thyroid tissue, as in cretinism), and gross psychological deprivation. No clear cause of disability can be established for more than half of individuals with an IQ of less than 70.

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mental illness

disordered functioning of the mind. Since normal working cannot easily be defined, the borderline between mild mental illness and normality is a matter of opinion (not to be confused with normative behaviour). It is broadly divided into two categories: neurosis, in which the patient remains in touch with reality; and psychosis, in which perception, thought, and belief are disordered.

Mental Health

Go to site

Aiming 'to improve understanding, diagnosis, and treatment of mental illness throughout the world', this well-designed encyclopedia of mental disorders offers comprehensive information on diagnosing and treating mental health problems, and includes an online magazine.

menu

in computing, a list of options, displayed on screen, from which the user may make a choice - for example, the choice of services offered to the customer by a bank cash dispenser: withdrawal, deposit, balance, or statement. Menus are used extensively in graphical user interface (GUI) systems, where the menu options are often selected using a pointing device called a mouse.

Mercalli scale

qualitative scale describing the **intensity** of an earthquake. It differs from the Richter scale, which indicates earthquake **magnitude** and is quantitative. It is named after the Italian seismologist Giuseppe Mercalli (1850-1914).

Intensity is a subjective value, based on observed phenomena, and varies from place to place even when describing the same earthquake.

Mercalli scale

The Mercalli scale is a measure of the intensity of an earthquake. It differs from the Richter scale, which measures magnitude. It is named after the Italian seismologist Giuseppe Mercalli (1850-1914). The scale shown here is the Modified Mercalli Intensity Scale, developed in 1931 by US seismologists Harry Wood and Frank Neumann.

Intensity value	Description
I	not felt, except by a very few under especially favourable conditions
II	felt only by a few persons at rest, especially on upper floors of buildings
III	felt quite noticeably by persons indoors, especially on upper floors of buildings; many people do not recognize it as an earthquake; standing motor cars may rock slightly
IV	felt indoors by many, outdoors by a few persons during the day; at night, some awakened; dishes, windows, doors disturbed; walls make cracking sound; standing motor cars rock noticeably
V	felt by nearly everyone; many awakened; some dishes, windows broken; unstable objects overturned; pendulum clocks may stop
VI	felt by all; some heavy furniture moved; a few instances of fallen plaster; damage slight
VII	damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken
VIII	damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse; damage great in poorly built structures; fall of chimneys, factory stacks, columns, monuments, walls; heavy furniture overturned
IX	damage considerable in specially designed structures; damage great in substantial buildings, with partial collapse; buildings shifted off foundations
X	some well built wooden structures destroyed; most masonry and frame structures with foundations destroyed; rails bent
XI	few, if any (masonry) structures remain standing; bridges destroyed; rails bent greatly
XII	damage total; lines of sight and level are distorted; objects thrown into the air

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Mercator, Gerardus (1512-1594)

Flemish Gerhard Kremer

Flemish mapmaker who devised **Mercator's projection** in which the parallels and meridians on maps are drawn uniformly at 90°. The projection continues to be used, in particular for navigational charts, because compass courses can be drawn as straight lines, but the true area of countries is increasingly distorted the further north or south they are from the Equator. For other types, see map projection.

Mercator, Gerardus

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of Gerardus Mercator. In addition to biographical information, you will find a list of references about Mercator and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Mercator. There is also an image of him, which can be enlarged, and a map of his birthplace.

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merchant navy

the passenger and cargo ships of a country. Most are owned by private companies. To avoid strict regulations on safety, union rules on crew wages, and so on, many ships are today registered under 'flags of convenience', that is, flags of countries that do not have such rules.

During wartime, merchant shipping may be drafted by the national government for military purposes.

Mercury

closest planet to the Sun. Its mass is 0.056 that of Earth. On its sunward side the surface temperature reaches over 400°C/752°F, but on the 'night' side it falls to -170°C/-274°F.

mean distance from the Sun

58 million km/36 million mi

equatorial diameter

4,880 km/3,030 mi

rotation period

59 Earth days

year

88 Earth days

atmosphere

Mercury's small mass and high daytime temperature mean that it is impossible for an atmosphere to be retained.

surface

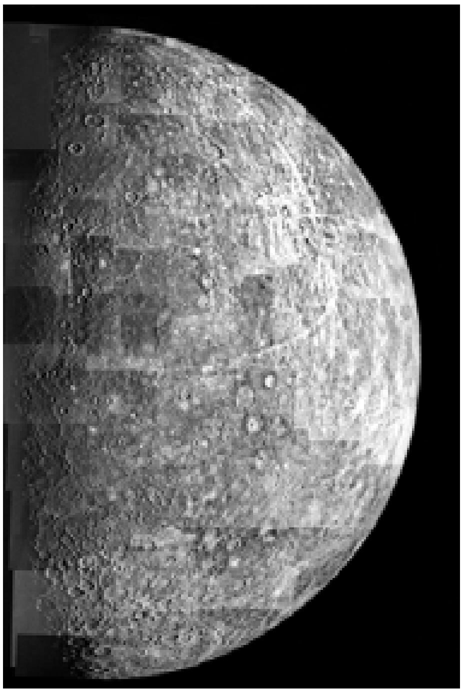
composed of silicate rock often in the form of lava flows. In 1974 the US space probe Mariner 10 showed that Mercury's surface is cratered by meteorite impacts.

satellites

none

NASA's Mariner 10 probe, launched on 3 November 1973, arrived at Mercury on 29 March 1974, and provided the first close-up images of the planet. NASA launched a US$286 million mission to Mercury in 2004 to orbit the planet during 2008, 2009, and 2011. It will photograph the planet's surface, analyse its atmospheric composition, and map its magnetic field. The European Space Agency, in collaboration with Japan, plans to send probes to orbit Mercury, arriving in 2015 after a four-year journey.

Mercury



(Image © NASA)

The surface of Mercury constructed from a montage of images taken by the Mariner 10 space probe in 1974 and 1975.

Mercury

Go to site

Detailed description of the planet Mercury. It includes statistics and information about the planet, along with a chronology of its exploration supported by a good selection of images.

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mercury

chemical symbol Hg; or quicksilver

(Latin mercurius)

heavy, silver-grey, metallic element, atomic number 80, relative atomic mass 200.59. Its symbol comes from the Latin *hydrargyrum*, derived from the Greek words for water and silver. It is a dense, mobile liquid with a low melting point (-38.87°C/-37.96°F). Its chief source is the mineral cinnabar, HgS, but it sometimes occurs in nature as a free metal.

uses

Its alloys with other metals are called amalgams (a silver-mercury amalgam is used in dentistry for filling cavities in teeth). Industrial uses include drugs and chemicals, mercury-vapour lamps, arc rectifiers, power-control switches, barometers, and thermometers.

hazards

Mercury is a cumulative poison that can contaminate the food chain, and cause intestinal disturbance, kidney and brain damage, and birth defects in humans. Where liquid mercury is handled, vapours are also a health risk. The World Health Organization's 'safe' limit for mercury is 0.5 milligrams of mercury per kilogram of muscle tissue. The US Environmental Protection Agency recommended a maximum safe level for mercury of 0.1 mg per kilogram of body weight in January 1998 (a fifth of that recommended by WHO). The discharge into the sea by industry of organic mercury compounds such as dimethylmercury was the chief cause of mercury poisoning in the latter half of the 20th century.

Between 1953 and 1975, 684 people in the Japanese fishing village of Minamata were poisoned (115 fatally) by organic mercury wastes that had been dumped into the bay and had accumulated in the bodies of fish and shellfish.

history

The element was known to the ancient Chinese and Hindus, and is found in Egyptian tombs of about 1500 BC. It was named by the alchemists after the fast-moving god, for its fluidity.

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mercury fulminate

highly explosive compound used in detonators and percussion caps. It is a grey, sandy powder and extremely poisonous.

Mercury project

US project 1961-63 to put a human in space using the one-seat *Mercury* spacecraft.

The first two *Mercury* flights, on Redstone rockets, were short voyages to the edge of space and back. The flights were known by the double name of *Mercury-Redstone*, with Alan Shepherd flying on *Mercury-Redstone 3* to become the first US astronaut in space. The orbital flights were launched by Atlas rockets. The *Mercury-Atlas 6* flight was made on 20 February 1962 by John Glenn, who became the first US astronaut to orbit the Earth.

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merganser

any of several diving ducks with long, slender, serrated bills for catching fish, widely distributed in the northern hemisphere. Most have crested heads. (Genus *Mergus*, family Anatidae.)

The male **common merganser** or **goosander** (*M. merganser*) has a greenish-black head, black back, and a pinkish-white breast and underparts; the male **red-breasted merganser** (*M. serrator*) drake has a crested glossy green head, white neck, red breast and black upper surface with white margins. The females of both are very similar, with crested chestnut heads, white underparts, and grey backs. *M. australis* is a rare species found only in the Auckland Islands.

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meridian

half a great circle drawn on the Earth's surface passing through both poles and thus through all places with the same longitude. Terrestrial longitudes are usually measured from the Greenwich Meridian.

An astronomical meridian is a great circle passing through the celestial pole and the zenith (the point immediately overhead).

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merino

breed of sheep. Its close-set, silky wool is highly valued. Originally from Spain, the merino is now found all over the world, and is the breed on which the Australian wool industry is built.

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meristem

region of plant tissue containing cells that are actively dividing to produce new tissues (or have the potential to do so). Meristems found in the tip of roots and stems, the apical meristems, are responsible for the growth in length of these organs.

The cambium is a lateral meristem that is responsible for increase in girth in perennial plants. Some plants also have intercalary meristems, as in the stems of grasses, for example. These are responsible for their continued growth after cutting or grazing has removed the apical meristems of the shoots.

Meristem culture involves growing meristems taken from shoots on a nutrient-containing medium, and using them to grow new plants.

It is used to propagate infertile plants or hybrids that do not breed true from seed and to generate virus-free stock, since viruses rarely infect apical meristems.

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merlin

small falcon of Europe, Asia, and North America, where it is also called a **pigeon hawk**. The male, 26 cm/10 in long, has a grey-blue back and reddish-brown barred front; the female, 32 cm/13 in long, has a dark brown back and lighter front with streaks. Merlins fly relatively low over the ground when hunting and 'stoop' quickly onto their prey, which consists mainly of small birds. (Species *Falco columbarius*, order Falconiformes.)

They are found mainly on rocks and moors. On moorland the nest is generally built on a slope among the heather, and in other localities on rock ledges. The eggs are bluish-white, blotched with brown markings; four or five are laid.

MERLIN array

radio telescope network centred on Jodrell Bank, northern England. The system is being upgraded by the introduction of optical fibre links to replace microwave links, and by making it possible to change rapidly the radio frequencies at which observations are made. The new system is called e-MERLIN.

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mermaid's purse

purse-shaped egg case of the skates and many sharks.

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mesa

(Spanish 'table')

flat-topped, steep-sided plateau, consisting of horizontal weak layers of rock topped by a resistant formation; in particular, those found in the desert areas of the USA and Mexico. A small mesa is called a butte.

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mescaline

psychedelic drug derived from a small, spineless cactus *Lophophora williamsii* of northern Mexico and the southwest USA, known as peyote. The tops (called mescal buttons), which scarcely appear above ground, are dried and chewed, or added to alcoholic drinks. Mescaline is a crystalline alkaloid $C_{11}H_{17}NO_3$. It is used by some North American Indians in religious rites.

Mesmer, Friedrich Anton (or Franz) (1734-1815)

Austrian physician, an early experimenter in hypnosis, which was formerly (and popularly) called 'mesmerism' after him.

He claimed to reduce people to trance state by consciously exerted 'animal magnetism', their willpower being entirely subordinated to his. Expelled by the police from Vienna, he created a sensation in Paris in 1778, but was denounced as a charlatan in 1785.

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mesmerism

former term for hypnosis, after Austrian physician Friedrich Mesmer.

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mesoglea

layer of jellylike noncellular tissue that separates the endoderm and ectoderm in jellyfish and other coelenterates.

Mesolithic

the Middle Stone Age developmental stage of human technology and of prehistory.

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meson

in physics, a group of unstable subatomic particles made up of a quark and an antiquark. They are found in cosmic radiation, and are emitted by nuclei under bombardment by very high-energy particles.

The mesons form a subclass of the hadrons and include the kaons and pions. Their existence was predicted in 1935 by Japanese physicist Hideki Yukawa.

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mesophyll

tissue between the upper and lower epidermis of a leaf blade (lamina), consisting of parenchyma-like cells containing numerous chloroplasts.

In many plants, mesophyll is divided into two distinct layers.

The **palisade mesophyll** is usually just below the upper epidermis and is composed of regular layers of elongated cells. Lying below them is the **spongy mesophyll**, composed of loosely arranged cells of irregular shape. This layer contains fewer chloroplasts and has many intercellular spaces for the diffusion of gases (required for respiration and photosynthesis), linked to the outside by means of stomata.

---

mesosphere

layer in the Earth's atmosphere above the stratosphere and below the thermosphere. It lies between about 50 km/31 mi and 80 km/50 mi above the ground.

Mesozoic

era of geological time 245–65 million years ago, consisting of the Triassic, Jurassic, and Cretaceous periods. At the beginning of the era, the continents were joined together as Pangaea; dinosaurs and other giant reptiles dominated the sea and air; and ferns, horsetails, and cycads thrived in a warm climate worldwide. By the end of the Mesozoic era, the continents had begun to assume their present positions, flowering plants were dominant, and many of the large reptiles and marine fauna were becoming extinct.

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messaging

sending text messages by phone; see text messaging.

Messerschmitt, Willy (Wilhelm Emil) (1898-1978)

German aeroplane designer. His Me-109 was a standard Luftwaffe fighter in World War II, and his Me-262 (1944) was the first mass-produced jet fighter.

Messerschmitt aeroplanes were characterized by simple concept, minimum weight and aerodynamic drag, and the possibility of continued development. He designed cantilever monoplanes from the early 1920s when the market still looked for biplanes with visible struts and bracing wires.

The Me-109 held the world speed record of 610 kph/379 mph from 1937.

Messier, Charles (1730-1817)

French astronomer. He discovered 15 comets and in 1784 published a list of 103 star clusters and nebulae. Objects on this list are given M (for Messier) numbers, which astronomers still use today, such as

M1 (the Crab nebula) and M31 (the Andromeda galaxy).

Messier catalogue

in astronomy, catalogue of 103 galaxies, nebulae, and star clusters (the Messier objects) published in 1784 by French astronomer Charles Messier. Catalogue entries are denoted by the prefix 'M'. Well-known examples include M31 (the Andromeda galaxy), M42 (the Orion nebula), and M45 (the Pleiades star cluster).

Messier compiled the catalogue to identify fuzzy objects that could be mistaken for comets. The list was later extended to 109.

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metabolism

chemical processes of living organisms enabling them to grow and to function. It involves a constant alternation of building up complex molecules (**anabolism**) and breaking them down (**catabolism**). For example, green plants build up complex organic substances from water, carbon dioxide, and mineral salts (photosynthesis); by digestion animals partially break down complex organic substances, ingested as food, and subsequently resynthesize them for use in their own bodies (see digestive system). Within cells, complex molecules are broken down by the process of respiration. The waste products of metabolism are removed by excretion.

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metal

any of a class of chemical elements with specific physical and chemical characteristics. Metallic elements compose about 75% of the 112 elements in the periodic table of the elements.

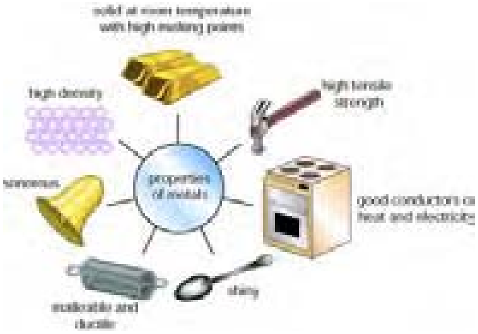
Physical properties include a sonorous tone when struck; good conduction of heat and electricity; high melting and boiling points; opacity but good reflection of light; malleability, which enables them to be cold-worked and rolled into sheets; and ductility, which permits them to be drawn into thin wires.

The majority of metals are found in nature in a combined form only, as compounds or mineral ores; about 16 of them also occur in the elemental form, as native metals. Their chemical properties are largely determined by the extent to which their atoms can lose one or more electrons and form positive ions (cations).

All metals except mercury are solid at ordinary temperatures, and all of them will crystallize under suitable conditions. The chief chemical properties of metals also include their strong affinity for certain non-metallic elements, for example sulphur and chlorine, with which they form sulphides and chlorides. Metals will, when fused, enter into the forming of alloys.

By comparing the reactions of metals with oxygen, water, acids, and other substances, the metals can be arranged in order of reactivity, known as the reactivity series of metals.

metal



(Image © Research Machines plc)

The properties shared by most metals.

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metal detector

electronic device for detecting metal, usually below ground, developed from the wartime mine detector. In the head of the metal detector is a coil, which is part of an electronic circuit. The presence of metal causes the frequency of the signal in the circuit to change, setting up an audible note in the headphones worn by the user.

They are used to survey areas for buried metallic objects, occasionally by archaeologists. However, their indiscriminate use by treasure hunters has led to their being banned on recognized archaeological sites in some countries.

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metal fatigue

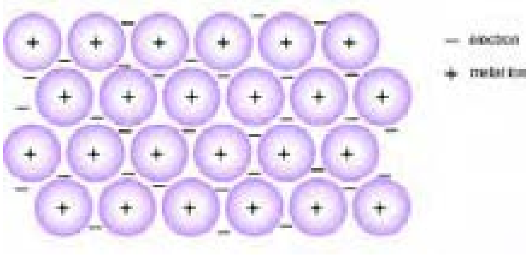
condition in which metals fail or fracture under relatively light loads, when these loads are applied repeatedly. Structures that are subject to flexing, such as the airframes of aircraft, are prone to metal fatigue.

metallic bond

force of attraction operating in a metal that holds the atoms together in a metallic structure. In metallic bonding, metal atoms form a close-packed, regular arrangement. The atoms lose their outer-shell electrons to become positive ions. The outer electrons become a 'sea' of mobile electrons surrounding a lattice of positive ions. The lattice is held together by the strong attractive forces between the mobile electrons and the positive ions.

The properties of metals can be explained in terms of metallic bonding. Metals conduct electricity as the electrons are free to move. Conduction of heat occurs by vibration of the positive ions as well as via the mobile electrons. Metals are both ductile and malleable because the bonding is not broken when metals are deformed; instead, the metal ions slide over each other to new lattice positions.

metallic bond



(Image © Research Machines plc)

In metallic bonding, metal ions are tightly packed with their outer shell electrons overlap, so each electron becomes detached from its parent atom (delocalized). The metal is held together by the strong forces of attraction between the positive nuclei and the surrounding sea of delocalized electrons.

metallic character

chemical properties associated with those elements classed as metals. These properties, which arise from the element's ability to lose electrons, are: the displacement of hydrogen from dilute acids; the formation of basic oxides; the formation of ionic chlorides; and their reducing reaction, as in the thermite process (see reduction).

In the periodic table of the elements, metallic character increases down any group and across a period from right to left.

metallic glass

substance produced from metallic materials (non-corrosive alloys rather than simple metals) in a liquid state which, by very rapid cooling, are prevented from reverting to their regular metallic structure. Instead they take on the properties of glass, while retaining the metallic properties of malleability and relatively good electrical conductivity.

metallographic examination

technique used by archaeologists for analysing the manufacturing techniques of metal artefacts. A cross-sectional slice of an artefact is polished, etched to highlight internal structures, and examined under a metallurgical microscope. The reflected light of the microscope enhances uneven surfaces, revealing grain size, shape, and boundaries, inclusions, fabric, defects, and other detail.

metalloid

or semimetal

any chemical element having some of but not all the properties of metals; metalloids are thus usually electrically semiconducting. They comprise the elements germanium, arsenic, antimony, and tellurium. Metalloids are found in the periodic table of the elements between metals and non-metals.

metallurgy

the science and technology of producing metals, which includes extraction, alloying, and hardening. **Extractive**, or **process, metallurgy** is concerned with the extraction of metals from their ores and refining and adapting them for use.
Physical metallurgy is concerned with their properties and application.
Metallography establishes the microscopic structures that contribute to hardness, ductility, and strength.

Metals can be extracted from their ores in three main ways: **dry processes**, such as smelting, volatilization, or amalgamation (treatment with mercury); **wet processes**, involving chemical reactions; and **electrolytic processes**, which work on the principle of electrolysis.

The foundations of metallurgical science were laid about 3500 BC in Egypt, Mesopotamia, China, and India, where the art of smelting metals from ores was discovered. Later, gold, silver, copper, lead, and tin were worked in various ways, although they had been cold-hammered as native metals for thousands of years. The smelting of iron was discovered about 1200 BC. The Romans hardened and tempered iron, using heat treatment. From then until about AD 1400, advances in metallurgy came into Europe by way of Arabian chemists. Cast iron was first made in Ancient Greece for casting statues and figures. In the 14th century it was made in a crude blast furnace and came into regular production in Europe in the 16th century. The demands of the Industrial Revolution led to an enormous increase in wrought iron production. The invention by British civil engineer Henry Bessemer of the Bessemer process in 1856 made cheap steel available for the first time, leading to its present widespread use and the industrial development of many specialized steel alloys.

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metamorphic rock

rock altered in structure, composition, and texture by pressure or heat after its original formation. (Rock that actually melts under heat is called igneous rock upon cooling.) For example, limestone can be metamorphosed by heat into marble, and shale by pressure into slate. The term was coined in 1833 by Scottish geologist Charles Lyell. Metamorphism is part of the rock cycle, the gradual formation, change, and re-formation of rocks over millions of years.

Composition of metamorphic rocks

Rock	Parent rock	Composition
amphibolite	basalt	biotite, chlorite, garnet, hornblende, etc.
gneiss	mudstones/shales	biotite, hornblende, muscovite, quartz, etc.
hornfels	mudstones/shales	andalusite, biotite, cordierite, corundum
marble	limestone	calcite, dolomite
phyllite	mudstones/shales	mainly micas and quartz
pyroxine	basalt	plagioclase, pyroxine, quartz, spinel
schist	mudstones/shales	biotite, chlorite, garnet, quartz, etc.
slate	mudstones/shales	mainly micas and quartz

Metamorphic rocks

	main primary material (before metamorphism)		
typical depth and temperature	**shale with several minerals**	**sandstone with only quartz**	**limestone with only calcite**
50,000 ft/570°F	slate	quartzite	marble
65,000 ft/750°F	schist		
82,000 ft/930°F	gneiss		
98,500 ft/1,100°F	hornfels	quartzite	marble

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metamorphism

geological term referring to the changes in rocks of the Earth's crust caused by increasing pressure and temperature. The resulting rocks are metamorphic rocks. All metamorphic changes take place in solid rocks. If the rocks melt and then harden, they are considered igneous rocks.

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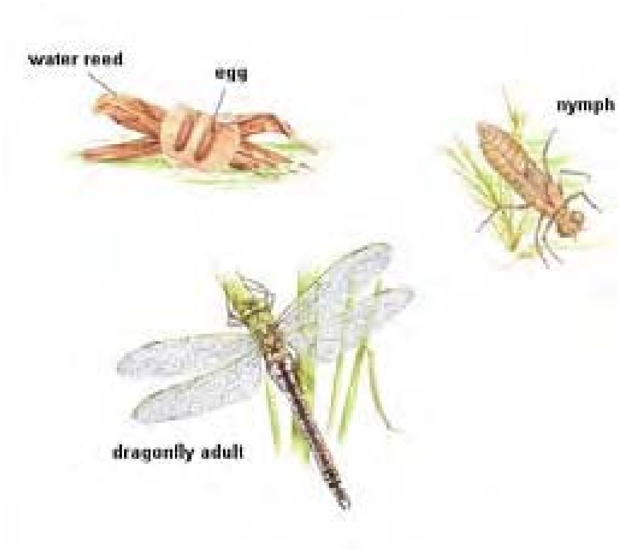
metamorphosis

period during the life cycle of many invertebrates, most amphibians, and some fish, during which the individual's body changes from one form to another through a major reconstitution of its tissues. For example, adult frogs are produced by metamorphosis from tadpoles, and butterflies are produced from caterpillars following metamorphosis within a pupa.

In classical thought and literature, metamorphosis is the transformation of a living being into another shape, either living or inanimate (for example Niobe). The Roman poet Ovid wrote about this theme.

metamorphosis



(Image © Research Machines plc)

The life cycle of the dragonfly. Eggs are usually laid under water and the larvae hatch as free-moving, water-dwelling nymphs. The carnivorous larva lives in the water for several weeks (or even years in some species) and undergoes a series of moults as it grows. It leaves the water when it is ready to undergo its final moult, during which it sheds its 'skin' to reveal the winged adult.

metazoa

another name for animals. It reflects a former system of classification, in which there were two main divisions within the animal kingdom, the multicellular animals, or metazoa, and the single-celled 'animals' or protozoa. The protozoa are no longer included in the animal kingdom, so only the metazoa remain.

Metchnikoff, Elie (1845-1916)

Russian Ilya Ilich Mechnikov

Russian zoologist and immunologist who was a pioneer of cellular immunology and shared the Nobel Prize for Physiology or Medicine in 1908 with Paul Ehrlich for the discovery of the innate immune response.

types of immunity

While at a teaching post in Italy, Metchnikoff started working on the immune cells of the starfish and discovered **innate immunity**; the process by which mobile white blood cells (phagocytes) engulf and digest potentially harmful micro-organisms. Innate immunity is the inborn, nonspecific defence against infection, since prior exposure to the pathogen is not required. Alternatively, **adaptive** or **acquired immunity** refers to the production of a specific antibody against a particular germ and is the basis of vaccination. Innate immunity is important to the fight against any infection, since it provides defence against pathogens during the three to five days it takes to elicit the acquired immune response.

meteor

flash of light in the sky, popularly known as a **shooting** or **falling star**, caused by a particle of dust, a meteoroid, entering the atmosphere at speeds up to 70 kps/45 mps and burning up by friction at a height of around 100 km/60 mi. On any clear night, several **sporadic meteors** can be seen each hour. A brilliant meteor is termed a **fireball**. Fragments found on the ground on the rare occasions when part of a meteoroid survives its passage through the atmosphere are called meteorites.

Several times each year, the Earth encounters swarms of dust shed by comets, which give rise to a **meteor shower**. This appears to radiate from one particular point in the sky, after which the shower is named. For example, the **Perseid** meteor shower in August appears to radiate from the constellation Perseus. The **Leonids** shoot out from the constellation Leo and are caused by dust from the comet Tempel-Tuttle, which orbits the Sun every 33 years. The Leonid shower reaches its peak when the comet is closest to the Sun.

Meteors, Meteorites, and Impacts

Go to site

Informative collection of facts about meteorites: how they are formed, classification, and what happens when one hits Earth. The site includes images of a selection of meteorites.

meteor-burst communications

technique for sending messages by bouncing radio waves off the trails of meteors. High-speed computer-controlled equipment is used to sense the presence of a meteor and to broadcast a signal during the short time that the meteor races across the sky.

The system, first suggested in the late 1920s, remained impracticable until data-compression techniques were developed, enabling messages to be sent in automatic high-speed bursts each time a meteor trail appeared. There are usually enough meteor trails in the sky at any time to permit continuous transmission of a message. The technique offers a communications link that is difficult to jam, is undisturbed by storms on the Sun, and would not be affected by nuclear war. The technology is in use by some amateur radio operators and by the US Department of Agriculture to collect data from remote automated weather stations.

meteorite

piece of rock or metal from space that reaches the surface of the Earth, Moon, or other body. Most meteorites are thought to be fragments from asteroids, although some may be pieces from the heads of comets. Most are stony, although some are made of iron and a few have a mixed rock-iron composition.

Stony meteorites can be divided into two kinds: **chondrites** and **achondrites**. Chondrites contain chondrules, small spheres of the silicate minerals olivine and orthopyroxene, and comprise 85% of meteorites. Achondrites do not contain chondrules. Meteorites provide evidence for the nature of the Solar System and may be similar to the Earth's core and mantle, neither of which can be observed directly.

Typical composition of meteorites

Type		Composition and structure
siderites (iron meteorites)		iron (more than 90%), nickel (8%), cobalt (0.6%), traces of other elements
stony-iron meteorites		mixtures of iron and stony materials (silicates). Teardrop-shaped stones are embedded in iron or iron droplets are embedded in stone.
aerolites (stone meteorites)	chondrites	many tiny millimetre-sized globules called chondrules embedded in a matrix of soft, porous material. Both chondrules and matrix consist mainly of olivine, pyroxene, and feldspar with tiny amounts of metal. Composition similar to that of Earth's crust
	carbonaceous chondrites	similar composition to ordinary chondrites but containing far fewer chondrules. The proportion of such minerals as feldspar is higher than in ordinary chondrites and may reach 15%
	achondrites	similar composition and structure to chondrites but showing a complete absence of chondrules. Almost identical to Earth rocks except for the fusion crust. Some achondrites are breccias, consisting of angular stone fragments held together by softer material

Meteorites and their Properties

Go to site

Well-presented guide to meteorites and their properties. Chapters describes meteorite origin, composition, impacts, as well as reporting meteors and hunting for meteorites. The clearly-written text is accompanied by excellent photographs.

Meteorites from Antarctica

Go to site

Superb NASA resource on Antarctic meteorites. As well as discussion of Antarctic meteorite research and details of the US meteorite collection, the Web site hosts an online version of the *Antarctic Meteorite* newsletter, with back issues available as downloadable PDF documents.

meteorology

scientific observation and study of the atmosphere, so that weather can be accurately forecast.

Data from meteorological stations and weather satellites are collated by computers at central agencies, and forecast and weather maps based on current readings are issued at regular intervals. Modern analysis, employing some of the most powerful computers, can give useful forecasts for up to six days ahead.

At meteorological stations readings are taken of the factors determining weather conditions: atmospheric pressure, temperature, humidity, wind (using the Beaufort scale), cloud cover (measuring both type of cloud and coverage), and precipitation such as rain, snow, and hail (measured at 12-hour intervals). Satellites are used either to relay information transmitted from the Earth-based stations, or to send pictures of cloud development, indicating wind patterns, and snow and ice cover.

history

Apart from some observations included by Aristotle in his book *Meteorologia*, meteorology did not become a precise science until the end of the 16th century, when Galileo and the Florentine academicians constructed the first thermometer of any importance, and when Evangelista Torricelli in 1643 discovered the principle of the barometer. Robert Boyle's work on gases, and that of his assistant, Robert Hooke, on barometers, advanced the physics necessary for the understanding of the weather. Gabriel Fahrenheit's invention of a superior mercury thermometer provided further means for temperature recording.

weather maps

In the early 19th century a chain of meteorological stations was established in France, and weather maps were constructed from the data collected. The first weather map in England, showing the trade winds and monsoons, was made in 1688, and the first telegraphic weather report appeared on 31 August 1848. The first daily telegraphic weather map was prepared at the Great Exhibition in 1851, but the Meteorological Office was not established in London until 1855. The first regular daily collections of weather observations by telegraph and the first British daily weather reports were made in 1860, and the first daily printed maps appeared in 1868.

collecting data

Observations can be collected not only from land stations, but also from weather ships, aircraft, and self-recording and automatic transmitting stations, such as the radiosonde. Radar may be used to map clouds and storms. Satellites have played an important role in televising pictures of global cloud distribution.

meteorology

(Image © Research Machines plc)

The Sphinx Hall Meteorological Station was built in 1950 on Sphinx summit, in the Bernese Alps, Switzerland, 3,573 m/11,723 ft above sea level. Nearby is the Jungfrau peak, at 4,158 m/13,642 ft one of the highest European mountains. Access to the station is via the mountain saddle known as the Jungfraujoch, which at 3,454 m/11,333 ft is the highest point in Europe accessible by rail.

NOAA

Go to site

The US government National Oceanic and Atmospheric Administration (NOAA) site is beautiful and user-friendly, with information and the latest news on weather, climate, oceanography, and remote sensing.

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meter

any instrument used for measurement. The term is often compounded with a prefix to denote a specific type of meter: for example, ammeter, voltmeter, flowmeter, or pedometer. Some meters not only indicate but also integrate (that is, combine and summarize) and/or record measurements.

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methanal

or formaldehyde; HCHO

gas at ordinary temperatures, condensing to a liquid at -21°C/-5.8°F. It has a powerful, penetrating smell. Dissolved in water, it is used as a biological preservative. It is used in the manufacture of plastics, dyes, foam (for example, urea-formaldehyde foam, used in insulation), and in medicine. It is the simplest example of an aldehyde.

Formaldehyde

Go to site

Page from the US Environmental Health Center which explains the dangers of formaldehyde, and explains what precautions can be made to decrease exposure to the chemical.

---

methane

CH_4

simplest hydrocarbon of the alkane series. Colourless, odourless, and lighter than air, it burns with a bluish flame and explodes when mixed with air or oxygen. As the chief constituent of natural gas, methane's main use is as a fuel. It also occurs in the explosive firedamp of coal mines. Methane emitted by rotting vegetation forms marsh gas, which may ignite by spontaneous combustion to produce the pale flame seen over marshland and known as will-o'-the-wisp.

Methane causes about 38% of the warming of the globe through the greenhouse effect; weight for weight it is 60–70 times more potent than carbon dioxide at trapping solar radiation in the atmosphere and so heating the planet. The rate of increase of atmospheric methane is declining and global emissions remained relatively constant over the period 1984–96, so atmospheric levels were predicted, in 1998, to stabilize by the 2020s. An estimated 15% of all methane gas in the atmosphere is produced by cattle and other cud-chewing animals, and 20% is produced by termites that feed on soil.

methane

The flatulence of a single sheep could power a small lorry for 40 km/25 mi a day. The digestive process produces methane gas, which can be burnt as fuel. According to one New Zealand scientist, the methane from 72 million sheep could supply the entire fuel needs of his country.

methane

The average dairy cow emits around 500 l/880 pt of methane per day.

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methanogenic bacteria

a group of micro-organisms belonging to the domain of the Archaea. They give off methane gas as a by-product of their metabolism, and are common in sewage treatment plants and hot springs, where the temperature is high and oxygen is absent.

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methanoic acid

or formic acid; HCOOH

colourless, slightly fuming liquid that freezes at 8°C/46.4°F and boils at 101°C/213.8°F. It occurs in stinging ants, nettles, sweat, and pine needles, and is used in dyeing, tanning, and electroplating.

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methanol

common name methyl alcohol; CH_3OH

simplest of the alcohols. It can be made by the dry distillation of wood (hence it is also known as wood alcohol), but is usually made from coal or natural gas. When pure, it is a colourless, flammable liquid with a pleasant odour, and is highly poisonous.

Methanol is used to produce methanal (formaldehyde, from which resins and plastics can be made), methyl-*tert*-butyl ether (MTB, a replacement for lead as an octane-booster in petrol), vinyl acetate (largely used in paint manufacture), and petrol. In 1993 Japanese engineers built an engine, made largely of ceramics, that runs on methanol. The prototype is lighter and has a cleaner exhaust than comparable metal, petrol-powered engines.

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methionine

one of the nine essential amino acids. It is also used as an antidote to paracetamol poisoning.

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methyl alcohol

common name for methanol.

---

methylated spirit

alcohol that has been rendered undrinkable, and is used for industrial purposes, as a fuel for spirit burners or a solvent.

Its consumption can lead to blindness and eventually death. One of the poisonous substances in it is methanol, or methyl alcohol, and this gives it its name. (The 'alcohol' of alcoholic drinks is ethanol.)

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methyl benzene

alternative name for toluene.

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methyl orange

$C_{14}H_{14}N_3NaO_3S$

orange-yellow powder used as an acid-base indicator in chemical tests, and as a stain in the preparation of slides of biological material. Its colour changes with pH; below pH 3.1 it is red, above pH 4.4 it is yellow.

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metre

symbol m

SI unit of length, equivalent to 1.093 yards or 39.37 inches. It is defined by scientists as the length of the path travelled by light in a vacuum during a time interval of 1/299,792,458 of a second.

metre

The metre was originally (in 1791) defined as one ten-millionth of the distance from the North Pole to the equator, on a line through Paris.

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metric system

system of weights and measures developed in France in the 18th century and recognized by other countries in the 19th century.

In 1960 an international conference on weights and measures recommended the universal adoption of a revised International System (Système International d'Unités, or SI), with seven prescribed 'base units': the metre (m) for length, kilogram (kg) for mass, second (s) for time, ampere (A) for electric current, kelvin (K) for thermodynamic temperature, candela (cd) for luminous intensity, and mole (mol) for quantity of matter.

supplementary units

Two supplementary units are included in the SI system - the radian (rad) and steradian (sr) - used to measure plane and solid angles. In addition, there are recognized derived units that can be expressed as simple products or divisions of powers of the basic units, with no other integers appearing in the expression; for example, the watt.

non-SI units

Some non-SI units, well established and internationally recognized, remain in use in conjunction with SI units: minute, hour, and day in measuring time; multiples or submultiples of base or derived units that have long-established names, such as tonne for mass and litre for volume; and specialist measures such as the metric carat for gemstones.

prefixes

Prefixes used with metric units are tera (T), million million times; giga (G), billion (thousand million) times; mega, (M) million times; kilo (k), thousand times; hecto (h), hundred times; deca (da), ten times; deci (d), tenth part; centi (c), hundredth part; milli (m), thousandth part; micro (μ), millionth part; nano (n), billionth part; pico (p), trillionth part; femto (f), quadrillionth part; atto (a), quintillionth part.

metric distances

To remember metric distances in descending order:

Kippers **m**ake **c**old **m**eals

Kilometres / **m**etres / **c**entimetres / **m**illimetres

Units in the metric system

Length		
1 centimetre	= 10 millimetres	
1 decimetre	= 10 centimetres	= 100 millimetres
1 metre	= 10 decimetres	= 1,000 millimetres
1 decametre	= 10 metres	
1 hectometre	= 10 decametres	= 100 metres
1 kilometre	= 10 hectometres	= 1,000 metres
Area		

1 square centimetre	= 100 square millimetres	
1 square metre	= 10,000 square centimetres	= 1,000,000 square millimetres
1 are	= 100 square metres	
1 hectare	= 100 ares	= 10,000 square metres
1 square kilometre	= 100 hectares	= 1,000,000 square metres
Mass (avoirdupois)		
1 centigram	= 10 milligrams	
1 decigram	= 10 centigrams	= 100 milligrams
1 gram	= 10 decigrams	= 1,000 milligrams
1 decagram	= 10 grams	
1 hectogram	= 10 decagrams	= 100 grams
1 kilogram	= 10 hectograms	= 1,000 grams
1 metric ton	= 1,000 kilograms	
Volume		
1 cubic centimetre	= 1,000 cubic millimetres	
1 cubic decimetre	= 1,000 cubic centimetres	= 1,000,000 cubic millimetres
1 cubic metre	= 1,000 cubic decimetres	= 1,000,000,000 cubic millimetres
Capacity		
1 centilitre	= 10 millilitres	
1 decilitre	= 10 centilitres	= 100 millilitres
1 litre	= 10 decilitres	= 1,000 millilitres
1 decalitre	= 10 litres	
1 hectolitre	= 10 decalitres	= 100 litres
1 kilolitre	= 10 hectolitres	= 1,000 litres

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metric ton

or tonne; symbol t or T

unit of mass equal to 1,000/kg/2,205 lb.

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mg

symbol for **milligram**.

MHD

abbreviation for magnetohydrodynamics.

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mho

SI unit of electrical conductance, now called the siemens; equivalent to a reciprocal ohm.

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mi

symbol for mile.

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mica

any of a group of silicate minerals that split easily into thin flakes along lines of weakness in their crystal structure (perfect basal cleavage). They are glossy, have a pearly lustre, and are found in many igneous and metamorphic rocks. Their good thermal and electrical insulation qualities make them valuable in industry.

Their chemical composition is complicated, but they are silicates with silicon-oxygen tetrahedra arranged in continuous sheets, with weak bonding between the layers, resulting in perfect cleavage.

A common example of mica is muscovite (white mica), $KAl_2Si_3AlO_{10}(OH,F)_2$.

Michaelmas daisy

popular name for a species of aster, and also for the sea aster or starwort.

Michelson, Albert Abraham (1852-1931)

German-born US physicist. With his colleague Edward Morley, he performed in 1887 the **Michelson-Morley experiment** to detect the motion of the Earth through the postulated ether (a medium believed to be necessary for the propagation of light). The failure of the experiment indicated the nonexistence of the ether, and led Albert Einstein to his theory of relativity. Michelson was awarded the Nobel Prize for Physics in 1907 for his measurement of the speed of light through the design and application of precise optical instruments such as the interferometer. He was the first American to be awarded a Nobel prize.

He invented the **Michelson interferometer** to detect any difference in the velocity of light in two directions at right angles. The negative result of the Michelson-Morley experiment demonstrated that the velocity of light is constant whatever the motion of the observer. Michelson also made a precise measurement of the speed of light.

MICR

abbreviation for magnetic-ink character recognition.

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micro-

symbol μ

prefix denoting a one-millionth part (10^{-6}). For example, a micrometre, μm, is one-millionth of a metre.

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microbe

another name for micro-organism.

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microbiology

study of micro-organisms, mostly viruses and single-celled organisms such as bacteria, protozoa, and yeasts. The practical applications of microbiology are in medicine (since many micro-organisms cause disease); in brewing, baking, and other food and beverage processes, where the micro-organisms carry out fermentation; and in genetic engineering, which is creating increasing interest in the field of microbiology. This discipline is also crucial for our understanding of the ecology and evolution of life on Earth, which for 2/3 of its history was inhabited exclusively by microbes.

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microchip

popular name for the silicon chip, or integrated circuit.

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microclimate

climate of a small area, such as a woodland, lake, or even a hedgerow. Significant differences can exist between the climates of two neighbouring areas - for example, a town is usually warmer than the surrounding countryside (forming a heat island), and a woodland cooler, darker, and less windy than an area of open land.

Microclimates play a significant role in agriculture and horticulture, as different crops require different growing conditions.

---

microcomputer

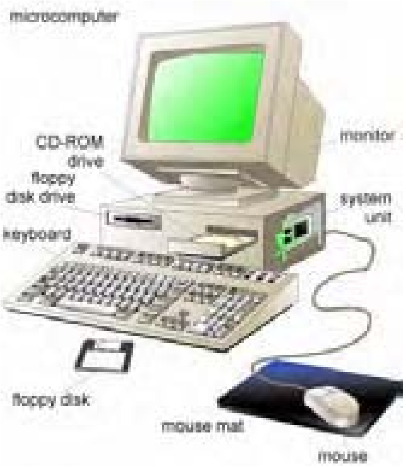
or micro or personal computer

small desktop or portable computer, typically designed to be used by one person at a time, although individual computers can be linked in a network so that users can share data and programs.

Its central processing unit is a microprocessor, contained on a single integrated circuit.

Microcomputers are the smallest of the four classes of computer (the others are supercomputer, mainframe, and minicomputer). Since the appearance in 1975 of the first commercially available microcomputer, the Altair 8800, micros have become ubiquitous in commerce, industry, and education.

microcomputer



(Image © Research Machines plc)

The component parts of the microcomputer: the system unit contains the hub of the system, including the central processing unit (CPU), information on all of the computer's peripheral devices, and often a fixed disk drive. The monitor (or visual display unit) displays text and graphics, the keyboard and mouse are used to input data, and the floppy disk and CD-ROM drives read data stored on disks.

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microfiche

sheet of film on which printed text is photographically reduced. See microform.

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microform

generic name for media on which text or images are photographically reduced. The main examples are **microfilm** (similar to the film in an ordinary camera) and **microfiche** (flat sheets of film, generally 105 mm/4 in × 148 mm/6 in, holding the equivalent of 420 standard pages). Microform has the advantage of low reproduction and storage costs, but it requires special devices for reading the text. It is widely used for archiving and for storing large volumes of text, such as library catalogues.

Computer data may be output directly and quickly in microform by means of COM (computer output on microfilm/microfiche) techniques.

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micrometer

instrument for measuring minute lengths or angles with great accuracy; different types of micrometer are used in astronomical and engineering work.

The type of micrometer used in astronomy consists of two fine wires, one fixed and the other movable, placed in the focal plane of a telescope; the movable wire is fixed on a sliding plate and can be positioned parallel to the other until the object appears between the wires.

The movement is then indicated by a scale on the adjusting screw.

---

micrometre

symbol μm

one-millionth of a metre.

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micro-organism

or microbe

living organism invisible to the naked eye but visible under a microscope. Micro-organisms include viruses and single-celled organisms such as bacteria and yeasts. Yeasts are fungi, but other fungi are often big enough to see with the naked eye and so are not micro-organisms. The study of micro-organisms is known as microbiology.

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microphone

primary component in a sound-reproducing system, whereby the mechanical energy of sound waves is converted into electrical signals by means of a transducer. In one type, a diaphragm is attached to a coil of wire placed between two poles of a permanent magnet. Sound waves cause the diaphragm to vibrate, which in turn causes the coil of wire to move in the magnetic field of the permanent magnet. An induced electrical current, matching the pattern of the sound waves, flows through the coil and is fed to an amplifier. The amplified signals are either stored or sent to a loudspeaker.

One of the simplest microphones is the telephone receiver mouthpiece, invented by Scottish-US inventor Alexander Graham Bell in 1876; other types of microphone are used with broadcasting and sound-film apparatus.

Telephones have a **carbon microphone**, which reproduces only a narrow range of frequencies. For live music, a **moving-coil microphone** is often used. In it, a diaphragm that vibrates with sound waves moves a coil through a magnetic field, thus generating an electric current. The **ribbon microphone** combines the diaphragm and coil. The **condenser microphone** is most commonly used in recording and works by a capacitor.

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microprocessor

complete computer central processing unit contained on a single integrated circuit, or chip. The appearance of the first microprocessor in 1971 designed by Intel for a pocket calculator manufacturer heralded the introduction of the microcomputer. The microprocessor has led to a dramatic fall in the size and cost of computers, and dedicated computers can now be found in washing machines, cars, and so on. Examples of microprocessors are the Intel Pentium family and the IBM/Motorola PowerPC, used by Apple Computer.

The earliest chips could process about 60,000 instructions per second; by 2006 they were capable of processing 27,100 million instructions per second.

How Microprocessors Work

Go to site

Interactive exploration of how a microprocessor works. It takes you step-by-step through a simple task on the chip to illustrate the function of its different parts. There is also a glossary containing definitions of the component parts of a microprocessor, plus classroom activities, and related topics such as 'How transistors work' and 'How chips are made'.

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micropropagation

mass production of plants by placing tiny pieces of plant tissue in sterile glass containers along with nutrients. Perfect clones of superplants are produced in sterile cabinets, with filtered air and carefully controlled light, temperature, and humidity. The system is used for the house-plant industry and for forestry – micropropagation gives immediate results, whereas obtaining genetically homogeneous tree seed by traditional means would take over a hundred years.

Micropropagation at Kew

Go to site

Report of the work of the Micropropagation Unit at Britain's prestigious Kew Gardens. It contains descriptions of how endangered species are cultured in vitro from seed or vegetative material. There are details of Kew's online publication *Micropropagation News*.

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micropyle

in flowering plants, a small hole towards one end of the ovule. At pollination the pollen tube growing down from the stigma eventually passes through this pore. The male gamete is contained within the tube and is able to travel to the egg in the interior of the ovule. Fertilization can then take place, with subsequent seed formation and dispersal.

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microscope

instrument for forming magnified images with high resolution for detail. Optical and electron microscopes are the ones chiefly in use; other types include acoustic, scanning tunnelling, and atomic force microscopes.

The **optical microscope** usually has two sets of glass lenses and an eyepiece. The first true compound microscope was developed in 1609 in the Netherlands by Zacharias Janssen (1580-*c.* 1638). **Fluorescence microscopy** makes use of fluorescent dyes to illuminate samples, or to highlight the presence of particular substances within a sample. Various illumination systems are also used to highlight details.

The **transmission electron microscope**, developed from 1932, passes a beam of electrons, instead of a beam of light, through a specimen. The eyepiece is replaced with a fluorescent screen or photographic plate; far higher magnification and resolution are possible than with the optical microscope.

The **scanning electron microscope** (SEM), developed in the mid-1960s, moves a fine beam of electrons over the surface of a specimen, the reflected electrons being collected to form the image. The specimen has to be in a vacuum chamber.

The **acoustic microscope** passes an ultrasonic (ultrahigh-frequency sound) wave through the specimen, the transmitted sound being used to form an image on a computer screen.

In the **scanned-probe microscope**, developed in the late 1980s, a probe with a tip so fine that it may consist only of a single atom is moved across the surface of the specimen. In the **scanning tunnelling microscope**, an electric current that flows through a probe is used to construct an image of the specimen. In 1988 a scanning tunnelling microscope was used to photograph a single protein molecule for the first time. In the **atomic force microscope**, the force felt by a probe is measured and used to form the image. These instruments can magnify a million times and give images of single atoms.

Microscope: The Scanning Tunnelling Microscope

seeing the unseeable

In Jan 1991, the Japanese electronics firm Hitachi produced the smallest writing of all time. The message read 'Peace 91', followed by the initials of the Hitachi Central Research Laboratory where the work was done. The letters were less than 1.5 nanometres (1.5 thousand-millionths of a metre) high. They were written by removing individual sulphur atoms from the surface of a crystal of molybdenum disulphide. This was not the first time that a message had been written with individual atoms. In late 1990, researchers at IBM wrote their company name by placing 35 xenon atoms on the surface of a nickel crystal.

how it was done

Both teams used scanning tunnelling microscopes (STM) to write their messages. These microscopes belong to a family of remarkable new microscopes developed in the late 1980s. These microscopes, called scanned probe microscopes, run a metal probe, with a tip so fine that it may consist only of a single atom, across the surface of the specimen. In the STM, an electric current that flows through the probe is used to construct an image of the specimen on a computer screen. A related instrument, the atomic force microscope, uses the force felt by the probe to form the image. These microscopes can magnify a million times and can give images of single atoms and molecules.

The STM can also be used to manipulate individual atoms, picking them up and moving them to new positions. The IBM message was written by bringing the tip of the STM probe very close to a xenon atom, and then increasing the current through the probe. This pins the atom down, allowing it to be dragged to a new position. The Japanese technique was to bring the probe tip very close to an atom in the crystal surface and subject the atom to a pulse of electricity. This blasts the atom away, leaving a space in the regular atomic arrangement of the crystal.

another possible application

The ability to manipulate individual atoms could be used to produce miniature data storage devices. The presence or absence of an atom at a particular site in a regular crystal arrangement could represent the 1s or 0s used in binary computer code. Hitachi claim that one thousand million bits of data could be held on a square 10 millionths of a metre across. Currently a computer disk 10 cm/4 in across would be needed to store this much data.

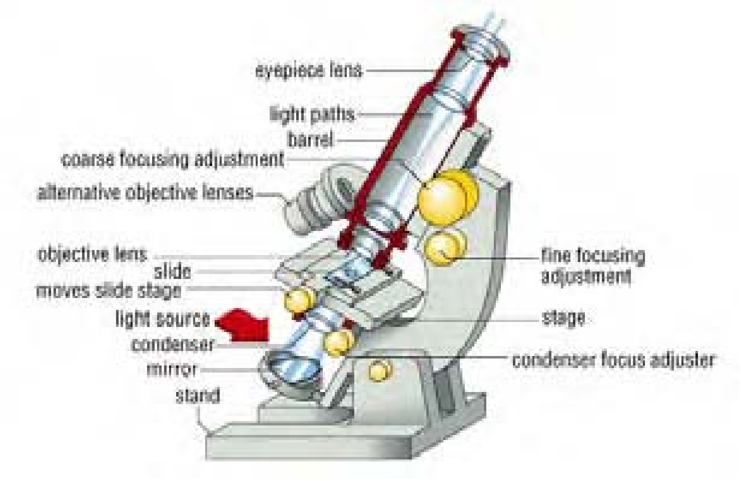
the photon STM

Probe technology has also produced an optical microscope that is capable of seeing details finer than the wavelength of visible light. Called the photon STM, the new microscope can see details at least ten times smaller than the best conventional optical microscopes. The photon STM has an advantage over the electron STM in that the specimen does not need to be electrically conducting, hence it can be used to examine biological samples. Biological samples examined by electron STMs must be coated with a thin film of conducting material before an image can be obtained. The photon STM, however, can produce images of both conducting and non-conducting materials, as long as they are transparent. Scientists at the Oak Ridge National Laboratory, where the new microscope was developed, have produced images of bacteria and viruses.

In the photon STM, the specimen is placed on the upper surface of a transparent prism. Light is shone upwards so that it reflects from the inside of the prism surface. A fine fibre optic probe is brought close to the specimen, and particles of light – photons – are collected by the probe as it travels across the specimen. The photons are collected by a photomultiplier and converted into an electrical signal. A computer forms an image from these signals.

Researchers expect to be able to increase the power of the photon STM in a number of ways. Firstly, they plan to reduce the wavelength of light used. At present they are using visible light, but plan to change to shorter-wavelength ultraviolet light, and then to X-rays. Another improvement would be to use a probe with a finer tip. This could be achieved by chemically etching the quartz probe until the tip is just 150 nanometres across. Finally, resolution could be increased by improving control of the scanning mechanism. As in all scanned probe microscopes, the distance between the probe and the specimen must be controlled and measured very accurately. These improvements should enable images of individual atoms to be produced, although the resolution of the photon STM will never match that of the electron STM.

microscope



(Image © Research Machines plc)

Terms used to describe an optical microscope. In essence, the optical microscope consists of an eyepiece lens and an objective lens, which are used to produce an enlarged image of a small object by focusing light from a light source. Optical microscopes can achieve magnifications of up to 1,500-2,000. Higher magnifications and resolutions are obtained by electron microscopes.

Dennis Kunkel's Microscopy

Go to site

This site is a photomicrographer's dream - full of pictures taken with both light and electron microscopes. As well as several differing galleries of images, there is also information about microscopy and how the pictures were taken.

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microsurgery

part or all of an intricate surgical operation - rejoining a severed limb, for example - performed with the aid of a binocular microscope, using miniaturized instruments. Sewing of the nerves and blood vessels is done with a nylon thread so fine that it is only just visible to the naked eye.

The technique permits treatment of previously inaccessible lesions in the eye or brain.

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microtubules

tiny tubes found in almost all cells with a nucleus. They help to define the shape of a cell by forming scaffolding for cilia and they also form the fibres of mitotic spindle (see mitosis).

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microwave heating

heating by means of microwaves. Microwave ovens use this form of heating for the rapid cooking or reheating of foods, where heat is generated throughout the interior of the food. If food is not heated completely, there is a danger of bacterial growth that may lead to food poisoning. This method is useful for rapid cooking of frozen and pre-prepared or convenience foods. Industrially, microwave heating is used for destroying insects in grain and enzymes in processed food, pasteurizing and sterilizing liquids, and drying timber and paper.

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microwave radiation

electromagnetic wave with a wavelength in the range 0.3 cm to 30 cm/0.1 in to 12 in, or 300-300,000 megahertz (between radio waves and infrared radiation). Microwaves are used in radar, in radio broadcasting, in satellite communications, and in microwave heating and cooking.

In microwave cooking, microwaves are used to transfer energy to food. The frequency of the microwaves matches the natural frequency at which the water molecules in food vibrate. The vibration energy of the water molecules results in an increase in temperature, which allows the food to be cooked.

Mid-Atlantic Ridge

mid-ocean ridge that runs along the centre of the Atlantic Ocean, parallel to its edges, for some 14,000 km/8,800 mi - almost from the Arctic to the Antarctic. Like other ocean ridges, the Mid-Atlantic Ridge is essentially a linear, segmented volcano.

The Mid-Atlantic Ridge runs down the centre of the ocean because the ocean crust has continually grown outwards from the ridge at a steady rate during the past 200 million years. Iceland straddles the ridge and was formed by volcanic outpourings.

Mid-Atlantic Ridge

(Image © Garret Nagle)

At Thingvellir, the North American plate is moving away from the European plate at an annual rate of 2 cm/0.8 in. Thingvellir marks the position of the Mid-Atlantic Ridge, a constructive plate boundary where new material is formed by the cooling of lava. There are steep-sided rift valleys, and a broad flat plain in the centre of the rift valley.

---

midge

common name for many insects resembling gnats, generally divided into biting midges (family Ceratopogonidae) that suck blood and non-biting midges (family Chironomidae).

The larvae of some midges are the 'bloodworms' of stagnant water.

MIDI

acronym for Musical Instrument Digital Interface

manufacturers' standard allowing different pieces of digital music equipment used in composing and recording to be freely connected.

The information-sending device (any electronic instrument) is called a controller, and the reading device (such as a computer) the sequencer. Pitch, dynamics, decay rate, and stereo position can all be transmitted via the interface. A computer with a MIDI interface can input and store the sounds produced by the connected instruments, and can then manipulate these sounds in many different ways. For example, a single keystroke may change the key of an entire composition. Even a full written score for the composition may be automatically produced, with software capable of producing this in 'real time', as the instrument is played.

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midnight sun

constant appearance of the Sun (within the Arctic and Antarctic circles) above the horizon during the summer.

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mid-ocean ridge

long submarine mountain range that winds along the middle of the ocean floor. The mid-ocean ridge system is essentially a segmented, linear shield volcano. There are a number of major ridges, including the Mid-Atlantic Ridge, which runs down the centre of the Atlantic; the East Pacific Rise in the southeast Pacific; and the Southeast Indian Ridge. These ridges are now known to be spreading centres, or divergent margins, where two plates of oceanic lithosphere are moving away from one another (see plate tectonics). Ocean ridges can rise thousands of metres above the surrounding seabed, and extend for up to 60,000 km/37,000 mi in length.

Ocean ridges usually have a rift valley along their crests, indicating where the flanks are being pulled apart by the growth of the plates of the lithosphere beneath. The crests are generally free of sediment; increasing depths of sediment are found with increasing distance down the flanks.

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midwifery

assistance of women in childbirth. Traditionally, it was undertaken by experienced specialists; in modern medical training it is a nursing speciality for practitioners called midwives. (See also obstetrics.)

The English physician William Harvey's 1653 work on generation contained an influential chapter on labour. Dr Peter Chamberlen II (1560-1631) made an important contribution to midwifery, particularly with his development of the first midwifery forceps.

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mifepristone

RU486

anti-progesterone drug used, in combination with a prostaglandin, to procure early abortion (up to the tenth week in pregnancy). It is administered only in hospitals or recognized clinics and a success rate of 95% is claimed. It was developed and first used in France in 1989. It was licensed in the UK in 1991, and became available in the USA from October 2000.

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mignonette

sweet-scented plant, native to North Africa, with yellowish-green flowers in racemes (along the main stem) and abundant foliage; it is widely cultivated. (*Reseda odorata*, family Resedaceae.)

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migraine

acute, sometimes incapacitating headache (generally only on one side), accompanied by nausea, that recurs, often with advance symptoms such as flashing lights. No cure has been discovered, but ergotamine normally relieves the symptoms. Some sufferers learn to avoid certain foods, such as chocolate, which suggests an allergic factor.

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migration

movement, either seasonal or as part of a single life cycle, of certain animals, chiefly birds and fish, to distant breeding or feeding grounds.

The precise methods by which animals navigate and know where to go are still obscure. Birds have much sharper eyesight and better visual memory of ground clues than humans, but in long-distance flights appear to navigate by the Sun and stars, possibly in combination with a 'reading' of the Earth's magnetic field through an inbuilt 'magnetic compass', which is a tiny mass of tissue between the eye and brain in birds. Similar cells occur in 'homing' honeybees and in certain bacteria that use it to determine which way is 'down'. Leatherback turtles use the contours of underwater mountains and valleys to navigate by. Most striking, however, is the migration of young birds that have never flown a route before and are unaccompanied by adults. It is postulated that they may inherit as part of their genetic code an overall 'sky chart' of their journey that is triggered into use when they become aware of how the local sky pattern, above the place in which they hatch, fits into it. Similar theories have been advanced in the case of fish, such as eels and salmon, with whom vision obviously plays a lesser role, but for whom currents and changes in the composition and temperature of the sea in particular locations may play a part - for example, in enabling salmon to return to the precise river in which they were spawned. Migration also occurs with land animals; for example, lemmings and antelope.

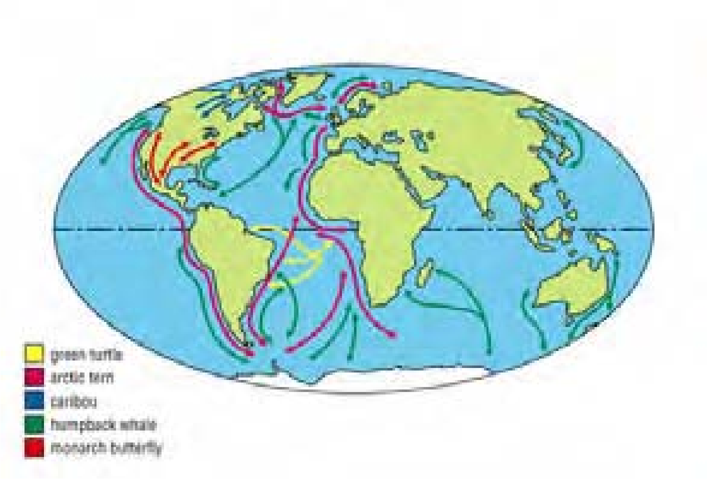
Species migration is the spread of the home range of a species over many years, for example the spread of the collared dove (*Streptopelia decaocto*) from Turkey to Britain over the period 1920-52. Any journey that takes an animal outside of its normal home range is called **individual migration**; when the animal does not return to its home range it is called **removal migration**. An example of **return migration** is the movement of birds that fly south for the winter and return to their home ranges in the spring. Many types of whale also make return migrations. In **remigration**, the return leg of the migration is completed by a subsequent generation, for example locust swarms migrate, but each part of the circuit is completed by a different generation.

Related to migration is the homing ability of pigeons, bees, and other creatures.

migration

The grey whale migrates further than any other mammal. It makes a round trip of 20,400 km/12,500 mi between its summer feeding grounds in the Arctic and its winter breeding lagoons off the western coast of Mexico.

migration



(Image © Research Machines plc)

Map showing animal migratory patterns.

Journey North

Go to site

US-based educational site for junior school children on the topic of wildlife migration. As well as the major ongoing project to track the southward migration of Monarch butterflies, there are projects on building garden areas to help migrating animals and the migration stories of a variety of species.

Milankovitch hypothesis

combination of factors governing the occurrence of ice ages proposed in 1930 by the Yugoslav geophysicist M Milankovitch (1879-1958). These include the variation in the angle of the Earth's axis, and the geometry of the Earth's orbit around the Sun.

mildew

any fungus that appears as a destructive growth on plants, paper, leather, or wood when they become damp for a certain length of time; such fungi usually form a thin white coating on the surface.

mile

symbol mi

imperial unit of linear measure. A statute mile is equal to 1,760 yards (1.60934 km), and an international nautical mile is equal to 2,026 yards (1,852 m).

milfoil

another name for the herb yarrow. Water milfoils are unrelated; they have whorls of fine leaves and grow underwater. (Genus *Miriophyllum*, family Haloragidaceae.)

milk

secretion of the mammary glands of female mammals, with which they suckle their young (during lactation). Over 85% is water, the remainder comprising protein, fat, lactose (a sugar), calcium, phosphorus, iron, and vitamins. The milk of cows, goats, and sheep is often consumed by humans, but regular drinking of milk after infancy is principally a Western practice.

milking machine

machine that uses suction to milk cows. The first milking machine was invented in the USA by L O Colvin in 1860. Later it was improved so that the suction was regularly released by a pulsating device, since it was found that continuous suction is harmful to cows.

milk teeth

or deciduous teeth

teeth that erupt in childhood between the ages of 6 and 30 months. They are replaced by the permanent teeth, which erupt between the ages of 6 and 21 years. See also dentition and tooth.

Milky Way

faint band of light crossing the night sky, consisting of stars in the plane of our Galaxy. The name Milky Way is often used for the Galaxy itself. It is a spiral galaxy, 100,000 light years in diameter and 2,000 light years thick, containing at least 100 billion stars. The Sun is in one of its spiral arms, about 27,000 light years from the centre, not far from its central plane. An extra arm to the Milky Way was discovered by astronomers in 2004. The arc of hydrogen is a few thousand light years thick and over 77,000 light years long, running along the outermost edge of the Milky Way.

The densest parts of the Milky Way, towards the Galaxy's centre, lie in the constellation Sagittarius. In places, the Milky Way is interrupted by lanes of dark dust that obscure light from the stars beyond, such as the Coalsack nebula in Crux (the Southern Cross). It is because of these that the Milky Way is irregular in width and appears to be divided into two between Centaurus and Cygnus.

Millennium Bug

crisis that faced computer professionals and users at the end of the year 1999. The crisis arose because it was feared that computers would be unable to operate normally when faced with the unfamiliar date format of the year 2000. Information about the year was typically stored in a two-digit instead of a four-digit field in order to save memory space, which without remedial work would have meant that after the year 1999 ended the year could have appeared as '00', interpreted as 1900 or not recognized at all. The turn of the century itself passed without significant breakdowns of normal services.

Many computer systems rely on the storage and use of dates to function, and many of the systems in use today were developed without taking into account the implications of the century date change. All affected parties in government, public sectors, and industry, had to prepare for the end of the century by testing and upgrading equipment and systems as necessary. Action to minimize these problems started in the mid 1990s.

Miller, Stanley Lloyd (1930-)

US chemist. In the early 1950s, under laboratory conditions, he tried to recreate the formation of life on Earth. To water under a gas mixture of methane, ammonia, and hydrogen, he added an electrical discharge. After a week he found that amino acids, the ingredients of protein, had been formed.

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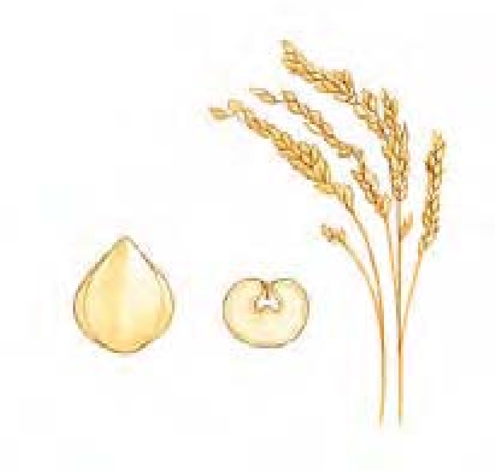
millet

any of several grasses of which the grains are used as a cereal food and the stems as animal fodder. Species include *Panicum miliaceum*, extensively cultivated in the warmer parts of Europe, and *Sorghum bicolor*, also known as durra. (Family Gramineae.)

millet



(Image © Research Machines plc)

Millet has been used as a cereal since ancient times. It is an important cereal in the tropics and warm temperate regions because it tolerates drought, growing well even in poor soil.

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milli-

symbol m

prefix denoting a one-thousandth part (10^{-3}).

For example, a millimetre, mm, is one thousandth of a metre.

millibar

unit of pressure, equal to one-thousandth of a bar.

Millikan, Robert Andrews (1868-1953)

US physicist who was awarded the Nobel Prize for Physics in 1923 for his determination of Planck's constant (a fundamental unit of quantum theory) in 1916 and the electric charge on an electron in 1913.

His experiment to determine the electronic charge, which took five years to perfect, involved observing oil droplets, charged by external radiation, falling under gravity between two horizontal metal plates connected to a high-voltage supply. By varying the voltage, he was able to make the electrostatic field between the plates balance the gravitational field so that some droplets became stationary and floated. If a droplet of weight W is held stationary between plates separated by a distance d and carrying a potential difference V, the charge, e, on the drop is equal to Wd/V.

milliliter

one-thousandth of a liter (ml), equivalent to 1 cu cm (cc) or 0.0338 fluid ounce.

millimeter of mercury

unit of pressure, used in barometers for measuring atmospheric pressure, defined as the pressure exerted by a column of mercury one millimeter high, at standard gravity and at a temperature of 32°F/0°C.

million

one thousand thousands, 1,000,000 or 10^6.

millipede

any of a group of arthropods that have segmented bodies, each segment usually bearing two pairs of legs, and a pair of short clubbed antennae on the distinct head. Most millipedes are no more than 2.5 cm/1 in long; a few in the tropics are 30 cm/12 in. (Class Diplopoda.)

Millipedes live in damp, dark places, feeding mainly on rotting vegetation. Some species injure crops by feeding on tender roots, and some produce a poisonous secretion in defence. Certain orders have silk glands.

Milner, Kit (Christopher) (1912-1998)

English-born Australian physicist who pioneered low-temperature physics and was part of the Manhattan Project to develop the atom bomb.

Milstein, César (1927-2002)

Argentine-born British molecular biologist who was awarded the Nobel Prize for Physiology or Medicine in 1984 for his work on immunity and the discovery of a technique for producing highly specific, monoclonal antibodies, which give immunity against specific diseases. He shared the prize with Georges Köhler and Niels Jerne.

Monoclonal antibodies are cloned cells that can be duplicated in limitless quantities and, when introduced into the body, can be targeted to seek out sites of disease. Milstein and his colleagues had thus devised a means of accessing the immune system for the purposes of research, diagnosis, and treatment.

Milstein

(Image © Research Machines plc)

César Milstein, a molecular biologist and winner of the 1984 Nobel Prize for Physiology or Medicine. This photograph was taken in the Medical Research Council Laboratory of Molecular Biology, Cambridge, where Milstein and his colleagues developed monoclonal antibodies, the achievement for which his Nobel Prize was awarded.

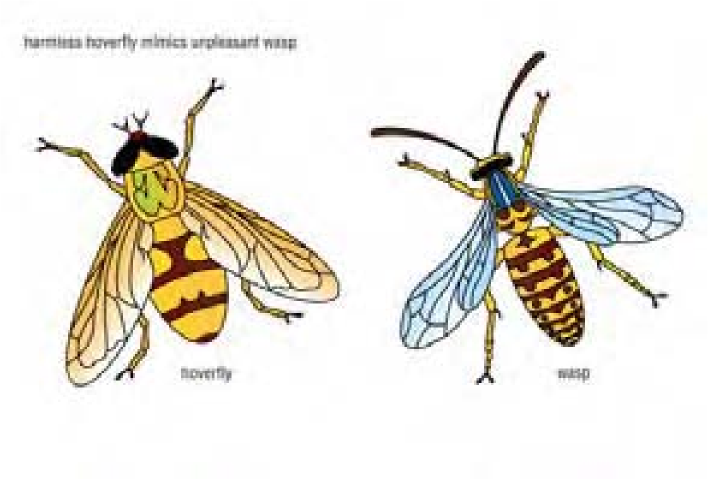
mimicry

imitation of one species (or group of species) by another. The most common form is **Batesian mimicry** (named after English naturalist H W Bates), where the mimic resembles a model that is poisonous or unpleasant to eat, and has aposematic, or warning, coloration; the mimic thus benefits from the fact that predators have learned to avoid the model. Hoverflies that resemble bees or wasps are an example. Appearance is usually the basis for mimicry, but calls, songs, scents, and other signals can also be mimicked.

In **Mullerian mimicry**, two or more equally poisonous or distasteful species have a similar colour pattern, thereby reinforcing the warning each gives to predators. The evolutionary benefit for the species involved is that they share the cost of 'predator learning', and thus reduce the number of events in which a predator harms one of their own. In 2005, British researchers demonstrated an additional benefit, namely that the predators learn more rapidly if two or more different kinds of unpalatable substances are coupled with the same warning sign.

In some cases, mimicry is not for protection, but allows the mimic to prey on, or parasitize, the model.

mimicry


harmless hoverfly mimics unpleasant wasp
hoverfly
wasp

(Image © Research Machines plc)

Batesian mimicry in which a harmless hoverfly is coloured like an unpleasant wasp in order to confuse a predator. A predator that has tried to eat a wasp will avoid the hoverfly.

mimosa

any of a group of leguminous trees, shrubs, or herbs belonging to the mimosa family, found in tropical and subtropical regions. They all have small, fluffy, golden, ball-like flowers. A similar but unrelated plant, *Acacia dealbata*, is sold as mimosa by European florists. (True mimosa genus *Mimosa*, family Mimosaceae.)

Certain species, such as the sensitive plant of Brazil *M. pudica*, shrink momentarily on being touched.

Mimosa

or Becrux or Beta Crucis

second-brightest star in the southern-hemisphere constellation of Crux, marking one of the four corners of the Southern Cross, and the 19th-brightest star in the night sky. It is a blue-white giant star of magnitude 0.8 around 460 light years from the Sun.

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mineral

naturally formed inorganic substance with a particular chemical composition and a regularly repeating internal structure. Either in their perfect crystalline form or otherwise, minerals are the constituents of rocks. In more general usage, a mineral is any substance economically valuable for mining (including coal and oil, despite their organic origins).

Mineral-forming processes include: melting of pre-existing rock and subsequent crystallization of a mineral to form igneous or volcanic rocks; weathering of rocks exposed at the land surface, with subsequent transport and grading by surface waters, ice, or wind to form sediments; and recrystallization through increasing temperature and pressure with depth to form metamorphic rocks. The transformation and recycling of the minerals of the Earth's outer layers is known as the rock cycle.

Minerals are usually classified as magmatic, sedimentary, or metamorphic. The magmatic minerals, in igneous rock, include the feldspars, quartz, pyroxenes, amphiboles, micas, and olivines that crystallize from silica-rich rock melts within the crust or from extruded lavas.

The most commonly occurring sedimentary minerals are either pure concentrates or mixtures of sand, clay minerals, and carbonates (chiefly calcite, aragonite, and dolomite).

Minerals typical of metamorphism include andalusite, cordierite, garnet, tremolite, lawsonite, pumpellyite, glaucophane, wollastonite, chlorite, micas, hornblende, staurolite, kyanite, and diopside.

Main dietary minerals

Mineral	Main dietary sources	Major functions in the body	Deficiency symptoms
calcium	milk, cheese, green vegetables, dried legumes	constituent of bones and teeth; essential for nerve transmission, muscle contraction, and blood clotting	tetany
chromium	vegetable oils, meat	involved in energy metabolism	impaired glucose metabolism
copper	drinking water, meat	associated with iron metabolism	anaemia
fluoride	drinking water, tea, seafoods	helps to keep bones and teeth healthy	increased rate of tooth decay
iodine	seafoods, dairy products, many vegetables, iodized table salt	essential for healthy growth and development	goitre
iron	meat (especially liver), legumes, green vegetables, whole grains, eggs	constituent of haemoglobin; involved in energy metabolism	anaemia
magnesium	whole grains, green vegetables	involved in protein synthesis	growth failure, weakness, behavioural disturbances
manganese	widely distributed in foods	involved in fat synthesis	not known in humans
molybdenum	legumes, cereals, offal	constituent of some enzymes	not known in humans
phosphorus	milk, cheese, meat, legumes, cereals	formation of bones and teeth, maintenance of acid-base balance	weakness, demineralization of bone
potassium	milk, meat, fruits	maintenance of acid-base balance, fluid balance, nerve transmission	muscular weakness, paralysis
selenium	seafoods, meat, cereals, egg yolk	role associated with that of vitamin E	not known in humans
sodium	widely distributed in foods	as for potassium	cramp, loss of appetite, apathy
zinc	widely distributed in foods	involved in digestion	growth failure, underdevelopment of reproductive organs

Mineral Gallery

Go to site

Collection of descriptions and images of minerals, organized by mineral name, class (sulphides, oxides, carbonates, and so on), and grouping (such as gemstones, birth stones, and fluorescent minerals).

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mineral extraction

recovery of valuable ores from the Earth's crust. The processes used include open-cast mining, shaft mining, and quarrying, as well as more specialized processes such as those used for sulphur (the Frasch process) and oil.

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mineralogy

study of minerals. The classification of minerals is based chiefly on their chemical composition and the kind of chemical bonding that holds their atoms together. The mineralogist also studies their crystallographic and physical characters, occurrence, and mode of formation.

The systematic study of minerals began in the 18th century, with the division of minerals into four classes: earths, metals, salts, and bituminous substances, distinguished by their reactions to heat and water.

Mineralogy Database

Go to site

Created by a mineral enthusiast, this is an extremely useful Web site if you need to know about a particular mineral. All major mineralogical data of each of the more than 3,700 minerals listed in *Dana's Mineralogy*, the definitive source on minerals, is in this searchable database.

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mineral oil

oil obtained from mineral sources, for example coal or petroleum, as distinct from oil obtained from vegetable or animal sources.

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mineral salt

in nutrition, simple inorganic chemicals that are required, as nutrients, by living organisms. Plants usually obtain their mineral salts from the soil, while animals get theirs from their food. Important mineral salts include iron salts (needed by both plants and animals), magnesium salts (needed mainly by plants, to make chlorophyll), and calcium salts (needed by animals to make bone or shell). A trace element is required only in tiny amounts.

Mineral salts are taken up in soluble form. When mineral salts dissolve in water they separate into particles called ions. Mineral salts do not usually contain the element carbon and are therefore inorganic (organic compounds always contain carbon).

Plant roots absorb individual mineral ions from soil water. Some of the ions travel by diffusion into the root; others are absorbed by active transport. The minerals required in the greatest amounts are those containing the element nitrogen, for example nitrate ions (or 'nitrates'), which are a key component of inorganic fertilizer. A plant uses nitrates in the production of proteins such as enzymes, so they are important for plant growth. They are often in short supply in the soil, which is why inorganic fertilizers are required. Plants also require magnesium in order to make chlorophyll, the green chemical that absorbs the energy of sunlight for photosynthesis.

Mammals absorb the mineral salts they need from their food. Important mineral salts include iron salts (needed for haemoglobin) and calcium salts (needed by animals to make bone). Both plants and animals need a range of other minerals in tiny amounts (trace elements).

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minicomputer

multi-user computer with a size and processing power between those of a mainframe and a microcomputer. Nowadays almost all minicomputers are based on microprocessors.

Minicomputers are often used in medium-sized businesses and in university departments handling database or other commercial programs and running scientific or graphical applications, however they are increasingly being replaced by networks of microcomputers.

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mining

extraction of minerals from under the land or sea for industrial or domestic uses. Exhaustion of traditionally accessible resources has led to the development of new mining techniques, for example extraction of oil from offshore deposits and from land shale reserves. Technology is also under development for the exploitation of minerals from entirely new sources such as mud deposits and mineral nodules from the seabed.

Mud deposits, for example, are laid down by hot springs (about 350°C/660°F): sea water penetrates beneath the ocean floor and carries copper, silver, and zinc with it on its return. Such springs occur along the mid-ocean ridges of the Atlantic and Pacific and in the geological rift between Africa and Arabia under the Red Sea.

Likewise, **mineral nodules** form on the ocean bed and contain manganese, cobalt, copper, molybdenum, and nickel; they stand out on the surface, and 'grow' by only a few millimetres every 100,000 years.

The deepest mine in Europe is a 1,100 m/3,610 ft deep working salt and potash mine at Boulby near Whitby on the northeast coast of England.

mining

(Image © Research Machines plc)

Cornish tin miners in the pit. Illnesses such as bronchitis, consumption, and rheumatism were common among the men who worked underground, and by the age of 40, many miners were no longer fit to work. Death and injury were accepted hazards of the job. The Cornish tin mines did, however, inspire several safety-based innovations, such as the miner's safety lamp, invented by Penzance-born Humphry Davy.

mink

either of two species of carnivorous mammals belonging to the weasel family, usually found in or near water. They have rich brown fur, and are up to 50 cm/1.6 ft long with bushy tails 20 cm/8 in long. They live in Europe and Asia (*M. lutreola*) and North America (*M. vison*). (Genus *Mustela*.)

They produce an annual litter of six in their riverbank burrows. The demand for their fur led to the establishment from the 1930s of mink ranches for breeding of the animals in a wide range of fur colours. In 1997 world production of mink skins was 26 million, which represented a 36% decline since 1986.

minnow

any of various small freshwater fishes of the carp family, found in streams and ponds worldwide. Most species are small and dull in colour, but some are brightly coloured. They feed on larvae and insects. (Family Cyprinidae.)

Minoan civilization

Bronze Age civilization on the Aegean island of Crete. The name is derived from Minos, the legendary king of Crete. The civilization is divided into three main periods: early Minoan, about 3000-2000 BC; middle Minoan, about 2000-1550 BC; and late Minoan, about 1550-1050 BC.

With the opening of the Bronze Age, about 3000 BC, the Minoan culture proper began. Each period was marked by cultural advances in copper and bronze weapons, pottery of increasingly intricate design, frescoes, and the construction of palaces and fine houses at Phaistos and Mallia, in addition to Knossos. About 1400 BC, in the late Minoan period, the civilization was suddenly destroyed by earthquake or war. A partial revival continued until about 1100.

The earlier (Linear A) of two languages used in Crete remains undeciphered; Linear B, which is also found at sites on the mainland of Greece, was deciphered by Michael Ventris.

In religion the Minoans seem to have worshipped principally a great mother goddess with whom was associated a young male god. The tales of Greek mythology about Rhea, the mother of Zeus, and the birth of Zeus himself in a Cretan cave seem to be based on Minoan religion.

Minoan Civilization

Go to site

Comprehensive source of information concerning Minoan civilization, which covers the history of Minoan Crete from the pre-palace period of 2,600 BC to the Sub-Minoan period of 1,000 BC. You will find articles on Sir Arthur Evans and the excavations at Knossos; the legend of King Minos; the story of the labyrinth, which includes the tale of Theseus and his battle with the Minotaur; and more. The articles include photographs, drawings, and diagrams. There is also an image gallery of Knossos and Minoan Crete.

minor planet

name sometimes given to the larger members of the asteroid belt.

mint

in botany, any aromatic plant of the mint family, widely distributed in temperate regions. The plants have square stems, creeping roots, and spikes of usually pink or purplish flowers. The family includes garden mint (*M. spicata*) and peppermint (*M. piperita*). (Genus *Mentha*, family Labiatae.)

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minute

unit of time consisting of 60 seconds; also a unit of angle equal to one sixtieth of a degree.

Miocene

('middle recent')

fourth epoch of the Tertiary period of geological time, 23.5-5.2 million years ago. At this time grasslands spread over the interior of continents, and hoofed mammals rapidly evolved.

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mips

acronym for Million Instructions Per Second

in computing, a measure of the speed of a processor. It does not equal the computer power in all cases.

Mir

(Russian 'peace' or 'world')

Russian space station, the core of which was launched on 20 February 1986. It was permanently occupied until 1999, and then purposely brought down on 23 March 2001 to crash into the Pacific Ocean. During its life, *Mir* travelled more than 3 billion km/2 billion mi, and was home to 104 cosmonauts.

The world's first modular space station, *Mir* weighed 135 tonnes and its core, weighing 20.9 tonnes, had four compartments for work, living, the engines, and docking. *Mir* evolved from, and somewhat resembled, the earlier series of *Salyut* space stations, but carried several improvements. Instead of one docking port there were six, four of which eventually had scientific and technical modules attached to them. The first was the 11-tonne *Kvant* (Russian 'quantum') astrophysics module in 1987. *Mir* had expanded to six modules by the early 1990s. The space shuttle *Atlantis* docked on 27 June 1995, exchanging crew members in the first of nine joint US-Russian missions to the station. A small wheat crop, the first successful cultivation of a plant from seed in space, was harvested on 6 December 1996.

During its orbiting life, *Mir* suffered more than 1,500 problems, including a fire in 1997, but all these were overcome by its crew. The most serious was a collision with an uncrewed cargo ship in June 1997, which damaged a solar panel and temporarily depressurized one of the modules.

The station's many residents included Valeri Poliakov, who established a space-endurance record of 14 months from January 1994 to March 1995; Helen Sharman, the first Briton in space, in May 1991; and Japanese journalist Toyohiro Akiyama, the first passenger in space, in December 1990.

Mir

(Image © NASA)

With shuttle mission STS-91, US astronauts made their final visit to the *Mir* space station. Pictured here is cosmonaut Nikolai Budarin (flight engineer) in *Mir* 's base block, the station's central module.

History of Shuttle-Mir

Go to site

Official site of the shuttle-*Mir* joint operations. There is extensive information ranging from the technical to human interest stories from crew members. The site also includes some low- and high-resolution images of the spacecraft, the crew at work, and the Earth.

Mira

or Omicron Ceti

brightest long-period pulsating variable star, located in the constellation Cetus. Mira was the first star discovered to vary periodically in brightness.

In 1596 Dutch astronomer David Fabricius noticed Mira as a third-magnitude object. Because it did not appear on any of the star charts available at the time, he mistook it for a nova. The German astronomer Johann Bayer included it on his star atlas in 1603 and designated it Omicron Ceti. The star vanished from view again, only to reappear within a year. It was named 'Stella Mira', 'the wonderful star', by Hevelius, who observed it 1659–82.

It has a periodic variation between third or fourth magnitude and ninth magnitude over an average period of 331 days. It can sometimes reach second magnitude and once almost attained first magnitude in 1779. At times it is easily visible to the naked eye, being the brightest star in that part of the sky, while at others it cannot be seen without a telescope.

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mirage

illusion caused by refraction of light in various atmospheric conditions. Mirages include the appearance of pools of water in the desert or on hot roads, or of places beyond the horizon apparently floating above it.

When there are hot layers of air near the ground, light rays from the sky near the horizon bend as they pass through them, so that they appear to come from the horizon. Because the light is from a blue sky, the horizon appears blue and watery. If, during the night, cold air collects near the ground, light can be bent in the opposite direction, so that objects below the horizon appear to float above it. In the same way, objects such as trees or rocks near the horizon can appear enlarged.

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mirror

any polished surface that reflects light; often made from 'silvered' glass (in practice, a mercury-alloy coating of glass). A plane (flat) mirror produces a same-size, erect 'virtual' image located behind the mirror at the same distance from it as the object is in front of it. A spherical concave mirror produces a reduced, inverted real image in front or an enlarged, erect virtual image behind it (as in a shaving mirror), depending on how close the object is to the mirror. A spherical convex mirror produces a reduced, erect virtual image behind it (as in a car's rear-view mirror).

formula

In a plane mirror the light rays appear to come from behind the mirror but do not actually do so. The inverted real image from a spherical concave mirror is an image in which the rays of light pass through it. The focal length$f$ of a spherical mirror is half the radius of curvature; it is related to the image distance v and object distance u by the equation $1/v + 1/u = 1/f$.

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miscarriage

spontaneous expulsion of a fetus from the womb before it is capable of independent survival. Miscarriage is believed to occur in 15% of pregnancies, often at such an early stage as to go unnoticed. Possible causes include fetal abnormality, abnormality of the uterus or cervix, infection, shock, underactive thyroid, and drug and alcohol use. The risk of miscarriage increases dramatically with age, from 5% for women under 30 to 50% for women in their mid-40s.

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missel thrush

bird belonging to the thrush family.

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missile

rocket-propelled weapon, which may be nuclear-armed. Modern missiles are often classified as surface-to-surface missiles (SSM), air-to-air missiles (AAM), surface-to-air missiles (SAM), or air-to-surface missiles (ASM). A **cruise missile** is in effect a pilotless, computer-guided aircraft; it can be sea-launched from submarines or surface ships, or launched from the air or the ground.

Rocket-propelled weapons were first used by the Chinese about AD 1100, and were encountered in the 18th century by the British forces. The rocket missile was then re-invented by William Congreve in England around 1805, and remained in use with various armies in the 19th century. The first wartime use of a long-range missile was against England in World War II, by the jet-powered German V1 (*Vergeltungswaffe*, 'revenge weapon' or Flying Bomb), a monoplane (wingspan about 6 m/18 ft, length 8.5 m/26 ft); the first rocket-propelled missile with a preset guidance system was the German V2, also launched by Germany against Britain in World War II.

Modern missiles are also classified as strategic or tactical: strategic missiles are the large, long-range **intercontinental ballistic missiles** (ICBMs, capable of reaching targets over 5,500 km/3,400 mi), and tactical missiles are the short-range weapons intended for use in limited warfare (with a range under 1,100 km/680 mi).

Not all missiles are large. There are many missiles that are small enough to be carried by one person. The Stinger, for example, is an anti-aircraft missile fired by a single soldier from a shoulder-held tube. Most fighter aircraft are equipped with missiles to use against enemy aircraft or against ground targets. Other small missiles are launched from a type of truck, called a MLRS (multiple-launch rocket system), that can move around a battlefield. Ship-to-ship missiles like the Exocet have proved very effective in naval battles.

The vast majority of missiles have systems that guide them to their target. The guidance system may consist of radar and computers, either in the missile or on the ground. These devices track the missile and determine the correct direction and distance required for it to hit its target. In the radio-guidance system, the computer is on the ground, and guidance signals are radio-transmitted to the missile. In the inertial guidance system, the computer is on board the missile. Some small missiles have heat-seeking devices fitted to their noses to seek out the engines of enemy aircraft, or are guided by laser light reflected from the target. Others (called TOW missiles) are guided by signals sent along wires that trail behind the missile in flight.

Outside the industrialized countries, 22 states had active ballistic-missile programmes by 1989, and 17 had deployed these weapons: Afghanistan, Argentina, Brazil, Cuba, Egypt, India, Iran, Iraq, Israel, North Korea, South Korea, Libya, Pakistan, Saudi Arabia, South Africa, Syria, and Taiwan. Non-nuclear short-range missiles were used during the Iran–Iraq War 1980–88 against Iraqi cities.

Battlefield missiles used in the 1991 Gulf War included antitank missiles and short-range attack missiles. NATO announced in 1990 that it was phasing out ground-launched nuclear battlefield missiles, and these are being replaced by types of tactical air-to-surface missile (TASM), also with nuclear warheads.

In the Falklands conflict in 1982, small, conventionally armed sea-skimming missiles were used (the French Exocet) against British ships by the Argentine forces, and similar small missiles have been used against aircraft and ships elsewhere.

missile

(Image © Corel)

An optically tracked anti-armour missile launched from a tube on top of an army vehicle. They are used to attack heavily armoured vehicles, such as tanks.

Mississippian

US term for the Lower or Early Carboniferous period of geological time, 363–323 million years ago. It is named after the state of Mississippi.

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mistletoe

any of several parasitic evergreen shrubs of the genera *Viscum* and *Phoradendron* of the family Loranthaceae, especially American mistletoe *P. flavescens*, parasitic on broad-leaved trees, and European mistletoe *V. album*. They grow on trees as branched bushes, with translucent white berries, and are used as Christmas decorations. The seeds of the European mistletoe are dispersed by birds, but the dwarf mistletoe *Arceuthobium pusillum* of North America shoots its seeds at 60 mph/100 kph as far as 16 yd/15 m. Mistletoes lose water more than ten times as fast as other plants to draw nutrients to them.

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mistral

cold, dry, northerly wind that occasionally blows during the winter on the Mediterranean coast of France, particularly concentrated along the Rhône valley. It has been known to reach a velocity of 145 kph/90 mph.

Mitchell, Juliet (1940-)

New Zealand-born British psychoanalyst and writer. Her article in *New Left Review* (1966) entitled 'Women: The Longest Revolution' was one of the first attempts to combine socialism and feminism, using Marxist theory to explain the reasons behind women's oppression. She published *Women's Estate* in 1971 and *Psychoanalysis and Feminism* in 1974.

Mitchell, R(eginald) J(oseph) (1895-1937)

English aircraft designer whose Spitfire fighter was a major factor in winning the Battle of Britain during World War II. The single-engined Spitfire prototype was produced in 1936, and put into service in 1938. More than 20,000 Spitfires were eventually built. The manoeuvrability and adaptability of the Spitfire accounted for its success.

Mitchell's first aeroplane, the Sea Lion (1919), was adapted from a standard design; faster models of Sea Lion followed. In 1924, Mitchell designed the Supermarine S-4. It was a monoplane and the whole wing section was made in one piece. He developed world-beating sea-planes for the Schneider Trophy races (1922-23) and won speed records with several of the S-model planes in the 1920s.

---

mite

minute arachnid related to the ticks. Some mites are free-living scavengers or predators. Some are parasitic, such as the **itch mite** (*Sarcoptes scabiei*), which burrows in skin causing scabies in humans and mange in dogs, and the **red mite** (*Dermanyssus gallinae*), which sucks blood from poultry and other birds. Others parasitize plants. (Order Acarina.)

The **harvest mite** (genus *Trombicula*) is harmless as an adult, but in the larval stage attacks people and animals, penetrating the skin and setting up great irritation. The **red spider mite** (*Tetranychus telarius*) is a troublesome pest in greenhouses as it feeds on plant juices. The face mite *Demodex folliculorum* is a microscopic and largely harmless, human parasite that lives in the follicles around the eyelids, nose, and ear canals. It has a life cycle of 14.5 days and females lay up to 25 eggs in a follicle. *Demodex* incidence increases with age, ranging from around 20% infestation in 20-year-olds to around 100% in 90-year-olds. A number of mites live in cheese, flour, and other foodstuffs. They are conveyed from place to place in the larval stage by attaching themselves to flies. Some mites live entirely in the water, and many are parasitic on insects. See also chigger.

mite

Human eyelashes are home to whole colonies of tiny mites. The follicle mite is 0.33 mm/0.01 in long and lives head-down inside the hair follicle. These mites do not restrict themselves to eyelashes, however, but also frequent other parts of the human body with large sebaceous glands - such as nipples.

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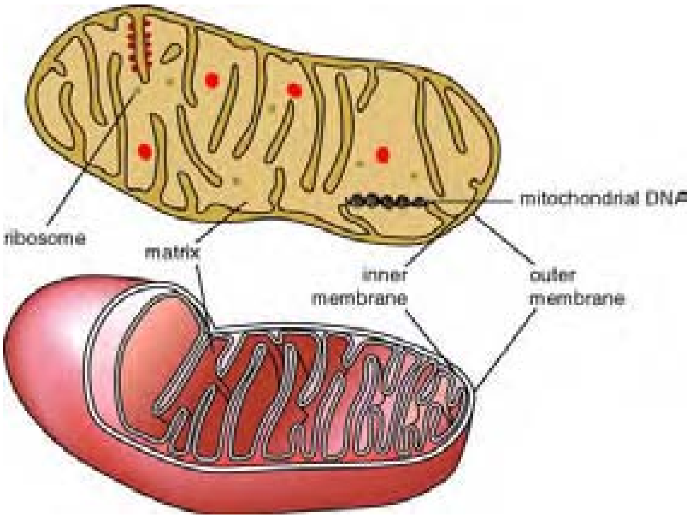
mitochondria

singular mitochondrion

membrane-enclosed organelles within eukaryotic cells, containing enzymes responsible for energy production during aerobic respiration. They are found in both plant and animal cells. Mitochondria absorb oxygen (O_2) and complete the breakdown of glucose to carbon dioxide (CO_2) and water (H_2O) to produce energy in the form of ATP, which is used in life processes in the cell. These rodlike or spherical bodies are thought to be derived from free-living bacteria that, at a very early stage in the history of life, invaded larger cells and took up a symbiotic way of life inside them. Each still contains its own small loop of DNA called mitochondrial DNA, and new mitochondria arise by division of existing ones. Mitochondria each have 37 genes.

Mutations in mitochondrial genes are always inherited from the mother. These mutations have been linked to a number of disorders, mainly degenerative, including Alzheimer's disease and diabetes.

mitochondria


mitochondrial DNA
ribosome
matrix
inner membrane
outer membrane

(Image © Research Machines plc)

A cross-section of a mitochondrion (above) and a 3-D cutaway. Mitochondria have an outer membrane and an inner membrane. The inner membrane is much folded to form christae. Mitochondria have their own DNA and ribosomes.

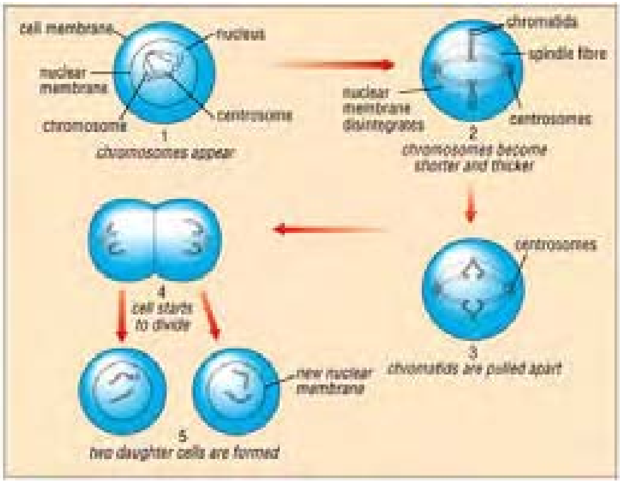
---

mitosis

in biology, the process of cell division by which one parent cell produces two genetically identical 'daughter' cells. The genetic material of eukaryotic cells is carried on a number of chromosomes. During mitosis the DNA is duplicated and the chromosome number doubled – identical copies of the chromosomes are separated into the two daughter cells, which contain the same amount of DNA as the original cell. To control movements of chromosomes during cell division so that both new cells get the correct number, a system of protein tubules, known as the spindle, organizes the chromosomes into position in the middle of the cell before they replicate. The spindle then controls the movement of chromosomes as the cell goes through the stages of division: **interphase**, **prophase**, **metaphase**, **anaphase**, and **telophase**. See also meiosis.

Mitosis is used for growth and for asexual reproduction. Growth is the increase in size and weight of an organism over a period of time. In biology growth is often measured as biomass. Growth results from mitosis followed by the increase in size of the new cells.

mitosis


cell membrane
nucleus
nuclear membrane
centrosome
chromosome
1
chromosomes appear
chromatids
spindle fibre
nuclear membrane disintegrates
centrosomes
2
chromosomes become shorter and thicker
centrosomes
3
chromatids are pulled apart
4
cell starts to divide
new nuclear membrane
5
two daughter cells are formed

(Image © Research Machines plc)

The stages of mitosis, the process of cell division that takes place when a plant or animal cell divides for growth or repair. The two 'daughter' cells each receive the same number of chromosomes as were in the original cell.

mitosis

To remember the five sub-phases of the prophase of mitosis:

Lazy **z**ebras **p**onder **d**ire **d**isasters

Leptotene, **z**ygotene, **p**olytene, **d**iplotene, **d**iakinesis

---

mixed farming

farming system where both arable and pastoral farming is carried out. Mixed farming is a lower-risk strategy than monoculture. If climate, pests, or market prices are unfavourable for one crop or type of livestock, another may be more successful and the risk is shared. Animals provide manure for the fields and help to maintain soil fertility.

---

mixture

in chemistry, a substance containing two or more elements or compounds that still retain their separate physical and chemical properties. There is no chemical bonding between them and they can be separated from each other by physical means (compare compound).

The separation of mixtures can be achieved by a number of methods, such as filtration and distillation. Examples of mixtures include rocks, air, crude oil (unrefined petroleum), all solutions (such as sea water), and all metal alloys (such as steel).

Introduction to Distillation

Go to site

Deals exclusively with distillation, the process of separating different liquids from each other by the application and removal of heat. The page begins with a short paragraph, which defines distillation, and then continues to the processes involved. A variety of links is at the bottom of the page, each of which deals with one specific step of the process.

---

m.k.s. system

system of units in which the base units metre, kilogram, and second replace the centimetre, gram, and second of the c.g.s. system. From it developed the SI system (see SI units).

It simplifies the incorporation of electrical units into the metric system, and was incorporated in SI. For application to electrical and magnetic phenomena, the ampere was added, creating what is called the m.k.s.a. system.

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ml

symbol for **millilitre**.

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mm

symbol for **millimetre**.

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mmHg

symbol for millimetre of mercury.

MMT (Multiple-Mirror Telescope)

telescope on Mount Hopkins, Arizona. When it began operation in 1979, it consisted of six 1.83-m/72-in mirrors mounted in a hexagon, the light-collecting area of which equals that of a single mirror of 4.5 m/176 in diameter. The six mirrors were replaced in 1996 with a single mirror 6.5 m/21.3 ft wide, and it is now generally know simply as the MMT.

---

mnemonic

in computing, a short sequence of letters used in low-level programming languages (see low-level language) to represent a machine code instruction.

---

moa

any of a group of extinct flightless kiwi-like birds, order Dinornithiformes, that lived in New Zealand. There were 19 species; they varied from 0.5 to 3.5 m/2 to 12 ft, with strong limbs, a long neck, and no wings. The largest species was *Dinornis maximus*. The last moa was killed in the 1800s.

The Maori killed them for food, and with the use of European firearms killed them in excessive numbers.

In February 2001, UK and Spanish researchers succeeded in sequencing the mitochondrial DNA of a moa, the first time this had been done for an extinct species.

---

mobile ion

in chemistry, an ion that is free to move; such ions are only found in the aqueous solutions or melts (molten masses) of an electrolyte. The mobility of the ions in an electrolyte is what allows it to conduct electricity.

---

mobile phone

or cell phone

cordless telephone linked to a cellular radio network. Early cellular networks used analogue technology, but since the late 1990s most services use a digital system. Calls are linked to the public telephone system via a network of connected base stations and exchanges; the area covered by each base station is called a cell. Each cell is about 5 km/3 mi across, and has a separate low-power transmitter. Mobility is possible as calls can be made while moving from one radio cell to another. In Europe, GSM (Global System for Mobile communications) has been adopted by many countries as a digital standard, enabling travellers to use a single phone across different national networks. Tri-band mobile phones are capable of changing frequencies to allow local networks in the USA to be accessed.

A trend for greater integration of phone and computer led to the development of WAP (wireless application protocol) phones in 1999. These allowed users to read e-mails and browse the Web, and by 2002 users could send digital images using a built-in digital camera. High-speed, 'third generation' (3G) phones were launched, capable of sending and receiving video messages, video calling, e-mail, photo-messaging, and news and information services. Other potential applications include interactive television and all the features of a personal digital assistant (PDA).

Möbius, August Ferdinand (1790-1868)

German mathematician and theoretical astronomer, discoverer of the Möbius strip and considered one of the founders of topology.

Möbius formulated his **barycentric calculus** in 1818, a mathematical system in which numerical coefficients were assigned to points. The position of any point in the system could be expressed by varying the numerical coefficients of any four or more noncoplanar points.

Möbius, August Ferdinand

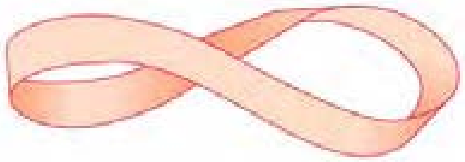
Go to site

Extensive biography of the mathematician. The site contains a description of his contribution to mathematics, especially of his conception of the Möbius strip, a two-dimensional surface with only one side. Several literature references for further reading are also listed, and the Web site also features a photograph of Möbius.

Möbius strip

structure made by giving a half twist to a flat strip of paper and joining the ends together. It has certain remarkable properties, arising from the fact that it has only one edge and one side. If cut down the centre of the strip, instead of two new strips of paper, only one long strip is produced. It was invented by the German mathematician August Möbius.

Möbius strip



(Image © Research Machines plc)

The Möbius strip has only one side and one edge. It consists of a strip of paper connected at its ends with a half-twist in the middle.

---

mockingbird

North American songbird of the mimic thrush family, found in the USA and Mexico. About 25 cm/10 in long, it is brownish grey, with white markings on the black wings and tail. It is remarkable for its ability to mimic the songs of other species. (Species *Mimus polyglottos*, family Mimidae, order Passeriformes.)

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mock orange

or syringa

any of a group of deciduous shrubs, including *P. coronarius*, which has white, strongly scented flowers similar to those of the orange tree. (Genus *Philadelphus*, family Philadelphaceae.)

---

mode

in mathematics, the element that appears most frequently in a given set of data. For example, the mode for the data 0, 0, 9, 9, 9, 12, 87, 87 is 9.

The mode together with the median and arithmetic mean make up the average of a set of data. In addition it is useful to know the range or spread of the data.

When dealing with grouped data, the **modal class** represents the most frequent group.

---

model

in computing, set of assumptions and criteria based on actual phenomena, used to conduct a computer simulation. Models are used to predict the behaviour of a system such as the movement of a hurricane or the flow of goods from a store. In industry, they are important tools for testing new products: engineers subject virtual prototypes of aircraft or bridges to various scenarios to find out what adjustments are necessary to the design. However, a model is only as good as the assumptions that underlie it.

Models may run at the same speed of the real situation (**real-time models**) or run at faster or slower speeds.

Models are also the basis for expert systems, which simulate the knowledge of a human expert.

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model

simplified version of some aspect of the real world. Models are produced to show the relationships between two or more factors, such as land use and the distance from the centre of a town (for example, concentric-ring theory). Because models are idealized, they give only a general guide to what may happen.

---

modem

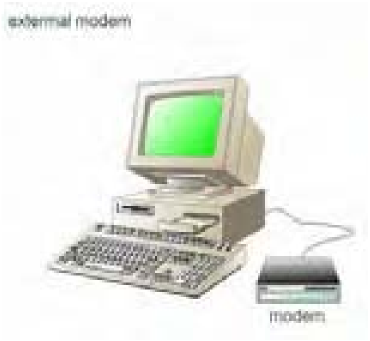
contraction of modulator/demodulator

device for transmitting computer data over telephone lines. Such a device is used to convert digital signals produced by computers to analogue signals compatible with the telephone network, and back again.

Modems are used for linking remote terminals to central computers and enable computers to communicate with each other anywhere in the world. In 1997 the fastest standard modems transmitted data at a nominal rate of about 33,600 bps (bits per second), often abbreviated to 33.6K.

56K modems, launched in 1997, achieved higher speeds by using a digital connection to the user's computer, while using a conventional analogue connection in the other direction. ADSL modems can achieve data transmission rates of up to 24Mbit/s downstream and 3.5Mbit/s upstream rate by using digital communications to both the computer and also over the telephone network.

modem



(Image © Research Machines plc)

Modems are available in various forms: microcomputers may use an plug-in device connected through a communications port, or an internal device, which takes the form of an expansion board inside the computer. Notebook computers use an external modem connected via a special interface card.

Modem HOWTO

Go to site

Comprehensive 'Frequently Asked Question' list on modems. The Web site forms a practical guide and provides technical information on modem set up and operation. The in-depth articles are headed with introductory-level explanations.

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moderator

in a nuclear reactor, a material such as graphite or heavy water used to reduce the speed of high-energy neutrons. Neutrons produced by nuclear fission are fast-moving and must be slowed to initiate further fission so that nuclear energy continues to be released at a controlled rate.

Slow neutrons are much more likely to cause fission in a uranium-235 nucleus than to be captured in a U-238 (nonfissile uranium) nucleus. By using a moderator, a reactor can thus be made to work with fuel containing only a small proportion of U-235.

---

modulation

in radio transmission, the variation of frequency, or amplitude, of a radio carrier wave, in accordance with the audio characteristics of the speaking voice, music, or other signal being transmitted.

---

module

in construction, a standard or unit that governs the form of the rest. For example, Japanese room sizes are traditionally governed by multiples of standard tatami floor mats; today prefabricated buildings are mass-produced in a similar way. Spacecraft components, designed in coordination, are also modules. For the *Apollo* Moon landings, the craft comprised a command module, a service module, and a lunar module.

---

modulus

in mathematics, a number that divides exactly into the difference between two given numbers. Also, the multiplication factor used to convert a logarithm of one base to a logarithm of another base. Also, another name for absolute value.

Moholy-Nagy, Laszlo (1895-1946)

Hungarian-born painter, sculptor and photographer. Inspired by constructivism, he made abstract sculptures from the early 1920s, and from 1923 to 1929 taught at the Bauhaus school in Weimar and later in the USA. He experimented with a wide range of media, materials, and techniques, including the use of photographic techniques to achieve non-naturalistic effects.

He worked in Paris, London and Amsterdam as well as in Germany, and in 1937 moved to the USA, where he spent the rest of his life. His commitment to innovation is reflected in the range of his works: in the books *Painting, Photography, Film* 1925 and *The New Vision* 1929; in his documentary film *Berlin Still Life* 1926; and in and his experiments with kinetic sculpture during the 1920s, and with what he called 'space modulators' - sculptures made of plexiglas and other materials - during the 1930s. An important teacher and theoretician, he had a great influence on 20th-century art and design.

Mohorovicic discontinuity

or Moho or M-discontinuity

seismic discontinuity, marked by a rapid increase in the speed of earthquake waves, that is taken to represent the boundary between the Earth's crust and mantle. It follows the variations in the thickness of the crust and is found approximately 35-40 km/22-25 mi below the continents and about 10 km/6 mi below the oceans. It is named after the Croatian geophysicist Andrija Mohorovicic, who suspected its presence after analysing seismic waves from the Kulpa Valley earthquake in 1909. The 'Moho' is as deep as 70 km/45 mi beneath high mountain ranges.

Mohs scale

scale of hardness for minerals (in ascending order): 1 talc; 2 gypsum; 3 calcite; 4 fluorite; 5 apatite; 6 orthoclase; 7 quartz; 8 topaz; 9 corundum; 10 diamond.

The scale is useful in mineral identification because any mineral will scratch any other mineral lower on the scale than itself, and similarly it will be scratched by any other mineral higher on the scale.

Mohs' scale of hardness

To remember the order of hardness:

Tall **gy**roscopes **ca**n **fl**y **a**part, **or**biting **qu**ickly **to co**mplete **di**sintegration.

talc, **gy**psum or rock salt, **ca**lcite, **fl**uorite, **a**patite, **o**rthaclase, **qu**artz, **t**opaz, **c**orundum, **d**iamond

Mohs scale

Note that the scale is not regular: diamond, at number 10 the hardest natural substance, is four times harder in absolute terms than corundum, at number 9.

number	defining mineral	other substances compared
1	talc	
2	gypsum	21/2 fingernail
3	calcite	31/2 copper coin
4	fluorite	
5	apatite	51/2 steel blade
6	orthoclase	53/4 glass
7	quartz	7 steel file
8	topaz	
9	corundum	
10	diamond	

Moissan, (Ferdinand Frédéric) Henri (1852-1907)

French chemist. He was awarded the Nobel Prize for Chemistry in 1906 for his isolation of pure fluorine in 1886, and adoption of the electric furnace. He attempted to create artificial diamonds by rapidly cooling carbon heated to high temperatures. His claims of success were treated with suspicion.

mol

symbol for mole, the SI unit of amount of substance, equal to the amount that contains as many elementary entities (such as atoms, ions, or molecules) as there are atoms in 12 grams of carbon.

molar

one of the large teeth found towards the back of the mammalian mouth. The structure of the jaw, and the relation of the muscles, allows a massive force to be applied to molars. In herbivores the molars are flat with sharp ridges of enamel and are used for grinding, an adaptation to a diet of tough plant material. Carnivores have sharp powerful molars called carnassials, which are adapted for cutting meat.

molar solution

solution that contains one mole of a substance per litre of solvent.

molar volume

volume occupied by one mole (the molecular mass in grams) of any gas at standard temperature and pressure, equal to 2.24136 × 10^{-2} m^3.

---

mole

symbol mol

unit of the amount of a substance. One mole of a substance is the mass that contains the same number of particles (atoms, molecules, ions, or electrons) as there are atoms in 12 grams of the isotope carbon-12.

One mole of a substance is 6.022045 × 10^{23} atoms, which is Avogadro's number. It is obtained by weighing out the relative atomic mass (RAM) or relative molecular mass (RMM) in grams (so one mole of carbon weighs 12 g).

---

mole

small burrowing mammal with typically dark, velvety fur. Moles grow up to 18 cm/7 in long, and have acute senses of hearing, smell, and touch, but poor eyesight. They have short, muscular forelimbs and shovel-like, clawed front feet for burrowing in search of insects, grubs, and worms. Their fur lies without direction so that they can move forwards or backwards in their tunnels without discomfort. Moles are greedy eaters; they cannot live more than a few hours without food. (Family Talpidae, order Insectivora.)

North American moles differ from those of the Old World in having tusklike front upper incisor teeth. The same ecological role is taken in Africa by the **golden moles** (family Chrysochloridae), and in Australia by **marsupial moles** (genus *Notoryctes*, order Marsupialia).

Some members of the Talpidae family are aquatic, such as the **Russian desman** (*Desmana moschata*) and the North American **star-nosed mole** (*Condylura cristata*).

---

mole cricket

dark brown burrowing insect about 35-50 mm/1.5-2 in long, covered with soft hairs. Over 50 species of mole crickets have been identified. They feed mainly on worms and other insects.

Mole crickets are particularly adapted for burrowing, the first pair of legs being large, flattened, and serrated for digging. The eyes are reduced, and the ovipositor (egg-laying organ) is vestigial. Some species have wings, which they use to fly at night. Other species have vestigial wings or the wings may be lacking.

Occasionally mole crickets may attack crops: for example the Puerto Rico mole cricket *Scapteriscus vicinus* is a serious pest.

classification

Mole crickets are members of family Gryllotalpidae, order Orthoptera, class Insecta, phylum Arthropoda.

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molecular biology

study of the molecular basis of life, including the biochemistry of molecules such as DNA, RNA, and proteins, and the molecular structure and function of the various parts of living cells.

---

molecular clock

use of rates of mutation in genetic material to calculate the length of time elapsed since two related species diverged from each other during evolution. The method can be based on comparisons of the DNA or of widely occurring proteins, such as haemoglobin.

Since mutations are thought to occur at a constant rate, the length of time that must have elapsed in order to produce the difference between two species can be estimated. This information can be compared with the evidence obtained from palaeontology to reconstruct evolutionary events.

---

molecular cloud

in astronomy, enormous cloud of cool interstellar dust and gas containing hydrogen molecules and more complex molecular species. Giant molecular clouds (GMCs), about a million times as massive as the Sun and up to 300 light years in diameter, are regions in which stars are being born. The Orion nebula is part of a GMC.

---

molecular formula

in chemistry, formula indicating the actual number of atoms of each element present in a single molecule of a chemical compound. For example, the molecular formula of carbon dioxide is CO_2, indicating that one molecule of carbon dioxide is made up of one atom of carbon and two atoms of oxygen. This is determined by two pieces of information: the empirical formula and the relative molecular mass, which is determined experimentally.

---

molecular mass

or relative molecular mass

mass of a molecule, calculated relative to one-twelfth the mass of an atom of carbon-12. It is found by adding the relative atomic masses of the atoms that make up the molecule.

---

molecular solid

in chemistry, solid composed of molecules that are held together by relatively weak intermolecular forces. Such solids are low-melting and tend to dissolve in organic solvents. Examples of molecular solids are sulphur, ice, sucrose, and solid carbon dioxide.

---

molecular weight

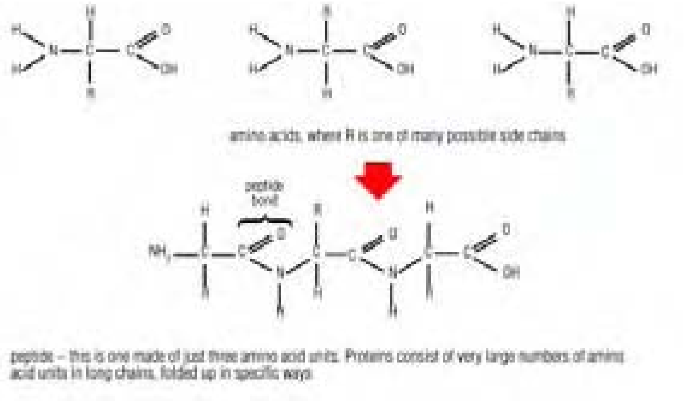
mass of a molecule, calculated relative to one-twelfth the mass of an atom of carbon-12. It is found by adding the molecular weights of the atoms that make up the molecule.

---

molecule

smallest configuration of an element or compound that can exist independently. One molecule is made up of a group of atoms held together by covalent or ionic bonds. Several non-metal elements exist as molecules. For example, hydrogen atoms, at room temperature, do not exist independently. They are bonded in pairs to form hydrogen molecules. A molecule of a compound consists of two or more different atoms bonded together. For example, carbon dioxide is made up of molecules, each containing one carbon and two oxygen atoms bonded together. The molecular formula is made up of the chemical symbols representing each element in the molecule and numbers showing how many atoms of each element are present. For example, the formula for hydrogen is H_2, and for carbon dioxide is CO_2. Molecules vary in size and complexity from the hydrogen molecule to the large macromolecules of proteins. In general, elements and compounds with molecular structures have similar properties. They have low melting and boiling points, so that many molecular substances are gases or liquids at room temperatures. They are usually insoluble in water and do not conduct electricity even when melted.

protein



amino acids, where R is one of many possible side chains

peptide – this is one made of just three amino acid units. Proteins consist of very large numbers of amino acid units in long chains, folded up in specific ways

(Image © Research Machines plc)

A protein molecule is a long chain of amino acids linked by peptide bonds. The properties of a protein are determined by the order, or sequence, of amino acids in its molecule, and by the three-dimensional structure of the molecular chain. The chain folds and twists, often forming a spiral shape.

Molecule of the Month

Go to site

Pages on interesting – and sometimes hypothetical – molecules, contributed by university chemistry departments throughout the world.

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mole rat, naked

small underground mammal, almost hairless, with a disproportionately large head. The mole rat is of importance to zoologists as one of the very few mammals that are eusocial, that is, living in colonies with sterile workers and one fertile female. (Species *Heterocephalus glaber*.)

Its underground colonies comprise one breeding female and up to three breeding males in a colony of approximately 75 closely related animals, most being functionally sterile workers of either sex. The breeding female produces litters of around 25 pups.

Tool use has been observed in naked mole rats by US researchers in 1998. The animals hold a piece of tuber or wood in their mouths when gnawing anything that produces dust. This 'mask' lessens the amount of dust inhaled.

mole rat, naked

The mole rat has the smallest brain relative to body size of any small mammal.

---

mollusk

any invertebrate of the phylum Mollusca with a body divided into three parts, a head, a central mass containing the main organs, and a foot for movement; the more sophisticated octopuses and related mollusks have arms to capture their prey. The majority of mollusks are marine animals, but some live in fresh water, and a few live on land. They include clams, mussels, and oysters (bivalves), snails and slugs (gastropods), and cuttlefish, squids, and octopuses (cephalopods). The body is soft, without limbs (except for the cephalopods), and cold-blooded. There is no internal skeleton, but many species have a hard shell covering the body.

Mollusks vary in diet, the carnivorous species feeding chiefly upon other members of the phylum. Some are vegetarian. Reproduction is by means of eggs and is sexual; many species are hermaphrodite. The shells of mollusks take a variety of forms: single or univalve (like the snail), double or bivalve (like the clam), chambered (like the nautilus), and many other variations. In some cases (for example cuttlefish and squid), the shell is internal. Every mollusk has a fold of skin, the mantle, which covers the whole body or the back only, and secretes the chalky substance that forms the shell. The lower ventral surface (belly area) of the body forms the foot, which enables the mollusk to move about.

---

molybdenite

molybdenum sulphide, MoS_2, the chief ore mineral of molybdenum. It possesses a hexagonal crystal structure similar to graphite, has a blue metallic lustre, and is very soft (1-1.5 on the Mohs scale).

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molybdenum

chemical symbol Mo

(Greek molybdos 'lead')

heavy, hard, lustrous, silver-white, metallic element, atomic number 42, relative atomic mass 95.94. The chief ore is the mineral sulphide molybdenite. The element is highly resistant to heat and conducts electricity easily. It is used in alloys, often to harden steels. It is a necessary trace element in human nutrition. It was named in 1781 by Swedish chemist Karl Scheele, after its isolation by another Swedish chemist Peter Jacob Hjelm (1746-1813), for its resemblance to lead ore.

---

moment of a force

in physics, measure of the turning effect, or torque, produced by a force acting on a body. It is equal to the product of the force and the perpendicular distance from its line of action to the point, or pivot, about which the body will turn. The turning force around the pivot is called the moment. Its unit is the newton metre.

The moment of a force can be worked out using the formula: moment = force applied × perpendicular distance from the pivot. If the magnitude of the force is F newtons and the perpendicular distance is d metres then:

moment = Fd

It is easier to undo a bolt using a long spanner than a short spanner. This is because more turning force is produced at the bolt (pivot) with less effort. A long spanner is an example of a force multiplier.

In a simple balanced see-saw, the forces acting on the left- and right-hand sides of the pivot are the same. This is known as balancing moments. Moving the load at one end will cause the see-saw to become unbalanced. To regain balance, the load on the opposite side must either be increased or its position changed. This is known as the principle of moments.

The application of balancing a moment of force (or a turning force) is used by a rope walker. By holding the pole in the middle the rope walker is balancing the turning force on either side of the rope. As the rope walker moves a leg, the turning force on one side is greater and becomes unbalanced. To regain the balance, the pole is shifted to balance the turning forces on both sides of the rope.

---

moment of inertia

in physics, the sum of all the point masses of a rotating object multiplied by the squares of their respective distances from the axis of rotation.

In linear dynamics, Newton's second law of motion states that the force F on a moving object equals the products of its mass m and acceleration a ($F = ma$); the analogous equation in rotational dynamics is $T = I\alpha$, where T is the torque (the turning effect of a force) that causes an angular acceleration α and I is the moment of inertia. For a given object, I depends on its shape and the position of its axis of rotation.

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momentum

product of the mass of a body and its velocity. If the mass of a body is m kilograms and its velocity is v m s^{-1}, then its momentum is given by: momentum = mv. Its unit is the kilogram metre-per-second (kg m s^{-1}) or the newton second. The momentum of a body does not change unless a resultant or unbalanced force acts on that body (see Newton's laws of motion).

According to Newton's second law of motion, the magnitude of a resultant force F equals the rate of change of momentum brought about by its action, or: $F = (mv - mu)/t$ where mu is the initial momentum of the body, mv is its final momentum, and t is the time in seconds over which the force acts. The change in momentum, or impulse, produced can therefore be expressed as: impulse = $mv - mu = Ft$. The law of conservation of momentum is one of the fundamental concepts of classical physics. It states that the total momentum of all bodies in a closed system is constant and unaffected by processes occurring within the system. The **angular momentum** of an orbiting or rotating body of mass m travelling at a velocity v in a circular orbit of radius R is expressed as mvR. Angular momentum is conserved, and should any of the values alter (such as the radius of orbit), the other values (such as the velocity) will compensate to preserve the value of angular momentum, and that lost by one component is passed to another.

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monazite

mineral, $(Ce,La,Th)PO_4$, yellow to red, valued as a source of lanthanides or rare earths, including cerium and europium; generally found in placer deposit (alluvial) sands.

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mongolism

former name (now considered offensive) for Down's syndrome.

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mongoose

any of a group of carnivorous tropical mammals. The **Indian mongoose** (*H. mungo*) is greyish in colour and about 50 cm/1.5 ft long, with a long tail. It can be tamed and is often kept for its ability to kill snakes. Like the snakes themselves, the acetylcholine receptors connecting the mongooses' nerves and muscle cells are unaffected by the venom. (Genera *Herpestes*, *Ichneumia*, and other related genera, family Viverridae.)

Most mongooses are solitary, but the **banded mongoose** *Mungos mungo* is highly gregarious, living in groups of 15-40 individuals. They feed on small reptiles and invertebrates and spend about 60% of their day foraging.

The **white-tailed mongoose** (*I. albicauda*) of central Africa has a distinctive grey or white bushy tail.

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monitor

any of various lizards found in Africa, South Asia, and Australasia. Monitors are generally large and carnivorous, with well-developed legs and claws and a long powerful tail that can be swung in defence. (Family Varanidae.)

Monitors include the **Komodo dragon** (*Varanus komodoensis*), the largest of all lizards, and also the slimmer **Salvador's monitor** (*V. salvadorii*), which may reach 2.5 m/8 ft. Several other monitors, such as the **lace monitor** (*V. varius*), the **perentie** (*V. giganteus*) of Australia, and the **Nile monitor** (*V. niloticus*) of Africa, are up to 2 m/6 ft long.

---

monkey

any of the various smaller, mainly tree-dwelling anthropoid primates, excluding humans and the apes. There are 125 species, living in Africa, Asia, and tropical Central and South America. Monkeys eat mainly leaves and fruit, and also small animals. Several species are endangered due to loss of forest habitat, for example the woolly spider monkey and black saki of the Amazonian forest.

Old World monkeys (family Cercopithecidae) of tropical Africa and Asia are distinguished by their close-set nostrils and differentiated thumbs, some also having cheek pouches and rumps with bare patches (callosities) of hardened skin. They include baboons, langurs, macaques, and guenons.

New World monkeys of Central and South America are characterized by wide-set nostrils, and some have highly sensitive prehensile tails that can be used as additional limbs, to grasp and hold branches or objects. They include two families:

(1) the family Cebidae, which includes the larger species saki, capuchin, squirrel, howler, and spider monkeys;

(2) the family Callithricidae, which includes the small marmosets and tamarins.

---

monkeypox

in medicine, very rare viral disease of humans that is transmitted by rodents. Its symptoms resemble those of smallpox, with crusted pustules, fever, and cough. The mortality rate is 10% and the disease was on the increase in Congo with 163 cases from 1996 to 1997 (compared with 37 cases between 1981 and 1986) indicating that it may be able to sustain itself in a human population. The smallpox vaccine is effective against monkeypox.

---

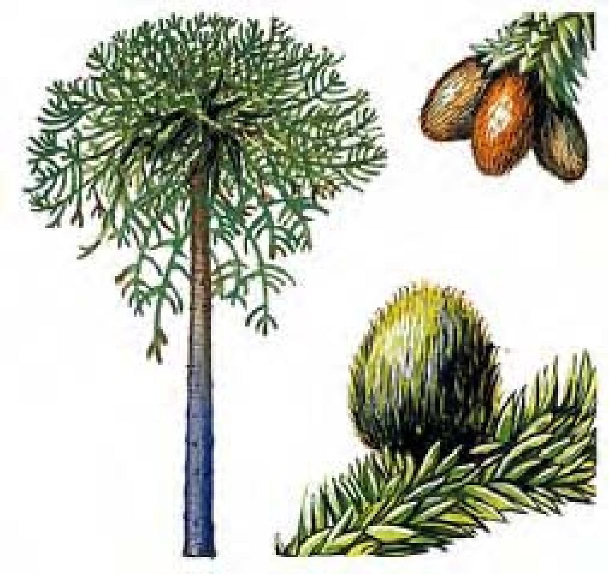
monkey puzzle

or Chilean pine

coniferous evergreen tree, native to Chile; its branches, growing in circular arrangements (whorls) around the trunk and larger branches, are covered in prickly, leathery leaves. (*Araucaria araucana*, family Araucariaceae.)

In May 2000 wild monkey puzzle trees in Argentina were placed on the Convention on International Trade in Endangered Species (CITES) Appendix I, which bans all trade in the species. Chilean monkey puzzle trees are already listed on Appendix I.

monkey puzzle



(Image © Research Machines plc)

The monkey-puzzle tree has a regular dome-shaped crown of downwards-pointing branches set with pointed leaves. Its name derives from the belief that monkeys have difficulty climbing it. It is the nearest living example of the trees of the Carboniferous period, about 300 million years ago, which gave us our coal.

---

monocarpic

or hapaxanthic

describing plants that flower and produce fruit only once during their life cycle, after which they die. Most annual plants and biennial plants are monocarpic, but there are also a small number of monocarpic perennial plants that flower just once, sometimes after as long as 90 years, dying shortly afterwards, for example, century plant *Agave* and some species of bamboo *Bambusa*. The general biological term related to organisms that reproduce only once during their lifetime is semelparity.

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monoclonal antibody

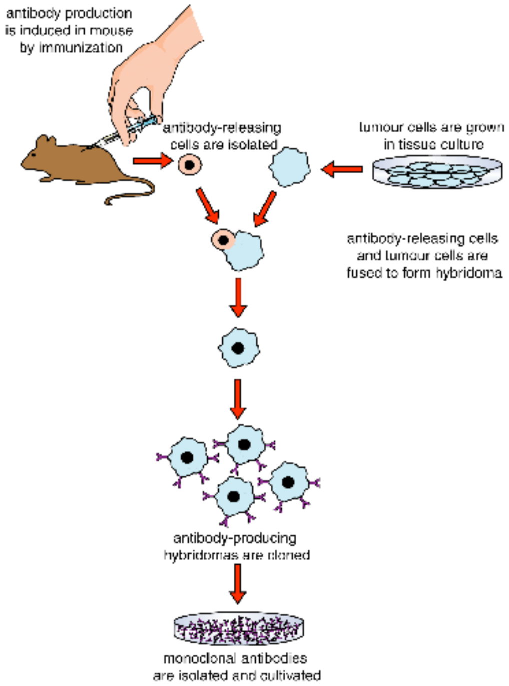
MAB

antibody produced by fusing an antibody-producing lymphocyte (white blood cell) with a cancerous myeloma (bone-marrow) cell. The resulting fused cell, called a hybridoma, is immortal and can be used to produce large quantities of a single, specific antibody. By choosing antibodies that are directed against antigens found on cancer cells, and combining them with cytotoxic drugs, it is hoped to make so-called magic bullets that will be able to pick out and kill cancers.

It is the antigens on the outer cell walls of germs entering the body that provoke the production of antibodies as a first line of defence against disease. Antibodies 'recognize' these foreign antigens, and, in locking on to them, cause the release of chemical signals in the bloodstream to alert the immune system for further action. MABs are copies of these natural antibodies, with the same ability to recognize specific antigens. Introduced into the body, they can be targeted at disease sites.

The full potential of these biological missiles, developed by César Milstein and others at Cambridge University, England, in 1975, is still under investigation. However, they are already in use in blood-grouping, in pinpointing viruses and other sources of disease, in tracing cancer sites, and in developing vaccines.

monoclonal antibody


antibody production is induced in mouse by immunization
antibody-releasing cells are isolated
tumour cells are grown in tissue culture
antibody-releasing cells and tumour cells are fused to form hybridoma
antibody-producing hybridomas are cloned
monoclonal antibodies are isolated and cultivated

(Image © Research Machines plc)

Monoclonal antibody production. Antibodies are collected from a mouse after immunization and are fused with tumour cells grown in tissue culture to form antibody hybridomas. These are cloned to give large numbers from which the antibodies can be harvested.

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monocotyledon

angiosperm (flowering plant) having an embryo with a single cotyledon, or seed leaf (as opposed to dicotyledons, which have two). Monocotyledons usually have narrow leaves with parallel veins and smooth edges, and hollow or soft stems. Their flower parts are arranged in threes. Most are small plants such as orchids, grasses, and lilies, but some are trees such as palms.

---

monoculture

farming system where only one crop is grown. In developing world countries this is often a cash crop, grown on plantations, for example sugar and coffee. Cereal crops in the industrialized world are also frequently grown on a monoculture basis, for example wheat in the Canadian prairies.

Monoculture allows the farmer to tailor production methods to the requirements of one crop, but it is a high-risk strategy since the crop may fail (because of pests, disease, or bad weather) and world prices for the crop may fall. Monoculture without crop rotation is likely to result in reduced soil quality despite the addition of artificial fertilizers, and it contributes to soil erosion.

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monocyte

type of white blood cell. They are found in the tissues and the lymphatic and circulatory systems where their purpose is to remove foreign particles, such as bacteria and tissue debris, by ingesting them.

Monod, Jacques Lucien (1910-1976)

French biochemist who was awarded the Nobel Prize for Physiology or Medicine in 1965 with his co-workers André Lwoff and François Jacob for research into the genetic control of enzyme and virus synthesis.

---

monoecious

having separate male and female flowers on the same plant. Maize *Zea mays*, for example, has a tassel of male flowers at the top of the stalk and a group of female flowers (on the ear, or cob) lower down. Monoecism is a way of avoiding self-fertilization.

Dioecious plants have male and female flowers on separate plants.

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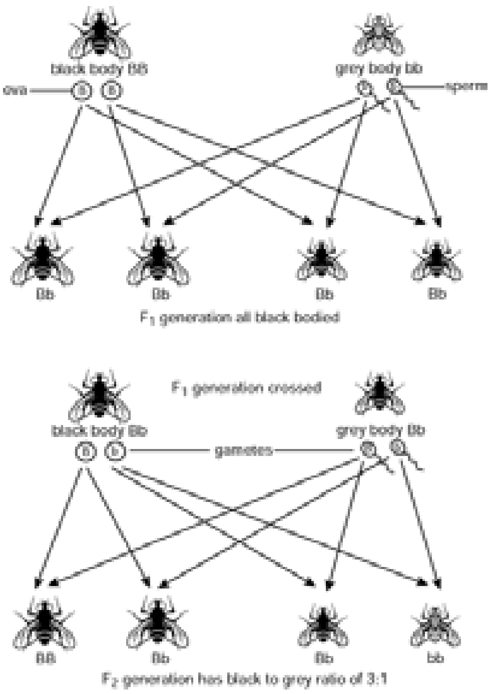
monohybrid inheritance

pattern of inheritance seen in simple genetics experiments, where the two animals (or two plants) being crossed are genetically identical except for one gene, which is heterozygous. In other words, inheritance is the passing of characteristics from parents to offspring, while monohybrid inheritance is inheritance for a single characteristic.

Characteristics that can be passed on in this way are determined by genes. Genes may exist in different forms known as alleles. Since chromosomes in animals and plants are found as matching pairs in the nucleus of each cell, there will always be two genes for a characteristic in a cell. If the same allele is present twice, the organism is said to be homozygous for this characteristic. If, however, one chromosome contains one allele and the other chromosome a contrasting allele, the organism is said to be heterozygous for that characteristic. In a heterozygous organism the appearance of the organism (phenotype) may be determined by one allele and not the other. The allele that determines the phenotype is said to be dominantly expressed (see dominance). The expression of the other allele is described as being recessive.

The gene in question may code for some obvious external features such as seed colour, with one parent having green seeds and the other having yellow seeds. The offspring are monohybrids, that is, hybrids for one gene only, having received one copy of the gene from each parent. Known as the F1 generation, they are all identical, and usually resemble one parent, whose version of the gene (the dominant allele) masks the effect of the other version (the recessive allele). Although the characteristic coded for by the recessive allele (for example, green seeds) completely disappears in this generation, it can reappear in offspring of the next generation if they have two recessive alleles. On average, this will occur in one out of four offspring from a cross between two of the monohybrids. The next generation (called F2) shows a 3:1 ratio for the characteristic in question, 75% being like the original parent with the recessive allele. Austrian biologist Gregor Mendel first carried out experiments of this type (crossing varieties of artificially bred plants, such as peas) and they revealed the principles of genetics. The same basic mechanism underlies all inheritance, but in most plants and animals there are so many genetic differences interacting to produce the external appearance that such simple, clear-cut patterns of inheritance are not evident.

monohybrid inheritance



(Image © Research Machines plc)

A simple monohybrid cross. The allele for a black body is dominant and the allele for a grey body is recessive in fruit flies, therefore a cross between a fly with a black body and one with a grey body will produce a generation of black-bodied flies (F_1 generation). If two flies from the F_1 generation are crossed then the ratio of black to grey flies in the F_2 generation will be 3:1.

monolith

(Greek monos 'sole', lithos 'stone')

single isolated stone or column, usually standing and of great size, used as a form of monument. Some are natural features, such as the Buck Stone in the Forest of Dean, England. Other monoliths may be quarried, resited, finished, or carved; those in Egypt of about 3000 BC take the form of obelisks. They have a wide distribution including Europe, South America, North Africa, and the Middle East.

Apart from their ritual or memorial function, monoliths have been used as sundials and calendars in the civilizations of the Aztecs, Egyptians, and Chaldeans (ancient peoples of southern Babylonia). In landscape archaeology, monoliths are interpreted in a wider context, possibly as boundary markers. The largest cut stone, weighing about 1,500 tonnes, is sited in the ancient Syrian city of Baalbek.

monomer

chemical compound composed of simple molecules from which polymers can be made. Under certain conditions the simple molecules (of the monomer) join together (polymerize) to form a very long chain molecule (macromolecule) called a polymer. For example, the polymerization of ethene (ethylene) monomers produces the polymer polythene (polyethylene):

$$2nCH_2 = CH_2 \rightarrow (CH_2 -CH_2 -CH_2 -CH_2)_n$$

mononucleosis

viral disease (also called 'kissing disease', since it may be passed by body fluids, including saliva) characterized at onset by fever and painfully swollen lymph nodes (in the neck); there may also be digestive upset, sore throat, and skin rashes. Lassitude persists for months and even years, and recovery is often very slow. It is caused by the Epstein-Barr virus. A serious to fatal complication may be hepatitis.

monorail

railway that runs on a single rail; the cars can be balanced on it or suspended from it. It was invented in 1882 to carry light loads, and when run by electricity was called a **telpher**.

The Wuppertal Schwebebahn, which has been running in Germany since 1901, is a suspension monorail, where the passenger cars hang from an arm fixed to a trolley that runs along the rail. Today most monorails are of the straddle type, where the passenger cars run on top of the rail. They are used to transport passengers between terminals at some airports; Japan has a monorail (1964) running from the city centre to Hameda airport.

monosaccharide

or simple sugar

carbohydrate that cannot be hydrolysed (split) into smaller carbohydrate units. Examples are glucose and fructose, both of which have the molecular formula $C_6H_{12}O_6$.

monosaccharides

To remember the molecular shape of fructose and glucose:

There are two simple sugars (monosaccharides) - fructose and glucose - which combine in a specific way to form sucrose. Remember the molecular shape of **f**ructose has **f**ive carbons (letter **f** starts both words) and hexa**g**on is the shape of **g**lucose (letter **g** in both words)

monosodium glutamate

MSG; $NaC_5H_8NO_4$

white, crystalline powder, the sodium salt of glutamic acid (an amino acid found in proteins that plays a role in the metabolism of plants and animals). It has been shown to possess its own taste receptor, making it the fifth taste (see umami), alongside sweet, sour, acid, and salt. It is used to enhance the flavour of many packaged and 'fast foods', and in Chinese cooking. Ill effects may arise from its overconsumption, and some people are very sensitive to it, even in small amounts. It is commercially derived from vegetable protein. It occurs naturally in soybeans and seaweed.

monotreme

any of a small group of primitive egg-laying mammals, found in Australasia. They include the echidnas (spiny anteaters) and the platypus. (Order Monotremata.)

In 1995 Australian palaeontologists announced a new (extinct) family of monotreme, the Kollikodontidae, following the discovery of a 120-million-year-old jawbone in New South Wales.

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monozygotic twin

one of a set of twins born to the same parents at the same time following the fertilization of a single ovum. They are of the same sex and virtually identical in appearance.

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monsoon

wind pattern that brings seasonally heavy rain to South Asia; it blows towards the sea in winter and towards the land in summer. The monsoon may cause destructive flooding all over India and Southeast Asia from April to September, leaving thousands of people homeless each year.

The monsoon cycle is believed to have started about 12 million years ago with the uplift of the Himalayas.

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monstera

or Swiss cheese plant

evergreen climbing plant belonging to the arum family, native to tropical America. *M. deliciosa* is grown as a house plant. Areas between the veins of the leaves dry up, forming deep notches and eventually holes. (Genus *Monstera*, family Araceae.)

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montbretia

plant belonging to the iris family, native to South Africa, with orange or reddish flowers on long stems. They are grown as ornamental pot plants. (*Tritonia crocosmiflora*, family Iridaceae.)

Montgolfier

Joseph Michel (1740-1810) and Jacques Etienne (1745-1799)

French brothers whose hot-air balloon was used for the first successful human flight 21 November 1783.

On 5 June 1783 they first sent up a balloon filled with hot air. After further experiments with wood-fuelled fabric-and-paper balloons, and one crewed ascent in a tethered balloon, they sent up two people who travelled for 20 minutes above Paris, a journey of 9 km/6 mi. The Montgolfier experiments greatly stimulated scientific interest in aviation.

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month

unit of time based on the motion of the Moon around the Earth.

The time taken for the Moon to orbit the Earth (from one new or full Moon to the next) is known as a **synodic** or **lunar month** and is 29.53 days. The Western calendar is not based on the lunar month, but rather on the **calendar month**, a human invention devised to fit the calendar year. However, the Islamic calendar is based on the lunar month, and therefore each year a fixed date goes back by about ten days.

The time for the Moon to complete one orbit around the Earth relative to the stars (the **sidereal month**) is 27.32 days. The **solar month** equals 30.44 days, and is exactly one-twelfth of the solar or tropical year, the time taken for the Earth to orbit the Sun.

months

To remember how many days in each month of the year:

Put your hands together (after making a fist, and tucking your thumbs under) then starting on your first knuckle and going across your knuckles and the spaces in between, saying the months for each knuckle and space: January (knuckle), February (space), March (knuckle), April (space), May (knuckle), June (space), July (knuckle), August (knuckle), September (space), October (knuckle), November (space), December (knuckle). (July and August are where your two hands are put together.) All the months on the knuckle have 31 days, while the ones that land on the space have 30 – except of course February! or
Thirty days hath September, April, June and November
All the rest have thirty-one
Except for February alone
Which has twenty-eight days clear
And twenty-nine in each leap year

Months of the year

Month	Derivation of name	Number of days
January	Janus, Roman god of doorways and beginnings	31
February	Februa, Roman festival of purification	28 (29 in a leap year)
March	Mars, Roman god of war	31
April	Latin *aperire*, 'to open'	30
May	Maia, Roman goddess of spring	31
June	Juno, Roman goddess of marriage	30
July	Julius Caesar, Roman general and dictator	31
August	Augustus Caesar, Roman emperor	31
September	Latin *septem*, 'seven'; September was the seventh month of the earliest Roman calendar	30
October	Latin *octo*, 'eight'; October was the eighth month of the earliest Roman calendar	31
November	Latin *novem*, 'nine'; November was the ninth month of the earliest Roman calendar	30
December	Latin *decem*, 'ten'; December was the tenth month of the earliest Roman calendar	31

Montréal Protocol

international agreement, signed in 1987, to stop the production of chemicals that are ozone depleters by the year 2000.

Originally the agreement was to reduce the production of ozone depleters by 35% by 1999. The green movement criticized the agreement as inadequate, arguing that an 85% reduction in ozone depleters would be necessary just to stabilize the ozone layer at 1987 levels. The protocol (under the Vienna Convention for the Protection of the Ozone Layer) was reviewed in 1992. Amendments added another 11 chemicals to the original list of eight chemicals suspected of harming the ozone layer. A controversial amendment concerns a fund established to pay for the transfer of ozone-safe technology to poor countries.

Moon

natural satellite of Earth, 3,476 km/2,160 mi in diameter, with a mass 0.012 (approximately one-eightieth) that of Earth.

Its surface gravity is only 0.16 (one-sixth) that of Earth. Its average distance from Earth is 384,400 km/238,855 mi, and it orbits in a west-to-east direction every 27.32 days (the **sidereal month**). It spins on its axis with one side permanently turned towards Earth. The Moon has no atmosphere and was thought to have no water until ice was discovered on its surface in 1998.

phases

The Moon is illuminated by sunlight, and goes through a cycle of phases of shadow, waxing from **new** (dark) via **first quarter** (half Moon) to **full**, and waning back again to new every 29.53 days (the **synodic month**, also known as a **lunation**). On its sunlit side, temperatures reach 110°C/230°F, but during the two-week lunar night the surface temperature drops to -170°C/-274°F.

origins

The origin of the Moon is still open to debate. Scientists suggest the following theories: that it split from the Earth; that it was a separate body captured by Earth's gravity; that it formed in orbit around Earth; or - the theory most widely favoured currently - that it was formed from debris thrown off when a body the size of Mars struck Earth.

research

70% of the far side of the Moon was photographed from the Soviet Lunik 3 in October 1959. Much of our information about the Moon has been derived from this and other photographs and measurements taken by US and Soviet Moon probes, from geological samples brought back by US *Apollo* astronauts and by Soviet Luna probes, and from experiments set up by US astronauts 1969-72. The US probe Lunar Prospector, launched in January 1998, examined the composition of the lunar crust, recorded gamma rays, and mapped the lunar magnetic field. It also discovered the ice on the moon in March 1998. In January 2004, US president George W Bush announced a plan to put astronauts back on the Moon by 2020.

composition

The Moon is rocky, with a surface heavily scarred by meteorite impacts that have formed craters up to 240 km/150 mi across. Seismic observations indicate that the Moon's surface extends downwards for tens of kilometres; below this crust is a solid mantle about 1,100 km/688 mi thick, and below that a silicate core, part of which may be molten. Rocks brought back by astronauts show that the Moon is 4.6 billion years old, the same age as Earth. It is made up of the same chemical elements as Earth, but in different proportions, and differs from Earth in that most of the Moon's surface features were formed within the first billion years of its history when it was hit repeatedly by meteorites.

The youngest craters are surrounded by bright rays of ejected rock. The largest scars have been filled by dark lava to produce the lowland plains called seas, or **maria** (plural of mare). These dark patches form the so-called 'man-in-the-Moon' pattern. Inside some craters that are permanently in shadow is up to 300 million tonnes/330 million tons of ice existing as a thin layer of crystals.

One of the Moon's easiest features to observe is the crater Plato, which is about 100 km/62 mi in diameter and 2,700 m/8,860 ft deep, and at times is visible with the naked eye.

Moon

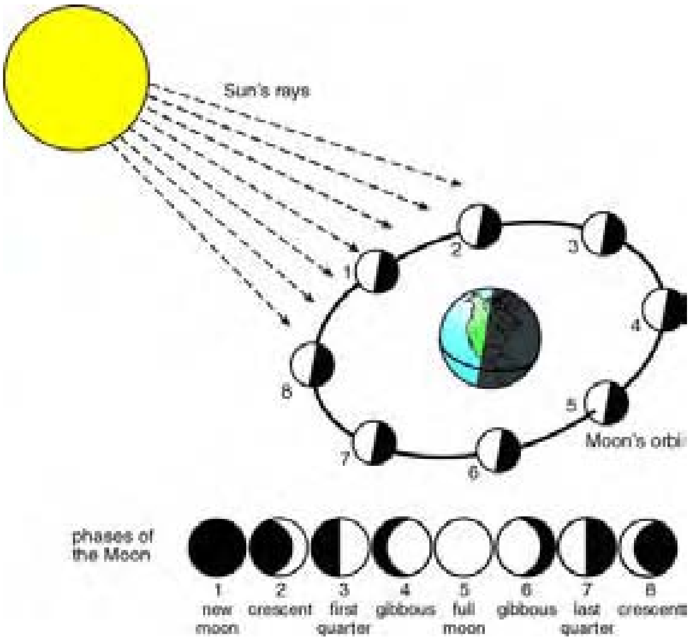
(Image © NASA)

A full Moon photographed from the *Apollo 11* spacecraft as it made the three-day, 386,000-km/240,000-mi journey back to Earth. This photograph was taken about 18,520 km/10,000 mi from the Moon.

(Image © NASA)

The far side of the Moon photographed from the *Apollo 13* spacecraft in 1970. The lunar landscape has been fashioned by the impact of countless meteorites. The bright-rayed crater seen here was caused by a relatively recent impact (still many millions of years ago). The darker areas are thought to be far older craters which have filled with lava welling up from the Moon's interior.

Moon



(Image © Research Machines plc)

The phases of the Moon as viewed from the Earth. The Moon takes a lunar month (about 29 days) to orbit the Earth. When the Earth is between the Sun and the Moon, the Moon appears to be 'full' because we can see all the light from the Sun reflected by the Moon.

Moon

To remember the order of the phases of the moon (to tell whether the current appearance of the moon indicates waxing or waning)

'What's up, **DOC**'

D indicates a (waxing) half-moon with the curve on the right, **O** indicates a full moon, and **C** indicates a (waning) crescent moon with the curve on the left, heading toward a new moon

Astromaterials Creation at NASA JSC

Go to site

Focuses on the use of the rock and soil returned from the Moon by the *Apollo* missions. Pages outline the ongoing research, and provide details of the whereabouts of lunar samples on display. The Web site hosts an online version of the *Lunar Newsletter*, with back issues available as downloadable PDF documents.

Earth and Moon Viewer

Go to site

Graphical simulations of the Moon and Earth. The Moon (or locations on the Moon) can be viewed from different locations on Earth, from the Sun, or as a map showing day and night across the lunar surface.

Future Lunar Missions

Go to site

Directory of lunar science missions planned by various international space agencies. There are also links to sites that discuss proposals for further crewed exploration of the Moon.

Inconstant Moon

Go to site

Packed with information, maps, lunar tables, and many other useful items. The site features a lunar tour, with photographs showing features to look out for as the Moon changes phase.

Moon

Go to site

Detailed description of the Moon. It includes statistics and information about the surface, eclipses, and phases of the Moon, along with details of the *Apollo* landing missions. The site is supported by a good selection of images.

Phases of the Moon 2001-2005

Go to site

Invaluable site for those interested in observing the phases of the Moon. Presented in calendar format, this site lists extremely precise times and dates for the phases of the Moon day by day up to the year 2005. There is also a list of definitions to explain the terminology used to describe the phases.

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moon

in astronomy, any natural satellite that orbits a planet. Mercury and Venus are the only planets in the Solar System not known to have moons.

Jupiter: moons

To remember the Gallilean moons of Jupiter:

I **e**at **g**reen **c**aterpillars or **I** **e**at **g**ood **c**ake

Io, **E**uropa, **G**anymede, **C**allisto

Moon probe

crewless spacecraft used to investigate the Moon. Early probes flew past the Moon or crash-landed on it, but later ones achieved soft landings or went into orbit. Soviet probes included the Luna series. US probes (Ranger space probes, Surveyor, Lunar Orbiter) prepared the way for the *Apollo* project crewed flights.

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moonstone

translucent, pearly variety of potassium sodium feldspar, found in Sri Lanka and Myanmar, and distinguished by a blue, silvery, or red opalescent tint. It is valued as a gem.

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moor

in earth science, a stretch of land, usually at a height, which is characterized by a vegetation of heather, coarse grass, and bracken. A moor may be poorly drained and contain boggy hollows.

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moorhen

marsh bird belonging to the rail family, common in swamps, lakes, and ponds throughout Europe, Asia, Africa, and North and South America. It is about 33 cm/13 in long, brown above and dark grey below, with a red bill and forehead, a white stripe along the edge of the folded wings, a vivid white underside to the tail, and green legs. Its big feet are not webbed or lobed, but the moorhen can swim well. The nest is built by the waterside, and the eggs are buff-coloured with orange-brown spots. (Species *Gallinula chloropus*, family Rallidae, order Gruiformes.)

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moose

large deer*Alces alces* inhabiting northern Asia and northern Europe, where it is known as the elk. It is brown in color, stands about 6 ft/2 m at the shoulders, and has very large palmate antlers, a fleshy muzzle, a short neck, and long legs. It feeds on leaves and shoots. In Europe, moose are called elk.

---

mopane worm

caterpillar of the southern African emperor moth *Gonimbrasia belina* which is eaten in South Africa, either dried as a snack or rehydrated in stews. They grow to around 10 cm/4 in in length and are very high in protein.

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moped

lightweight motorcycle with pedals. Early mopeds (like the autocycle) were like motorized bicycles, using the pedals to start the bicycle and assist propulsion uphill. The pedals have little function in many mopeds today.

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moraine

rocky debris or till carried along and deposited by a glacier. Material eroded from the side of a glaciated valley and carried along the glacier's edge is called a **lateral moraine**; that worn from the valley floor and carried along the base of the glacier is called a **ground moraine**. Rubble dropped at the snout (front end) of a melting glacier is called a **terminal moraine**.

When two glaciers converge their lateral moraines unite to form a **medial moraine**. Debris that has fallen down crevasses and becomes embedded in the ice is termed an **englacial moraine**; when this is exposed at the surface due to partial melting it becomes an **ablation moraine**.

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morbidity

in medicine, a term used to describe the condition of being diseased. The number of times a disease occurs within a particular number of the population is the morbidity rate of that disease.

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morel

any of a group of edible mushrooms. The common morel (*M. esculenta*) grows in Europe and North America. The yellowish-brown cap is pitted with holes like a sponge and is about 2.5 cm/1 in long. It is used for seasoning gravies, soups, and sauces and is second only to the truffle as the world's most sought-after mushroom. (Genus *Morchella*, order Pezizales.)

Morgagni, Giovanni Battista (1682-1771)

Italian anatomist who developed the view that disease was not an imbalance of the body's humours but a result of alterations in the organs. His work *De sedibus et causis morborum per anatomen indagatis/On the Seats and Causes of Diseases as Investigated by Anatomy* (1761) formed the basis of pathology.

Morgan, Thomas Hunt (1866-1945)

US geneticist who was awarded the Nobel Prize for Physiology or Medicine in 1933 for his work on the role of chromosomes in heredity. He helped establish that genes are located on the chromosomes, discovered sex chromosomes, and invented the techniques of genetic mapping. He was the first to work on the fruit fly *Drosophila*, which has since become a major subject of genetic studies.

Morgan horse

breed of riding and driving show horse originating in the USA in the 1780s from a single stallion named *Justin Morgan* after his owner. They are marked by high, curved necks and a high-stepping action. The breed is valued for its strength, endurance, and speed.

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moribund

in medicine, term used to describe a patient who is dying.

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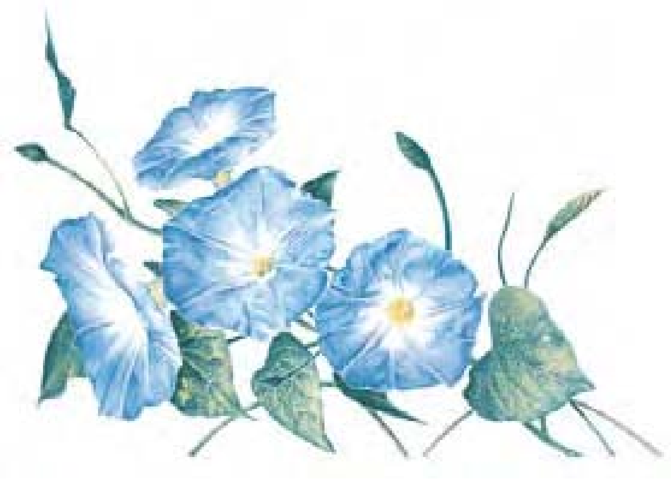
morning glory

any of a group of twining or creeping plants native to tropical America, especially *I. purpurea*, with dazzling blue flowers. Small quantities of substances similar to the hallucinogenic drug LSD are found in the seeds of some species. (Genus *Ipomoea*, family Convolvulaceae.)

morning glory



(Image © Research Machines plc)

The morning glory is a vinelike plant that bears large, purplish-blue, trumpet-shaped flowers. The seeds of certain species were once used by the Central American Indians, the Aztecs, to induce hallucinations during religious ceremonies. Nowadays, it is grown as an ornamental.

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morphine

narcotic alkaloid, $C_{17}H_{19}NO_3$, derived from opium and prescribed only to alleviate severe pain. Its use produces serious side effects, including nausea, constipation, tolerance, and addiction, but it is highly valued for the relief of the terminally ill.

The risk of addiction arising from the use of morphine for pain relief is much lower than for recreational use (about 1 in 3,000) as the drug is processed differently by the body when pain is present.

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morphing

short for 'metamorphosing'

metamorphosis of one shape or object into another by computer-generated animation. First used in film-making in 1990, it has transformed cinema special effects. Conventional animation is limited to two dimensions; morphing enables the creation of three-dimensional transformations.

To create such effects, the start and end of the transformation must be specified on screen. Once the beginning and end objects have been created, the computer can calculate the morphing process.

Morphing and Cinema

creatures from the Morph Lagoon

Cinema history is full of artificially created monsters and fantasy characters, from King Kong to Roger Rabbit. Until 1990, all these were either cartoon characters or the products of model shops. Either way, those sequences had to be created a frame at a time, whether it was by drawing each frame by hand on plastic 'cels' or by stop-motion photography. *The Abyss* 1990 was the first film to be made with a character that was wholly computer-generated and animated. This was an alien water creature that sent a watery pseudopod through a ship, mimicking the faces of the humans it met.

computer-generated effects

It was the 1991 film *Terminator 2*, however, that really took computer-generated effects off the hard disks and into people's imaginations. In it, the T1000 Terminator is an invincible killing machine made of liquid metal. Flowing into different shapes, the T1000 thoroughly upstages its on-screen arch-enemy, played by Arnold Schwarzenegger.

The T1000 made extensive use of a technique known as **morphing**, the computer-handled metamorphosis of one shape or object into another: the liquid metal man, the actor Robert Patrick, the actor Linda Hamilton, a shapeless blob. This sort of effect is a direct extension of the earliest uses of computers in animation, in-betweening.

how it's done

Animators of a cartoon sequence start with drawings of the characters at specific points in the action. The necessary in-between images are drawn up based on the speed at which the characters are moving and the number of images needed to fill the time - for film, 24 per second. Computers are ideal for this kind of drudgery.

Morphing adds a geometrical degree of complexity: instead of two-dimensional in-betweening, morphing is a three-dimensional transformation. To create such effects, you must first specify the beginning and end points. This means creating the objects that start and finish the transformation - in *Terminator 2*, for example, the liquid-metal man and the police-uniformed actor Robert Patrick. You begin with a wire-frame model on the computer screen that mathematically defines your object. To make the object three-dimensional, the wire frame can be extruded from a cross-section or turned, as if on a lathe, to produce an evenly curved surface. This is then rendered, or filled in and shaded.

a long process

The artist must specify the object's colour, lighting colour and direction, colour and brightness of reflections, surface texture, bumps, transparency, and the object's location in space and its environment. A technique known as ray-tracing calculates how the light directed at the object reaches it, with what intensity, and in what areas. From all this information, the computer calculates the colour intensity of each pixel that makes up the on-screen object.

This sounds a long process, and it is: a single frame may take hours. The 50 shots (less than five minutes' worth of screen time) needed for *Terminator 2* took the special-effects house Industrial Light and Magic one year to create.

traditional skills are still needed

Once the beginning and end objects are created, the computer can calculate the morphing process. Even so, a great deal of traditional animation skill is needed to make the images look realistic. Often, it is the small details that count, as in a famous shot where the Terminator walks out of a fire: it is the slight flattening of its foot on the ground that makes it look so real.

putting the object into place

Creating the objects is only the first step, however. They must be placed against the film's background, into the action. In the past, inserting models like King Kong into a shot was known as 'matte-processing', and creating those shots involved re-photographing each model in front of the already filmed background sequence.

This involves a loss of quality, since each time a sequence is photographed it loses sharpness - and today's special effects are complicated enough to require many 'generations' of photography. The advent of computer animation has brought with it digital compositing, which eliminates this loss of quality: the film is scanned into the computer, where the objects are superimposed, and then the finished image is converted back into film.

more subtle uses

Predictions are, however, that the flashy morphing effects that we have seen so far will give way to more subtle uses, much as Technicolor gave way to selective use of colours. The 1992 film *Death Becomes Her*, for example, used morphing to blur the actor Meryl Streep's hand from old to young. Morphing is also useful in blurring the transition between live action and computer animation.

In addition, the constantly decreasing cost of computer power means that we are on the verge of wholly digital characters. Even some of the people working on this find the technology they are creating frightening. This goes beyond seamless editing of video or audiotapes. Imagine seeing dead politicians, such as Winston Churchill or Abraham Lincoln, giving speeches, or films starring dead or retired actors. All that is a logical extension of the technology we have today. Such movie effects will inspire even more heated arguments - and litigation - than the comparatively simple but emotive issue of musicians giving 'live' concerts by lip-synching to their own recordings.

In the end, it all comes down to light, the way we see everything. As Steve Williams, ILM's animation director for *Terminator 2*, has said, 'Reality is in a paint palette of 13 million colours.' Coordinate that, and you can create illusions that the human eye can't distinguish from reality.

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morphogen

in medicine, one of a class of substances believed to be present in the growing embryo, controlling its growth pattern.

It is thought that variations in the concentration of morphogens in different parts of the embryo cause them to grow at different rates.

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morphology

in biology, the study of the physical structure and form of organisms, in particular their soft tissues.

Morse, Samuel Finley Breese (1791-1872)

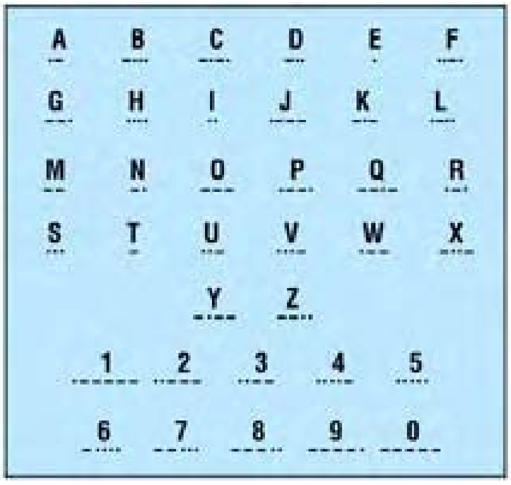
US inventor. In 1835 he produced an electric telegraph (see telegraphy), and in 1843 was granted $30,000 by Congress for an experimental line between Washington, DC, and Baltimore. With his assistant Alexander Bain (1810-1877) he invented the Morse code.

Morse code

international code for transmitting messages by wire or radio using signals of short (dots) and long (dashes) duration, originated by US inventor Samuel Morse for use on his invention, the telegraph (see telegraphy).

The letters SOS (3 short, 3 long, 3 short) form the international distress signal, being distinctive and easily transmitted (popularly but erroneously **s**ave **o**ur **s**ouls). Its use was discontinued in 1997. By radio telephone the distress call is 'Mayday', for similar reasons (popularly alleged to derive from French *m'aidez*, help me).

Morse code



(Image © Research Machines plc)

The Morse telegraph and workable code was first demonstrated in 1844. When a message was received, a series of short or long dashes ('dots' and 'dashes') were recorded onto a moving strip of paper. The pattern of the dots and dashes could be interpreted using Morse's Alphabetical Code.

Morse Code Translator

Go to site

Interactive Web site that allows you to type in words or phrases and it will then translate it into Morse code and even play the sound for you.

Morton, William Thomas Green (1819-1868)

US dentist who in 1846, with Charles Thomas Jackson (1805-1880), a chemist and physician, introduced ether as an anaesthetic. They were not the first to use it but they patented the process and successfully publicized it.

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mosquito

any of a group of flies in which the female has needlelike mouthparts and sucks blood before laying eggs. The males feed on plant juices. Some mosquitoes carry diseases such as malaria. (Family Culicidae, order Diptera.)

Human odour in general is attractive to mosquitos, as well as the lactic acid in sweat and the heat of the human body at close range. Peoples' varying reactions to mosquito bites depend on their general allergic reaction and not on the degree of the bite; the allergic reaction is caused by the saliva injected from the mosquito's salivary glands to prevent the host's blood from clotting. The mosquito consumes 4 microlitres of blood when it feeds. Natural mosquito repellents include lavender oil, citronella (from lemon grass), thyme, and eucalyptus oils.

mosquito

There is a population of mosquitoes living in the London Underground. The species originally fed on birds, but since its genetic separation below ground it has evolved a taste for mammalian blood and feeds on maintenance workers and passengers.

Mosquito Bytes

Go to site

Part of the Why Files project, published by the National Institute for Science Education (NISE) and funded by the National Science Foundation, this page provides extensive information about mosquitoes, the diseases they carry, and ways to protect yourself from these tiny bugs that carry a big bite. The highly readable text, laid out over 14 pages, includes information on malaria and why, these days, it's more dangerous than ever. Numerous images and diagrams enhance the text throughout. The more tricky terms are linked to a glossary, and you will find a comprehensive bibliography of sources for further research.

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moss

small nonflowering plant of the class Musci (10,000 species), forming with the liverworts and the hornworts the order Bryophyta. The stem of each plant bears rhizoids that anchor it; there are no true roots. Leaves spirally arranged on its lower portion have sexual organs at their tips. Most mosses flourish best in damp conditions where other vegetation is thin. There are 1,000 British species of moss and more than 1,200 North American species.

The peat or bog moss *Sphagnum* was formerly used for surgical dressings. The smallest moss is the Cape pygmy moss *Ephemerum capensi*, only slightly larger than a pin head.

Mössbauer, Rudolf (Ludwig) (1929-)

German physicist who was awarded the Nobel Prize for Physics in 1961 for his discovery in 1958 that under certain conditions an atomic nucleus can be stimulated to emit very sharply defined beams of gamma rays - a phenomenon that became known as the Mössbauer effect.

Mössbauer effect

recoil-free emission of gamma rays from atomic nuclei under certain conditions. The effect was discovered in 1958 by German physicist Rudolf Mössbauer, and used in 1960 to provide the first laboratory test of Einstein's general theory of relativity.

The absorption and subsequent re-emission of a gamma ray by an atomic nucleus usually causes it to recoil, so affecting the wavelength of the emitted ray. Mössbauer found that at low temperatures, crystals will absorb gamma rays of a specific wavelength and resonate so that the crystal as a whole recoils while individual nuclei do not. The wavelength of the re-emitted gamma rays is therefore virtually unaltered by recoil and may be measured to a high degree of accuracy. Changes in the wavelength may therefore be studied as evidence of the effect of, say, neighbouring electrons or gravity. For example, the effect provided the first verification of the general theory of relativity by showing that gamma-ray wavelengths become longer in a gravitational field, as predicted by Einstein.

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moth

any of a large number of mainly night-flying insects closely related to butterflies. Their wings are covered with microscopic scales. Most moths have a long sucking mouthpart (proboscis) for feeding on the nectar of flowers, but some have no functional mouthparts and rely instead upon stores of fat and other reserves built up during the caterpillar stage. At least 100,000 different species of moth are known. (Order Lepidoptera.)

Moths feed chiefly on nectar and other fluid matter; some, like the hawk moths, frequent flowers and feed while hovering. The females of some species (such as bagworm moths) have no wings at all or wings that are reduced to tiny flaps. Moths vary greatly in size: the minute Nepticulidae sometimes have a wingspread less than 3 mm/0.1 in, while the giant Noctuid or owlet moth (*Erebus agrippina*) measures about 280 mm/11 in across. In many cases the males are smaller and more brightly coloured than the females.

The larvae (caterpillars) have a well-developed head and three thoracic (middle) and ten abdominal (end) segments. Each thoracic segment has a pair of short legs, ending in single claws; a pair of suckerlike feet is present on segments three to six and ten of the end part of the body. In the family Geometridae the caterpillars have abdominal feet only on segments six and ten of the end part of the body. They move in a characteristic looping way and are known as 'loopers', 'inchworms', or geometers. Projecting from the middle of the lower lip of a caterpillar is a tiny tube or spinneret, through which silk is produced to make a cocoon within which the change to the pupa or chrysalis occurs. Silk glands are especially large in the silkworm moth. Many caterpillars, including the geometers, which are hunted by birds, are protected by their resemblance in both form and colour to their immediate surroundings. Others, which are distasteful to such enemies, are brightly coloured or densely hairy.

The feeding caterpillars of many moths cause damage: the codling moth, for example, attacks fruit trees; and several species of clothes moth eat natural fibres.

moth: blood-sucking

There is a blood-sucking moth species, the Southeast Asian *Calpe eustrigata*.

moth: environment

The moth *Cryptoses chalepi* lives within the algae-encrusted fur of the sloth. When the sloth descends to the forest floor to defecate, the moth emerges to lay her eggs in the dung heap, on which her young will feed.

moth: puddling

Males of the US moth *Gluphisia septentrionis* spend up to three hours at a time 'puddling'. Puddling is like drinking, except that the water passes straight through the insect after its sodium has been extracted. As it puddles, the moth squirts out the unwanted liquid from its anus about 18 times per minute. It passes the water equivalent of 600 times its own body mass.

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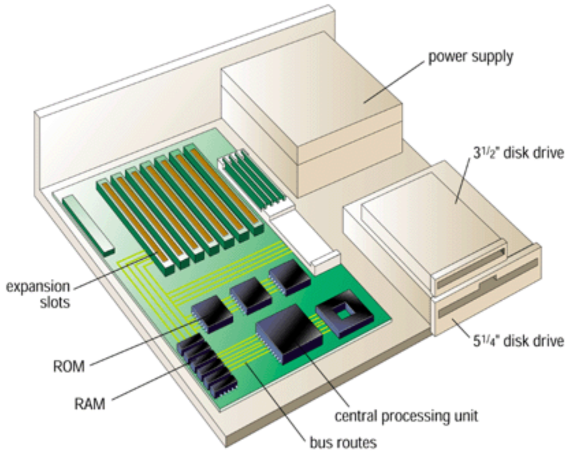
motherboard

printed circuit board that contains the main components of a microcomputer. The power, memory capacity, and capability of the microcomputer may be enhanced by adding expansion boards to the motherboard, now more commonly called a mainboard.

motherboard



(Image © Research Machines plc)

The position of a motherboard within a computer's system unit. The motherboard contains the central processing unit, random access memory (RAM) chips, read-only memory (ROM), and a number of expansion slots.

mother-of-pearl

or nacre

the smooth lustrous lining in the shells of certain molluscs – for example pearl oysters, abalones, and mussels. When this layer is especially thick it is used commercially for jewellery and decorations. Mother-of-pearl consists of calcium carbonate. See pearl.

motility

ability to move spontaneously. The term is often restricted to those cells that are capable of independent locomotion, such as spermatozoa. Many single-celled organisms are motile, for example, the amoeba. Research has shown that cells capable of movement, including vertebrate muscle cells, have certain biochemical features in common. Filaments of the proteins actin and myosin are associated with motility, as are the metabolic processes needed for breaking down the energy-rich compound ATP (adenosine triphosphate).

motion

process of moving; an object that is moving is said to be 'in motion'. The speed at which an object is moving is often measured in metres per second (m/s) or kilometres per hour (kph). The motion of objects can be described using Newton's laws of motion.

motion sickness

nausea and vomiting caused by the motion of cars, boats, or other forms of transport. Constant vibration and movement sometimes stimulates changes in the fluid of the semicircular canals (responsible for balance) of the inner ear, to which the individual fails to adapt, and to which are added visual and psychological factors.

Space sickness is a special case where normal body movements result in unexpected and unfamiliar signals to the brain, due to the unique environment of weightlessness. Astronauts achieve some control over symptoms by wedging themselves in their bunks.

motor

anything that produces or imparts motion; a machine that provides mechanical power, particularly an electric motor. Machines that burn fuel (gasoline, diesel) are usually called engines, but the internal-combustion engine that propels vehicles has long been called a motor, hence 'motoring' and 'motorcar' were used as early automotive terms.

motorboat

small, waterborne craft for pleasure cruising or racing, powered by a petrol, diesel, or gas-turbine engine. A boat not equipped as a motorboat may be converted by a detachable outboard motor. For increased speed, such as in racing, motorboat hulls are designed to skim the water (aquaplane) and reduce frictional resistance. Plastics, steel, and light alloys are now used in construction as well as the traditional wood.

In recent designs, drag is further reduced with hydrofins and hydrofoils, which enable the hull to rise clear of the water at normal speeds. Notable events in motorboat or 'powerboat' racing include the American Gold Cup in 1947 (over a 145 km/90 mi course) and the Round-Britain race in 1969.

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motorcycle

or motorbike

two-wheeled vehicle propelled by a gasoline engine. The motorbike is the lightweight version, with less power than the motorcycle, which may be equipped with a sidecar. The first successful motorized bicycle was built in France in 1901, and British and US manufacturers first produced motorbikes in 1903.

history

In 1868 Ernest and Pierre Michaux in France experimented with a steam-powered bicycle, but the steam power unit was too heavy and cumbersome. Gottlieb Daimler, a German engineer, created the first motorcycle when he installed his lightweight gasoline engine in a bicycle frame in 1886. Daimler soon lost interest in two wheels in favor of four and went on to pioneer the automobile.

The first really successful two-wheel design was devised by Michael and Eugene Werner in France in 1901. They adopted the classic motorcycle layout with the engine low down between the wheels.

Harley Davidson in the USA and Triumph in the UK began manufacture in 1903. Road races like the Isle of Man TT (Tourist Trophy), established in 1907, helped improve motorcycle design and it soon evolved into more or less its present form.

industry

Until the 1970s British manufacturers predominated but today Japanese motorcycles, such as Honda, Kawasaki, Suzuki, and Yamaha, dominate the world market. They make a wide variety of machines, from mopeds (lightweights with pedal assistance) to streamlined superbikes capable of speeds up to 160 mph/250 kph. There is still a smaller but thriving Italian motorcycle industry, making more specialist bikes. Laverda, Moto Guzzi, and Ducati continue to manufacture in Italy.

technical description

The lightweight bikes are generally powered by a two-stroke gasoline engine (see two-stroke cycle), while bikes with an engine capacity of 250 cc or more are generally four-strokes (see four-stroke cycle). However, many special-use larger bikes (such as those developed for off-road riding and racing) are two-stroke. Most motorcycles are air-cooled – their engines are surrounded by metal fins to offer a large surface area – although some have a water-cooling system similar to that of a car. Most small bikes have single-cylinder engines, but larger machines can have as many as six. The single-cylinder engine is economical and was popular in British manufacture; the Japanese developed multiple-cylinder models, but there has recently been some return to single-cylinder engines. A revived British Norton racing motorcycle uses a Wankel (rotary) engine. In the majority of bikes a chain carries the drive from the engine to the rear wheel, though some machines are now fitted with shaft drive.

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motor effect

tendency of a wire carrying an electric current in a magnetic field to move. The direction of the movement is given by the left-hand rule (see Fleming's rules). This effect is used in the electric motor. It also explains why streams of electrons produced, for instance, in a television tube can be directed by electromagnets.

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motor nerve

in anatomy, any nerve that transmits impulses from the central nervous system to muscles or organs. Motor nerves cause voluntary and involuntary muscle contractions, and stimulate glands to secrete hormones.

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motor neuron disease

MND; or amyotrophic lateral sclerosis

chronic disease in which there is progressive degeneration of the nerve cells which instigate movement. It leads to weakness, wasting, and loss of muscle function and usually proves fatal within two to three years of onset. Motor neuron disease occurs in both familial and sporadic forms but its causes remain unclear. A gene believed to be implicated in familial cases was discovered in 1993.

Results of a US trial in 1995 showed that the drug Myotrophin, a genetically engineered version of a chemical produced in the muscles, slowed deterioration in people with MND by 25%.

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mouflon

wild sheep found in mountain areas of Cyprus, Corsica, and Sardinia. It has woolly underfur in winter, but this is covered by heavy guard hairs. The coat is brown with a white belly and rump. Males have strong, curving horns. (Species *Ovis ammon*, family Bovidae.)

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mould

furlike growth caused by any of a group of fungi (see fungus) living on foodstuffs and other organic matter; a few are parasitic on plants, animals, or each other. Many moulds are of medical or industrial importance; for example, the antibiotic penicillin comes from a type of mould.

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moulding

use of a pattern, hollow form, or matrix to give a specific shape to something in a plastic or molten state. It is commonly used for shaping plastics, clays, and glass. When metals are used, the process is called casting.

In **injection moulding**, molten plastic, for example, is injected into a water-cooled mould and takes the shape of the mould when it solidifies. In **blow moulding**, air is blown into a blob of molten plastic inside a hollow mould. In **compression moulding**, synthetic resin powder is simultaneously heated and pressed into a mould.

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moulting

periodic shedding of the hair or fur of mammals, feathers of birds, or skin of reptiles. In mammals and birds, moulting is usually seasonal and is triggered by changes of day length.

The term is also often applied to the shedding of the exoskeleton of arthropods, but this is more correctly called ecdysis.

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mountain

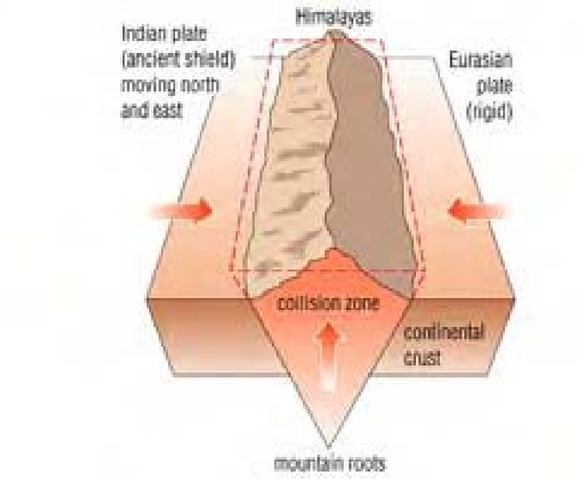
natural upward projection of the Earth's surface, higher and steeper than a hill. Mountains are at least 330 m/1,000 ft above the surrounding topography. The existing rock below a high mountain may be subjected to high temperatures and pressures, causing metamorphism. Plutonic activity also can accompany mountain building.

mountain

(Image © Garret Nagle)

Compassberg Mountains in South Africa. Many geological processes are at work here, particularly freeze-thaw action in which rocks are broken apart by the expansion of frozen water and repeated heating and cooling.

mountain


Himalayas
Indian plate
(ancient shield)
moving north
and east
Eurasian
plate
(rigid)
collision zone
continental
crust
mountain roots

(Image © Research Machines plc)

Mountains are created when two continental plates collide and no subduction takes place, resulting in the land at the collision zone being squeezed together and thrust upwards.

mountain

(Image © Garret Nagle)

A mountain landscape near Compassberg, South Africa.

mountain

(Image © Research Machines plc)

Pen y Fan, one of the major peaks or beacons that give the South Wales National Park its name, the Brecon Beacons. The mountain rises to a height of 886 m/2,907 ft above sea level and towers over Neuadd reservoir. It is a popular challenge for climbers from all over the UK.

Highest elevations and lowest depressions in the world by continent

Continent	Highest elevation	Height		Lowest depression	Depth below sea level	
		m	ft		m	ft
Africa	Kilimanjaro, Tanzania	5,895	19,337	Lake Assal, Djibouti	153	502
Antarctica	Vinson Massif	5,140	16,863	Lake Vostok[1]	4,000	13,123
Asia	Everest, China-Nepal	8,848	29,028	Dead Sea, Israel/Jordan	400	1,312
Europe	Elbrus, Russian Federation	5,642	18,510	Caspian Sea, Azerbaijan/Russian Federation/Kazakhstan/Turkmenistan/Iran	28	92
North America	McKinley (AK), USA	6,194	20,321	Death Valley (CA), USA	86	282
Oceania	Jaya, New Guinea	5,030	16,502	Lake Eyre, South Australia	16	52
South America	Cerro Aconcagua, Argentina	6,960	22,834	Valdés Peninsula, Argentina	40	131

[1] Discovered by the British Antarctic Survey in 1996, the freshwater Lake Vostok lies beneath the ice sheets and covers an area of 14,000 sq km/5,400 sq mi.

Highest mountains in the world by region

Region/mountain	Location	Height	
		m	ft
Africa			
Kilimanjaro	Tanzania	5,895	19,337
Kenya (Batian)	Kenya	5,199	17,057
Ngaliema (formerly Mt Stanley and Margherita Peak)	Democratic Republic of Congo/Uganda	5,110	16,765
Duwoni (formerly Umberto Peak)	Uganda	4,896	16,063
Baker (Edward Peak)	Uganda	4,843	15,889
Alpine Europe			
Mont Blanc	France/Italy	4,807	15,771
Monte Rosa	Switzerland	4,634	15,203
Dom	Switzerland	4,545	14,911
Liskamm	Switzerland/Italy	4,527	14,852
Weisshorn	Switzerland	4,505	14,780
Antarctica			
Vinson Massif		5,140	16,863
Tyree		4,965	16,289
Shinn		4,800	15,748
Gardner		4,690	15,387
Epperley		4,511	14,800
Asia			
Everest	China/Nepal	8,848	29,028
K2	Kashmir/Jammu	8,611	28,251
Kangchenjunga	India/Nepal	8,598	28,208
Lhotse	China/Nepal	8,511	27,923
Yalung Kang	India/Nepal	8,502	27,893
Australia			
Kosciusko	Snowy Mountains, New South Wales	2,230	7,316
Carpathians			
Gerlachvka	Slovak Republic	2,655	8,711
Moldoveanu	Romania	2,544	8,346
Negoiu	Romania	2,535	8,317
Mindra	Romania	2,518	8,261
Peleaga	Romania	2,509	8,232
Caucasia			
Elbrus, West Peak	Russian Federation	5,642	18,510
Dykh Tau	Russian Federation/Georgia	5,203	17,070
Shkhara	Russian Federation/Georgia	5,201	17,063
Kashtan Tau	Russian Federation/Georgia	5,144	16,876
Dzanghi Tau	Russian Federation	5,049	16,565
New Zealand			
Cook (called Aorangi in Maori)	west coast, South Island	3,754	12,316
North and Central America			
McKinley	Alaska, USA	6,194	20,321
Logan, Yukon	Canada	6,050	19,849
Citlaltépetl (Orizaba)	Mexico	5,610	18,405
St Elias	Alaska, USA/Yukon, Canada	5,489	18,008
Popocatépetl	Mexico	5,452	17,887
Oceania[1]			
Jaya	West Irian, Papua New Guinea	5,030	16,502
Daam	West Irian, Papua New Guinea	4,922	16,148

Oost Carstensz (also known as Jayakusumu Timur)	West Irian, Papua New Guinea	4,840	15,879
Trikora	West Irian, Papua New Guinea	4,730	15,518
Enggea	West Irian, Papua New Guinea	4,717	15,476
Polynesia			
Mauna Kea	Hawaii, USA	4,205	13,796
Mauna Loa	Hawaii, USA	4,170	13,681
Pyrenees			
Pico de Aneto	Spain	3,404	11,168
Pico de Posets	Spain	3,371	11,060
Monte Perdido	Spain	3,348	10,984
Pico de la Maladeta	Spain	3,312	10,866
Pic de Vignemale	France/Spain	3,298	10,820
Scandinavia			
Glittertind	Norway	2,472	8,110
Galdhøpiggen	Norway	2,469	8,100
Skagastolstindane	Norway	2,405	7,890
Snohetta	Norway	2,286	7,500
South America			
Cerro Aconcagua	Argentina	6,960	22,834
Ojos del Salado	Argentina/Chile	6,908	22,664
Bonete	Argentina	6,872	22,546
Nevado de Pissis	Argentina/Chile	6,779	22,241
Huascarán Sur	Peru	6,768	22,204

[1] Including all of Papua New Guinea.

Highest mountains in the world and first ascents

Mountain	Location	Height		Year of first ascent	Expedition nationality (leader)
		m	ft		
Everest	China/Nepal	8,848	29,028	1953	British/New Zealander (J Hunt)
K2	Kashmir/Jammu	8,611	28,251	1954	Italian (A Desio)
Kangchenjunga	India/Nepal	8,598	28,208	1955	British (C Evans; by the southwest face)
Lhotse	China/Nepal	8,511	27,923	1956	Swiss (E Reiss)
Yalung Kang (formerly Kangchenjunga West Peak)	India/Nepal	8,502	27,893	1973	Japanese (Y Ageta)
Kangchenjunga South Peak	India/Nepal	8,488	27,847	1978	Polish (W Wróz)
Makalu I	China/Nepal	8,481	27,824	1955	French (J Couzy)
Kangchenjunga Middle Peak	India/Nepal	8,475	27,805	1973	Polish (W Wróz)
Lhotse Shar	China/Nepal	8,383	27,503	1970	Austrian (S Mayerl)
Dhaulagiri	Nepal	8,172	26,811	1960	Swiss/Austrian (K Diemberger)
Manaslu	Nepal	8,156	26,759	1956	Japanese (T Imanishi)
Cho Oyu	China/Nepal	8,153	26,748	1954	Austrian (H Tichy)
Nanga Parbat	Kashmir/Jammu	8,126	26,660	1953	German (K M Herrligkoffer)
Annapurna I	Nepal	8,078	26,502	1950	French (M Herzog)
Gasherbrum I	Kashmir/Jammu	8,068	26,469	1958	US (P K Schoening; by the southwest ridge)
Broad Peak	Kashmir/Jammu	8,047	26,401	1957	Austrian (M Schmuck)
Gasherbrum II	Kashmir/Jammu	8,034	26,358	1956	Austrian (S Larch; by the southwest spur)
Gosainthan	China	8,012	26,286	1964	Chinese (195-strong team; accounts are inconclusive)
Broad Peak (Middle)	Kashmir/Jammu	8,000	26,246	1975	Polish (K Glazek)
Gasherbrum III	Kashmir/Jammu	7,952	26,089	1975	Polish (J Onyszkiewicz)
Annapurna II	Nepal	7,937	26,040	1960	British (C Bonington)
Gasherbrum IV	Kashmir/Jammu	7,923	25,994	1958	Italian (W Bonatti, C Mouri)
Gyachung Kang	Nepal	7,921	25,987	1964	Japanese (Y Kato, K Sakaizqwa)
Disteghil Shar	Kashmir	7,884	25,866	1960	Austrian (G Stärker, D Marchart)
Himalchuli	Nepal	7,864	25,800	1960	Japanese (M Harada, H Tanabe)
Nuptse	Nepal	7,841	25,725	1961	British (D Davis, C Bonington, L Brown)
Manaslu II	Nepal	7,835	25,705	1970	Japanese (H Watanabe, Lhakpa Tsering)
Masherbrum East	Kashmir	7,821	25,659	1960	Pakistani/US (G Bell, W Unsoeld)
Nanda Devi	India	7,817	25,646	1936	British (H W Tilman)
Chomo Lonzo	Nepal	7,815	25,639	1954	French (J Couzy, L Terry)

---

mountain ash

or rowan

flowering tree of the genus *Sorbus*, family Rosaceae. It has pinnate leaves and large clusters of whitish flowers, followed by scarlet berries. The American mountain ash *S. americana* grows to 30 ft/9 m and is native to the northeastern USA. The European mountain ash or rowan tree *S. aucaparia* is planted widely as an ornamental.

---

mountain gorilla

highly endangered ape found in bamboo and rainforest on the Rwanda, Democratic Republic of Congo (formerly Zaire), and Uganda borders in central Africa, with a total population of around 600 (1995). It is threatened by deforestation and illegal hunting for skins and the zoo trade. (Subspecies *Gorilla gorilla beringei*.)

---

mountain lion

another name for the puma.

Mount Palomar

astronomical observatory near Pasadena, California. Its telescopes include the 5.1-m/200-in diameter reflector called the Hale, and the 1.2-m/48-in Schmidt Telescope. Completed in 1948, it was the world's premier observatory during the 1950s.

Mount Stromlo Observatory

astronomical observatory established in Canberra, Australia, in 1923. Important observations have been made there on the Magellanic Clouds, two nearby galaxies, which can be seen clearly from southern Australia. The observatory suffered serious damage in the bushfires of January 2003.

Mount Wilson

site near Los Angeles, California, of the 2.5-m/100-in Hooker telescope, opened in 1917, with which US astronomer Edwin Hubble discovered the expansion of the universe. Two solar telescopes in towers 18.3 m/60 ft and 45.7 m/150 ft tall, and a 1.5-m/60-in reflector opened in 1908, also operate there.

Mount Wilson Observatory

Go to site

Featuring many articles and images relating to the history of the observatory, which is located near Los Angeles, California, this site contains links to the historical picture archive at the observatory, including images of visits to the 2.5-m/100-in telescope by such luminaries as German-born US physicist Albert Einstein and US astronaut George Hale.

---

mouse

in computing, an input device used to control a pointer on a computer screen. It is a feature of graphical user interface (GUI) systems. The mouse is about the size of a pack of playing cards, is connected to the computer by a wire or infrared (or other wireless) link, and incorporates one or more buttons that can be pressed ('clicked'). Moving the mouse across a flat surface causes a corresponding movement of the pointer. In this way, the operator can manipulate objects on the screen and make menu selections.

Mice work either mechanically (with electrical contacts to sense the movement in two planes of a ball on a level surface), or optically (photocells detecting movement by recording light reflected from a grid on which the mouse is moved). Many modern laptops incorporate a Glide Pad or touchpad, just below the keyboard, which performs the same function.

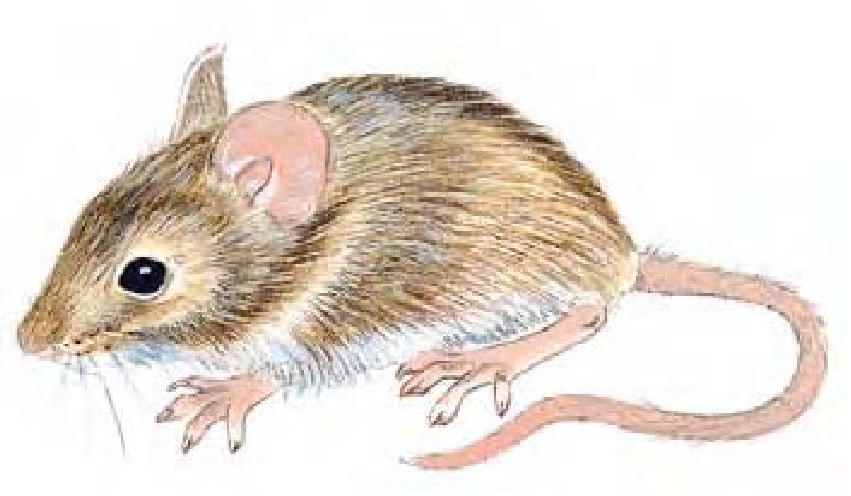
Most GUIs provide alternative keystrokes and these are also useful for advanced users or in emergencies when a mouse fails, or its drivers are deleted or corrupted.

---

mouse

in zoology, one of a number of small rodents with small ears and a long, thin tail. The **house mouse** (*Mus musculus*) is distributed worldwide. It is 75 mm/3 in long, with a naked tail of the same length, and has a grey-brown body. (Family Muridae.)

mouse



(Image © Research Machines plc)

The mouse is one of the most adaptable and successful animals. It can live in a wide range of conditions and occurs throughout the world. Although they eat relatively little, mice destroy vast quantities of stored food.

---

mousebird

any of a family of small crested birds found only in Africa. They have hairlike feathers, long tails, and move with a mouselike agility. The largest is the **blue-naped mousebird** (*Colius macrourus*), about 35 cm/14 in long. (Family Coliidae, order Coliiformes.)

Moustier, Le

rock shelter in the Dordogne, southwestern France, with prehistoric remains. It gave the name Mousterian to a type of flint-tool culture associated with Neanderthal sites of 100,000-40,000 years ago.

---

mouth

cavity forming the entrance to the digestive tract (gut or alimentary canal). In land vertebrates, air from the nostrils enters the mouth cavity to pass down the trachea. The mouth in mammals is enclosed by the jaws, cheeks, and palate. It contains teeth that may have a variety of functions depending on the way of life of the mammal. They may be used to hold things, to kill other organisms, or to cut food.

Teeth are usually also involved in digestion in that they cut or crush large pieces of food into smaller pieces and mix them with saliva. Saliva is a digestive juice which contains the enzyme amylase. This enzyme breaks down the large insoluble molecules of starch into smaller soluble molecules of complex sugar. These sugar molecules are broken into the simpler sugar glucose later in the alimentary canal.

Starch is rarely in the mouth long enough to be digested completely. However, in the small intestine the pancreas produces a digestive juice that also contains amylase, so it is here that starch digestion is completed.

mouth

In human mouths there are over 200 different species of bacteria, fungi, and protozoa. Billions of bacteria still cling to a tooth just brushed. Most species are harmless and some may be even be beneficial.

---

movie camera

or motion picture camera

camera that takes a rapid sequence of still photographs – usually 24 frames (pictures) each second. When the pictures are projected one after the other at the same speed onto a screen, they appear to show movement, because our eyes hold on to the image of one picture before the next one appears.

The movie camera differs from an ordinary still camera in having a motor that winds on the film continuously, but the film is held still by a claw mechanism while each frame is exposed. When the film is moved between frames, a semicircular disk slides between the lens and the film and prevents exposure.

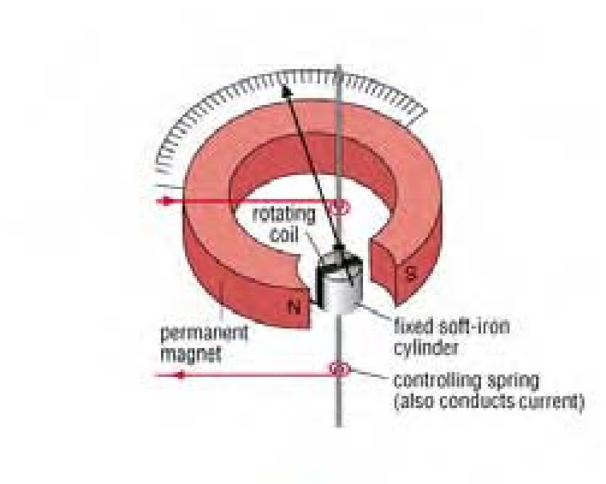
---

moving-coil meter

instrument used to detect and measure electrical current. A coil of wire pivoted between the poles of a permanent magnet is turned by the motor effect of an electric current (by which a force acts on a wire carrying a current in a magnetic field). The extent to which the coil turns can then be related to the magnitude of the current.

The sensitivity of the instrument depends directly upon the strength of the permanent magnet used, the number of turns making up the moving coil, and the coil's area. It depends inversely upon the strength of the controlling springs used to restrain the rotation of the coil. By the addition of a suitable large resistor, a moving-coil meter can be adapted to read potential difference in volts.

moving-coil meter



(Image © Research Machines plc)

A simple moving-coil meter. Direct electric current (DC) flowing through the wire coil combined with the presence of a magnetic field causes the coil to rotate; this in turn moves a pointer across a calibrated scale so that the degree of rotation can be related to the magnitude of the current.

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mp

in chemistry, abbreviation for melting point.

MS-DOS

acronym for MicroSoft Disk Operating System

computer operating system produced by Microsoft Corporation, widely used on microcomputers with Intel x86 and Pentium family microprocessors. A version called PC-DOS is sold by IBM specifically for its personal computers. MS-DOS and PC-DOS are usually referred to as DOS. MS-DOS first appeared in 1981, and was similar to an earlier system from Digital Research called CP/M. Developments in Windows software have led Microsoft to cease work on any further versions of MS-DOS.

MTBF

abbreviation for **mean time between failures**, the statistically average time a component can be used before it goes wrong. The MTBF of a computer hard disk, for example, is around 150,000 hours.

---

mucous membrane

thin skin lining all animal body cavities and canals that come into contact with the air (for example, eyelids, breathing and digestive passages, genital tract). It contains goblet cells that secrete mucus, a moistening, lubricating, and protective fluid. In the air passages mucus captures dust and bacteria. In the gut it helps food slip along, and protects the epithelial cells from being damaged by digestive enzymes. Mucous membranes line the air passages from the mouth to the lungs and to the gut. The layer of cells next to the space in the tubes is an epithelium. In the air passages many of these cells have hair-like projections called cilia and the epithelium is then called a ciliated epithelium.

---

mucus

lubricating and protective fluid, secreted by mucous membranes in many different parts of the body. In the gut, mucus smooths the passage of food and keeps potentially damaging digestive enzymes away from the gut lining. In the lungs, it traps airborne particles so that they can be expelled.

mudfish

another name for the bowfin.

---

mudnester

any of an Australian group of birds that make their nests from mud, including the **apostle bird** (*Struthidea cinerea*) (so called from its appearance in little flocks of about 12), the **white-winged chough** (*Corcorax melanorhamphos*), and the **magpie lark** (*Grallina cyanoleuca*).

---

mudpuppy

any of five species of brownish salamanders, living in fresh water in North America. They all breathe in water using external gills. The species *N. maculatus* is about 20 cm/8 in long. Mudpuppies eat fish, snails, and other invertebrates. (Genus *Necturus*, family Proteidae.)

---

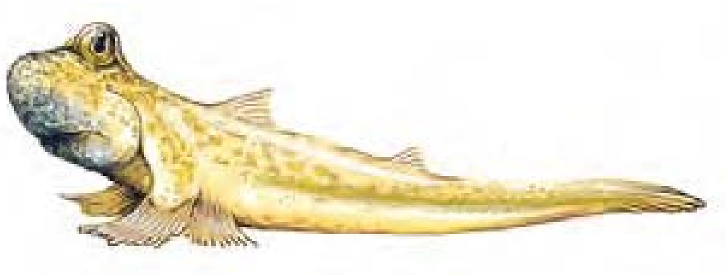
mudskipper

any of a group of fishes belonging to the goby family, found in brackish water and shores in the tropics, except for the Americas. It can walk or climb over mudflats, using its strong pectoral (chest) fins as legs, and has eyes set close together on top of the head. It grows up to 30 cm/12 in long. (Genus *Periophthalmus*, family Gobiidae.)

mudskipper

There is a fish that can climb trees. The mudskipper spends three-quarters of its time out of water. Malaysian mudskippers live in mangrove swamps, where they climb among the tangled stems and roots, and sometimes into the branches.

mudskipper



(Image © Research Machines plc)

Mudskippers use their fins as rudimentary legs. They often leave the waters of the mangrove swamps and tidal flats of the Indian and Pacific Oceans where they live, to lie on the mud or climb on exposed mangrove roots. Alert to danger, they quickly skip away when disturbed.

---

mudstone

fine-grained sedimentary rock made up of clay- to silt-sized particles (up to 0.0625 mm/0.0025 in).

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muffler

device in the exhaust system of automobiles and motorcycles. Gases leave the engine at supersonic speeds. The exhaust system and muffler are designed to slow them down, thereby silencing them.

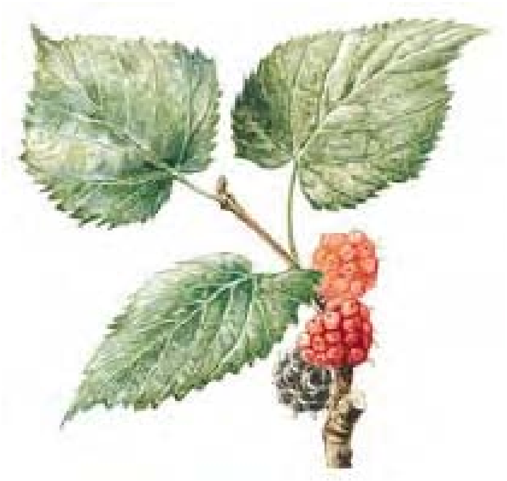
Some mufflers use baffle plates (plates with holes, which disrupt the airflow); others use perforated tubes and an expansion box (a large chamber that slows down airflow.)

---

mulberry

any of a group of trees consisting of a dozen species, including the black mulberry (*M. nigra*). It is native to western Asia and has heart-shaped, toothed leaves and spikes of whitish flowers. It is widely cultivated for its compound fruits, which resemble raspberries. The leaves of the Asiatic white mulberry (*M. alba*) are those used in feeding silkworms. (Genus *Morus*, family Moraceae.)

mulberry



(Image © Research Machines plc)

Male and female flowers of the black mulberry grow on separate bushes but the fruits form on the female trees whether or not they have been fertilized.

mule

hybrid animal, usually the offspring of a male ass and a female horse.

Mullard Radio Astronomy Observatory

radio observatory of the University of Cambridge, England, opened in 1972. Its main instrument is the Ryle Telescope, with eight dishes 12.8 m/42 ft wide; four are mounted on a rail track, and the others are fixed at 1.2 km/0.7 mi intervals, in a 5-km/3-mi long line. It is currently used as part of an array of telescopes that make up the Arcminute Microkelvin Imager (AMI), which observes fine detail in the cosmic background radiation.

Mullard Radio Astronomy Observatory

Go to site

Cambridge University's radio observatory site, which includes a description of current research interests, technical details of the four telescopes, details of the observatory's publications, and links to individual scientists.

mullein

any of a group of herbaceous plants belonging to the figwort family. The great mullein (*V. thapsus*) has lance-shaped leaves 30 cm/12 in or more in length, covered in woolly down, and a large spike of yellow flowers. It is found in Europe and Asia and is naturalized in North America. (Genus *Verbascum*, family Scrophulariaceae.)

Muller, Hermann Joseph (1890-1967)

US geneticist who was awarded a Nobel Prize for Physiology or Medicine in 1946 for his discovery, in 1926, that X-ray irradiation can cause mutation. This showed that mutations are nothing more than chemical changes.

Muller campaigned against the needless use of X-rays in diagnosis and treatment, and pressed for safety regulations to ensure that people who were regularly exposed to X-rays were adequately protected. He also opposed nuclear-bomb tests.

Müller, Johannes Peter (1801-1858)

German comparative anatomist whose studies of nerves and sense organs opened a new chapter in physiology by demonstrating the physical nature of sensory perception. His name is associated with a number of discoveries, including the **Müllerian ducts** in the mammalian fetus and the lymph heart in frogs.

Müller, Paul Hermann (1899-1965)

Swiss chemist who was awarded a Nobel Prize for Physiology or Medicine in 1948 for his discovery of the first synthetic contact insecticide, DDT, in 1939.

---

mullet

blunt-nosed warm-water fish of the family Muglidae, found in the Atlantic and Pacific. The striped mullet *Mugil cephalus*, about 2 ft/60 cm long, is commonly netted and smoked. The name mullet is sometimes used for goatfishes, tropical reef fishes of the family Mullidae.

---

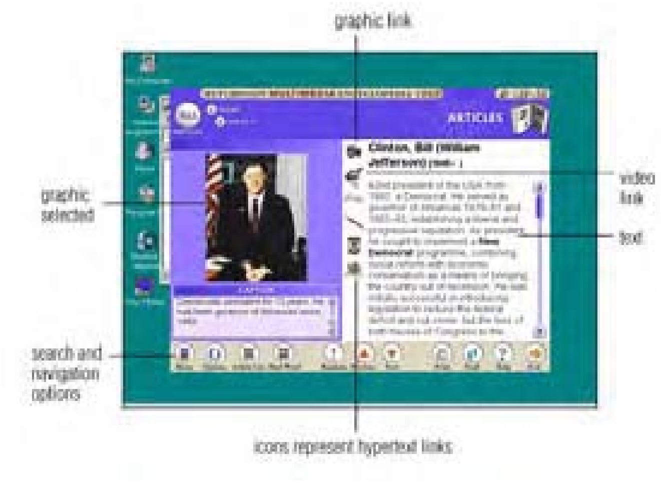
multimedia

computerized method of presenting information by combining audio and video components using text, sound, and graphics (still, animated, and video sequences). For example, a multimedia database of musical instruments may allow a user not only to search and retrieve text about a particular instrument but also to see pictures of it and hear it play a piece of music. Multimedia applications emphasize interactivity between the computer and the user.

As graphics, video, and audio are demanding of storage space, and as multimedia elements are increasingly used in digital content and applications, CD-ROMs have replaced lower capacity floppy disks for software distribution.

In the mid-1990s developments in compression techniques and software made it possible to incorporate multimedia elements into Internet Web sites.

multimedia


graphic link
graphic selected
video link
text
search and navigation options
icons represent hypertext links

(Image © Research Machines plc)

An example of how various elements can be combined to create a multimedia presentation. Text is combined with still images, and icons signify related video, audio, and hypertext links.

Definition of Multimedia

Go to site

Site that starts off with a basic definition of what multimedia is, and then shows how it can be used in different contexts. It outlines 'Real world applications of multimedia', including examples of how multimedia is used differently by consumers and businesses, and also looks at the role it can play in education and government.

---

multiple birth

in humans, the production of more than two babies from one pregnancy. Multiple births can be caused by more than two eggs being produced and fertilized (often as the result of hormone therapy to assist pregnancy), or by a single fertilized egg dividing more than once before implantation. See also twin.

---

multiple proportions, law of

in chemistry, the principle that if two elements combine with each other to form more than one compound, then the ratio of the masses of one of them that combine with a particular mass of the other is a small whole number.

---

multiple sclerosis

MS; or disseminated sclerosis

incurable chronic disease of the central nervous system, occurring in young or middle adulthood. Most prevalent in temperate zones, it affects more women than men. It is characterized by degeneration of the myelin sheath that surrounds nerves in the brain and spinal cord.

Depending on where the demyelination occurs – which nerves are affected – the symptoms of MS can mimic almost any neurological disorder. Typically seen are unsteadiness, ataxia (loss of muscular coordination), weakness, speech difficulties, and rapid involuntary movements of the eyes. The course of the disease is episodic, with frequent intervals of remission. Its cause is unknown, but it may be initiated in childhood by some environmental factor, such as infection, in genetically susceptible people. It has been shown that there is a genetic component: identical twins of MS sufferers have a 1 in 4 chance of developing the disease, compared to the 1 in 1,000 chance for the general population.

In 1993 interferon beta 1b became the first drug to be approved in the USA for treating MS. It reduces the number and severity of relapses, and slows the formation of brain lesions giving hope that it may slow down the progression of the disease. Clinical trials have shown some benefits of cannabis in alleviating some of the symptoms of multiple sclerosis. Use of medical cannabis products for this purpose has been legalized in Canada.

Multiple Sclerosis Support

Go to site

Embryonic site run by the British Multiple Sclerosis Society. There is information on the society itself and resources of help to sufferers and their families.

World of Multiple Sclerosis

Go to site

International cooperative effort utilizing experts in all areas of MS to offer current and useful information to all members of the MS community. The Web site includes answers to common questions, publications, current news, databases, services, and societies.

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multiplexer

in telecommunications, a device that allows a transmission medium to carry a number of separate signals at the same time – enabling, for example, several telephone conversations to be carried by one telephone line, and radio signals to be transmitted in stereo.

In **frequency-division multiplexing**, signals of different frequency, each carrying a different message, are transmitted. Electrical frequency filters separate the message at the receiving station. In **time-division multiplexing**, the messages are broken into sections and the sections of several messages interleaved during transmission. Pulse-code modulation allows hundreds of messages to be sent simultaneously over a single link.

---

multistage rocket

rocket launch vehicle made up of several rocket stages (often three) joined end to end. The bottom, or first, stage fires first, boosting the vehicle to high speed, then it falls away. The second stage fires, thrusting the now lighter vehicle even faster. The remaining stages fire and fall away in turn, ending with the upper stage, boosting the vehicle's payload (cargo) to orbital velocity or escape velocity.

---

multitasking

or multiprogramming

in computing, a system in which one processor appears to run several different programs (or different parts of the same program) at the same time. All the programs are held in memory together and each is allowed to run for a certain period.

For example, one program may run while other programs are waiting for a peripheral device to work or for input from an operator. The ability to multitask depends on the operating system rather than the type of computer. Unix is one of the commonest.

---

multi-user

or multi-access

in computing, an operating system that enables several users to access centrally stored data and programs simultaneously over a network. Each user has a terminal, which may be local (connected directly to the computer) or remote (connected to the computer via a modem and a telephone line). The growth of the internet has given rise to new forms of application level multi-user systems. Multi-user online games and meeting software are examples of a growing range of collaboration and interaction systems.

Multi-access is usually achieved by **time-sharing**: the computer switches very rapidly between terminals and programs so that each user has sole use of the computer for only a fraction of a second but can work as if she or he had continuous access.

Multi-user systems are becoming increasingly common in the workplace, and have many advantages – such as enabling employees to refer to and update a shared corporate database. The travel industry uses a multi-user system to manage bookings of airline tickets; travel agents around the world using the system can access information on available seats as readily as an airline's own office.

---

mummy

any dead body, human or animal, that has been naturally or artificially preserved. Natural mummification can occur through freezing (for example, mammoths in glacial ice from 25,000 years ago), drying, or preservation in bogs or oil seeps. Artificial mummification may be achieved by embalming (for example, the mummies of ancient Egypt) or by freeze-drying (see cryonics).

mummy

Thousands of mummified cats were discovered in an underground cavern at Ben Hassan, Egypt, in 1889. Most were sold off for use as fertilizer.

Mysterious Mummies of China

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page tells the remarkable story of the 3,000-year-old mummies with European features which were retrieved from the Takla Makan Desert in China. It includes numerous photographs and brief notes about the recovered bodies, plus a crash-course on mummification called 'Mummies 101' and a section on linguistics. You can download a transcript of the television programme, and there is a list of resources for further research.

---

mumps

or infectious parotitis

virus infection marked by fever, pain, and swelling of one or both parotid salivary glands (situated in front of the ears). It is usually short-lived in children, although meningitis is a possible complication. In adults the symptoms are more serious and it may cause sterility in men.

Mumps is the most common cause of meningitis in children, but it follows a much milder course than bacterial meningitis, and a complete recovery is usual. Rarely, mumps meningitis may lead to deafness. An effective vaccine against mumps, measles, and rubella (MMR vaccine) is now offered for children aged 18 months.

Childhood Infections - Mumps

Go to site

Useful information about mumps. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

Münchhausen's syndrome

emotional disorder in which a patient feigns or invents symptoms to secure medical treatment. It is the chronic form of factitious disorder, which is more common, and probably underdiagnosed. In some cases the patient will secretly ingest substances to produce real symptoms. It was named after the exaggerated tales of Baron Münchhausen. Some patients invent symptoms for their children, a phenomenon known as Münchhausen's by proxy.

---

muntjac

any of about nine species of small deer found in Southeast Asia. They live mostly in dense vegetation and do not form herds. The males have short spiked antlers and two sharp canine teeth forming tusks. They are sometimes called 'barking deer' because of their voices. (Genus *Muntiacus*.)

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muon

elementary particle similar to the electron except for its mass which is 207 times greater than that of the electron. It has a half-life of 2 millionths of a second, decaying into electrons and neutrinos. The muon was originally thought to be a meson but is now classified as a lepton. See also tau.

---

murmur

in medicine, the characteristic uneven sound that is heard when examining the diseased heart and various blood vessels using a stethoscope. Murmurs may be an indication of disease of the heart valves.

Murray, Joseph Edward (1919-)

US surgeon who was awarded a Nobel Prize for Physiology or Medicine in 1990 for his pioneering work in organ and cell transplants.

Murray cod

Australian freshwater fish that grows to about 2 m/6 ft. It is is named after the river in which it is found. (Species *Maccullochella macquariensis*.)

---

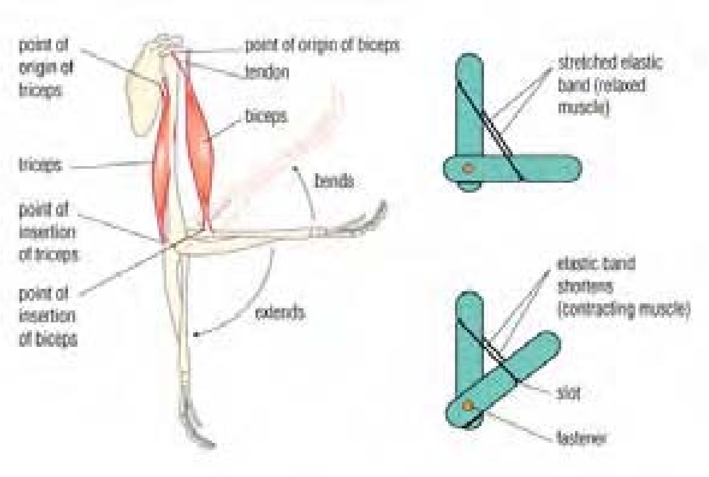
muscle

contractile animal tissue that produces locomotion and power and maintains the movement of body substances. Muscle contains very specialized animal cells – long cells – that can contract to between one-half and one-third of their relaxed length.

Muscle tissue is sometimes found in large amounts, forming muscles, that are organs. Muscle tissue enables movement. It may move the whole body, or part of it, or some material along a tube within it. Muscles can only do this work by contracting. This explains why muscles are usually found in pairs (antagonistic pairs) where the work done in the contraction of one causes the stretching of the other.

Muscle is categorized into three main groups: striped (or striated) muscles are activated by motor nerves under voluntary control – their ends are usually attached via tendons to bones; involuntary or smooth muscles are controlled by motor nerves of the autonomic nervous system, and are located in the gut, blood vessels, iris, and various ducts; cardiac muscle occurs only in the heart, and is also controlled by the autonomic nervous system.

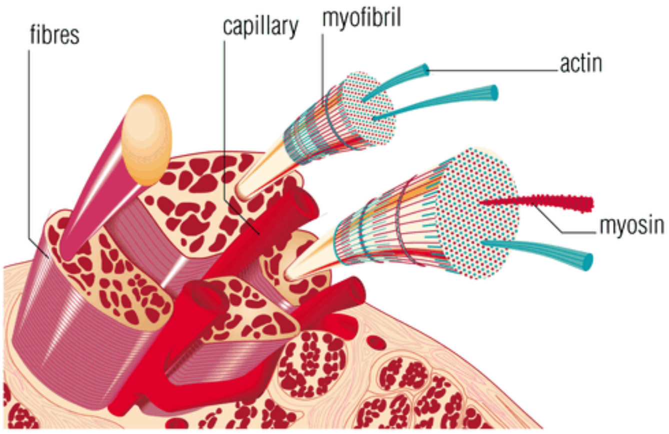
muscle


point of origin of triceps
point of origin of biceps
tendon
biceps
triceps
bends
point of insertion of triceps
point of insertion of biceps
extends
stretched elastic band (relaxed muscle)
elastic band shortens (contracting muscle)
slot
fastener

(Image © Research Machines plc)

The movements of the arm depend on two muscles, the biceps and the triceps. To lift the arm, the biceps shortens and the triceps lengthens. To lower the arm, the opposite occurs: the biceps lengthens and the triceps shortens.

muscle



(Image © Research Machines plc)

Muscles make up 35-45% of our body weight; there are over 650 skeletal muscles. Muscle cells may be up to 20 cm/0.8 in long. They are arranged in bundles, fibres, fibrils, and myofilaments.

List of Muscles

Go to site

Resource detailing all the muscles in the body. The page is divided into two frames: the left-hand frame lists all of the muscles alphabetically, and clicking on a specific muscle brings up information and a diagram in the right-hand frame.

Muscular System

Go to site

Based around annotated diagrams, linked to clear descriptions, this site has lots of useful facts about muscles. Click on a marker to bring up a new window that explains all about that type of muscle.

---

muscle relaxant

in medicine, one of a number of drugs used to relax skeletal muscles. Muscle relaxants are used in patients undergoing surgery under general anaesthesia and in patients with disorders affecting the musculoskeletal system, such as chronic muscle spasm or spasticity.

Muscle relaxants used in general anaesthesia are also known as neuromuscular blocking drugs. They block the transmission of nerve impulses between the nerve and the skeletal muscle, which results in relaxation of the abdomen and diaphragm. The vocal cords are also relaxed to allow the passage of an endotrachael tube.

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muscovite

white mica, $KAl_2Si_3AlO_{10}(OH,F)_2$, a common silicate mineral. It is colourless to silvery white with shiny surfaces, and like all micas it splits into thin flakes along its one perfect cleavage. Muscovite is a metamorphic mineral occurring mainly in schists; it is also found in some granites, and appears as shiny flakes on bedding planes of some sandstones.

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muscular dystrophy

any of a group of inherited chronic muscle disorders marked by weakening and wasting of muscle. Muscle fibres degenerate, to be replaced by fatty tissue, although the nerve supply remains unimpaired. Death occurs in early adult life.

The commonest form, Duchenne muscular dystrophy, strikes boys (1 in 3,000), usually before the age of four. The child develops a waddling gait and an inward curvature (lordosis) of the lumbar spine. The muscles affected by dystrophy and the rate of progress vary. There is no cure, but physical treatments can minimize disability. Death usually occurs before the age of 20.

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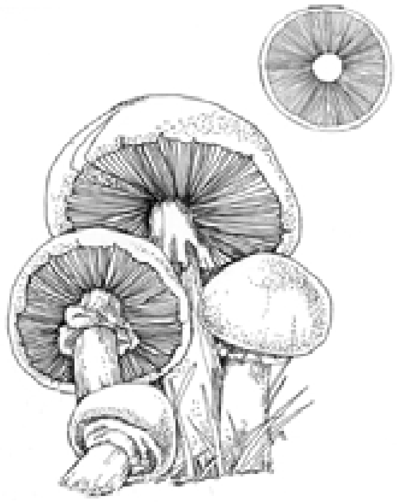
mushroom

fruiting body of certain fungi (see fungus), consisting of an upright stem and a spore-producing cap with radiating gills on the undersurface. There are many edible species belonging to the genus *Agaricus*, including the field mushroom (*A. campestris*). See also toadstool.

mushroom



(Image © Research Machines plc)

Field, or meadow mushroom (*Agaricus campestris*). The edible field mushroom is one of about 60 species of *Agaricus*, a genus of gill fungi. The gills on the underside of the cap or pileus, contain the reproductive spore-bearing cells. Unlike plants, mushrooms (which are classified as part of the fungi kingdom) are not photosynthetic, but absorb food from the organic matter they live on or within. *Agaricus bisporus*, a close relative of the field mushroom, is the most widely commercially-cultivated mushroom.

musical instrument digital interface

manufacturer's standard for digital music equipment; see MIDI.

music therapy

use of music as an adjunct to relaxation therapy, or in psychotherapy to elicit expressions of suppressed emotions by prompting patients to dance, shout, laugh, cry, or other, in response.

Music therapists are most frequently called upon to help the mentally or physically disabled; for instance, patients suffering from speech difficulties or autism may be enabled to express themselves more effectively by making musical sounds, and music can help the physically disabled to develop better motor control.

musk

in botany, perennial plant whose small oblong leaves give off the musky scent from which it takes its name; it is also called **monkey flower**. The name 'musk' is also given to several other plants with a similar scent, including the musk mallow (*Malva moschata*) and the musk rose (*Rosa moschata*). (*Mimulus moschatus*, family Scrophulariaceae.)

musk deer

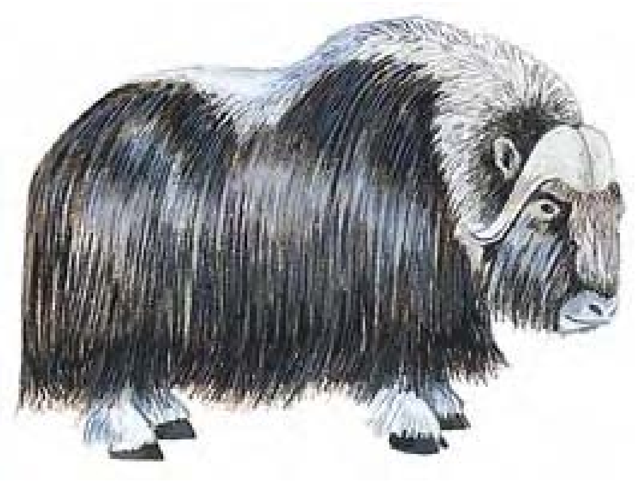
any of three species of small deer native to the mountains of central and northeastern Asia. A solitary animal, the musk deer is about 80–100 cm/30–40 in, sure-footed, and has large ears and no antlers. Males have long tusklike upper canine teeth. They are hunted and farmed for their musk (a waxy substance secreted by the male from a gland in the stomach area), which is used as medicine or perfume. (Genus *Moschus*.)

musk ox

ruminant (cud-chewing) mammal native to the Arctic regions of North America. It has characteristics of both sheep and oxen, is about the size of a small domestic cow, and has long brown hair. At certain seasons it has a musky smell. (Species *Ovibos moschatus*, family Bovidae.)

Its underwool (**qiviut**) is almost as fine as that of the vicuna, and musk-ox farms have been established in Alaska, Québec, and Norway to harvest this wool.

musk ox



(Image © Research Machines plc)

The musk ox once roamed throughout Northern Europe and America, but now survives only in North Canada and Greenland. Living in herds of up to 100 individuals, musk oxen form a circle when threatened, facing outwards with horns lowered and with the young inside the circle. This is an effective defence against wolves, their natural enemy, but not against hunters with guns.

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muskrat

North American rodent, about 30 cm/12 in long, that lives beside streams, rivers, and lakes. It has webbed hind feet, a side-to-side flattened tail, and shiny, light-brown fur. It builds up a store of food, plastering it over with mud, for winter consumption. It is hunted for its fur. (Species *Ondatra zibethicus*, family Cricetidae.)

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mussel

any of a group of shellfish, some of which are edible, such as the **common mussel** (*Mytilus edulis*) which has a blue-black hinged shell and is found in clusters attached to rocks around the North Atlantic and American coasts. Mussels are bivalve molluscs. (Class Bivalvia, phylum Mollusca.)

Freshwater pearl mussels, such as the species *Unio margaritiferus*, are found in some North American and European rivers. The larvae of the North American freshwater mussel *Lampsilis perovalis* are parasitic, living on the gills or fins of freshwater bass. The larvae of the British **swan mussel** (*Anodonta cygnea*) are also parasitic. *Margaritifera margaritifera* became a protected species in 1991 having suffered from pollution and from amateur fishers who, unlike professionals, are not able to extract the pearl without killing the mussel itself. The **green-lipped mussel**, found only off New Zealand, produces an extract that is used in the treatment of arthritis.

mussel: environment

Some freshwater mussels begin their lives as parasites living in a fish's gills. The mother releases them in mucus-coated packets resembling the favoured prey of the host fish. In some mussels the packets look like leeches or insect larvae, and in one type of North American freshwater mussel the larvae are released together in one big fish-shaped packet.

mussel: life span

The European freshwater mussel *Margaritifera margaritifera* lives for at least 90 years.

mussel

(Image © Research Machines plc)

Mussel farming in Chile. Chile is one of the most important fisheries in the world, and in addition to line- and-net caught fish such as mackerel and anchovy, fish farming is now increasingly practised. Large clusters of mussels attach themselves to lines, from which the fish farmers collect them.

mustard

any of several annual plants belonging to the cress family, with seed-bearing pods and sweet-smelling yellow flowers. Brown and white mustard are cultivated as an accompaniment to food in Europe and North America. The seeds of brown mustard (*B. juncea*) and white mustard (*Sinapis alba*) are used in the preparation of table mustard. (Genus mainly *Brassica*, family Cruciferae.)

Brown mustard replaced black mustard (*B. nigra*) in commercial mustard products during the 1950s with the introduction of mechanized harvesting. *B. nigra* is unsuitable for mechanized harvesting since its pods split open to release their seeds; those of *B. juncea* do not. Table mustard is most often used as an accompaniment to meat, although it can also be used in sauces and dressings, and with fish. **English mustard** is made from finely milled brown and white mustard seed to which ground turmeric is added for colour. French **Dijon mustard** contains brown mustard seed, verjuice (the juice of unripe grapes), oil, and white wine. Other varieties are made with vinegar, and may be flavoured with herbs or garlic. The seedlings of white mustard are used in salads. White mustard is also sometimes grown by farmers and ploughed back to enrich the soil. Brown mustard is grown on a large scale as an oil-seed crop throughout India, China, and southern Russia.

mutagen

any substance that increases the rate of gene mutation. A mutagen may also act as a carcinogen.

mutation

in biology, a change in the genes produced by a change in the DNA that makes up the hereditary material of all living organisms. It can be a change in a single gene or a change that affects sections of chromosomes. In the process of DNA replication, which takes place before any cell divides, the two halves of DNA separate and new halves are made. Because of specific base pairing, the inherited information is copied exactly. Despite this, rarely, a mistake occurs and the sequence of bases is altered. This changes the sequence of amino acids in a protein. This is mutation, the raw material of evolution. The consequences of mutation are varied. Due to the redundancy built into genetic code many mutations have no effect upon DNA functions. Genes describe how to make proteins. As a result of mutation a protein may not be produced, may be produced but act abnormally, or remain fully functional. Only a few mutations improve the organism's performance and are therefore favoured by natural selection. Mutation rates are increased by certain chemicals and by ionizing radiation.

Common mutations include the omission or insertion of a base (one of the chemical subunits of DNA); these are known as **point mutations**. Larger-scale mutations include removal of a whole segment of DNA or its inversion within the DNA strand. Not all mutations affect the organism, because there is a certain amount of redundancy in the genetic information. If a mutation is 'translated' from DNA into the protein that makes up the organism's structure, it may be in a non-functional part of the protein and thus have no detectable effect. This is known as a **neutral mutation**, and is of importance in molecular clock studies because such mutations tend to accumulate gradually as time passes. Some mutations do affect genes that control protein production or functional parts of protein, and most of these are lethal to the organism.

mutton bird

any of various shearwaters and petrels that breed in burrows on Australasian islands. Each parent feeds the chick for 2-3 days and then leaves for up to three weeks in search of food. These foraging trips can cover a distance of 15,000 km/9,300 mi and mean the chick may be left unattended for over a week. By the time the chicks have reached independence they weigh around 900 g/32 lb, twice as heavy as their parents.

The young are killed for food and oil.

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mutual induction

in physics, the production of an electromotive force (emf) or voltage in an electric circuit caused by a changing magnetic flux in a neighbouring circuit. The two circuits are often coils of wire, as in a transformer, and the size of the induced emf depends on the numbers of turns of wire in each of the coils.

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mutualism

association between two organisms of different species whereby both profit from the relationship; see symbiosis.

Muybridge, Eadweard (1830-1904)

adopted name of Edward James Muggeridge

English-born US photographer. He made a series of animal locomotion photographs in the USA in the 1870s and proved that, when a horse trots, there are times when all its feet are off the ground. He also explored motion in birds and humans.

Eadweard Muybridge of Kingston upon Thames

Go to site

Introduction to this pivotal figure in the early history of the cinema. The site includes a well-illustrated biography, broken into easy-to-read sections, on such topics as 'Early years' and 'The zoopraxiscope'. There is also a separate index of all the images on the site and information about the Muybridge Museum in Kingston.

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myasthenia gravis

in medicine, an uncommon condition characterized by loss of muscle power, especially in the face and neck. The muscles tire rapidly and fail to respond to repeated nervous stimulation. Autoimmunity is the cause.

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mycelium

interwoven mass of threadlike filaments or hyphae, forming the main body of most fungi. The reproductive structures, or 'fruiting bodies', grow from the mycelium.

Mycenaean civilization

Bronze Age civilization that flourished in Crete, Cyprus, Greece, the Aegean Islands, and western Anatolia about 3000-1000 BC. During this period, magnificent architecture and sophisticated artefacts were produced.

Mycenean civilization was strongly influenced by the Minoan from Crete, from about 1600 BC. It continued to thrive, with its centre at Mycenae, after the decline of Crete in about 1400. It was finally overthrown by the Dorian invasions, about 1100. The system of government was by kings, who also monopolized priestly functions. The Mycenaeans have been identified with the Achaeans of Homer; they may also have been the marauding Sea Peoples of Egyptian records.

They used a form of Greek deciphered by Michael Ventris called Linear B, which has been discovered on large numbers of clay tablets containing administrative records. Their palaces were large and luxurious, and their tombs (known as beehive tombs) were massive and impressive monuments. Pottery, frescoes, and metalwork reached a high artistic level. Evidence of the civilization was brought to light by the excavations of Heinrich Schliemann at Troy, Mycenae, and Tiryns (a stronghold on the plain of Argolis) from 1870 onwards, and of Arthur Evans in Crete from 1899.

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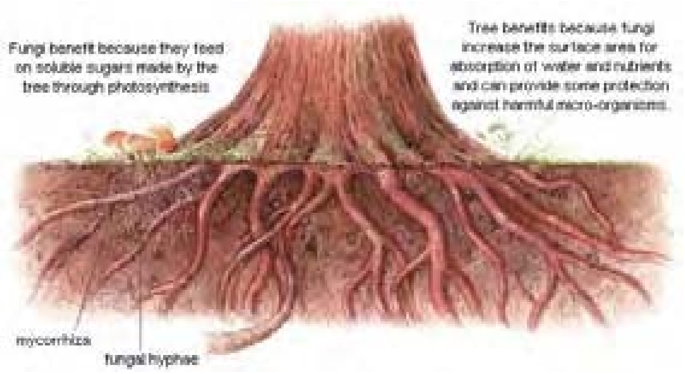
mycorrhiza

mutually beneficial (mutualistic) association occurring between plant roots and a soil fungus. Mycorrhizal roots take up nutrients more efficiently than non-mycorrhizal roots, and the fungus benefits by obtaining carbohydrates from the plant or tree.

An **ectotrophic mycorrhiza** occurs on many tree species, which usually grow much better, most noticeably in the seeding stage, as a result. Typically the roots become repeatedly branched and coral-like, penetrated by hyphae of a surrounding fungal mycelium. In an **endotrophic mycorrhiza**, the growth of the fungus is mainly inside the root, as in orchids. Such plants do not usually grow properly, and may not even germinate, unless the appropriate fungus is present.

mycorrhiza


Fungi benefit because they feed on soluble sugars made by the tree through photosynthesis
Tree benefits because fungi increase the surface area for absorption of water and nutrients and can provide some protection against harmful micro-organisms.
mycorrhiza
fungal hyphae

(Image © Research Machines plc)

The tree and fungus both benefit from their symbiotic relationship.

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myelin sheath

insulating layer that surrounds nerve cells in vertebrate animals. It serves to speed up the passage of nerve impulses.

Myelin is made up of fats and proteins and is formed from up to a hundred layers, laid down by special cells, the **Schwann cells**.

---

myelitis

in medicine, inflammation of the spinal cord. It occurs in diseases such as meningitis.

Myers, F(rederic) W(illiam) H(enry) (1843-1901)

English psychic researcher, classical scholar, and poet. He coined the word 'telepathy' and was a founder in 1882 and one of the first presidents, in 1900, of the Society for Psychical Research. His main works include *Essays Classical and Modern* (1883), *Phantasms of the Living* (1886), *Science and a Future Life* (1893), and the posthumous *Human Personality and its Survival of Bodily Death* (1903). His best-known poem is 'St Paul' (1867), and his *Collected Poems* were published in 1921.

---

myiasis

in medicine, infestation of the tissue of living animals by maggots. In some cases the larvae may be able to penetrate unbroken skin, in others some form of wound is required as a means of entry. Botflies and screw-worms live on cattle, as well as more rarely attacking humans.

The African tumbu fly, can penetrate unbroken skin, causing very painful bites, and the lesions can be serious in a heavy infestation.

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myna

or mynah

any of various tropical starlings, family Sturnidae, order Passeriformes, of Southeast Asia. The glossy blackhill myna *Gracula religiosa* of India is a realistic mimic of sounds and human speech. It is up to 16 in/40 cm long with yellow wattles on the head, and a yellow bill and legs.

---

myoglobin

globular protein, closely related to haemoglobin and located in vertebrate muscle. Oxygen binds to myoglobin and is released only when the haemoglobin can no longer supply adequate oxygen to muscle cells.

Myoglobin was the very first protein to have its detailed molecular structure solved by X-ray crystallography. The English biochemist John Kendrew reported this structure in 1960, beating his Cambridge colleague Max Perutz who studied the structure of the larger haemoglobin molecule. Both shared the Nobel Prize for Chemistry in 1962.

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myopia

or nearsightedness

defect of the eye in which a person can see clearly only those objects that are close up. It is caused either by the eyeball being too long or by the cornea and lens system of the eye being too powerful, both of which cause the images of distant objects to be formed in front of the retina instead of on it. Nearby objects are sharply perceived. The defect can be corrected by suitable eyeglasses or contact lenses. About 25% of Americans are affected by myopia.

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myopia, low-luminance

poor night vision. About 20% of people have poor vision in twilight and nearly 50% in the dark. Low-luminance myopia does not show up in normal optical tests, but in 1989 a method was developed of measuring the degree of blurring by projecting images on a screen using a weak laser beam.

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myrmecophyte

plant that lives in association with a colony of ants and possesses specialized organs in which the ants live. For example, *Myrmecodia*, an epiphytic plant from Malaysia, develops root tubers containing a network of cavities inhabited by ants.

Several species of *Acacia* from tropical America have specialized hollow thorns for the same purpose. This is probably a mutualistic (mutually beneficial) relationship, with the ants helping to protect the plant from other insect pests and in return receiving shelter.

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myrrh

gum resin produced by several small trees belonging to the bursera family, especially *C. myrrha*, found in Ethiopia and Arabia. In ancient times it was used for incense and perfume and in embalming dead bodies. (Genus *Commiphora*, family Burseraceae.)

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myrtle

any of a group of Old World evergreen shrubs belonging to the myrtle family. The commonly cultivated Mediterranean myrtle (*M. communis*) has oval opposite leaves and white flowers followed by purple berries, all of which are fragrant. (Genus *Myrtus*, family Myrtaceae.)

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mystery reproductive syndrome

MRS

viral disease of pigs that causes sows to lose up to 10% of their litter. It was first seen in the USA in 1987 and in Europe in 1991. The symptoms are flulike.

---

myxoedema

thyroid-deficiency disease developing in adult life, most commonly in middle-aged women. The symptoms include loss of energy and appetite, weight gain, inability to keep warm, mental dullness, and dry, puffy skin. It is reversed by giving the thyroid hormone thyroxine.

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myxomatosis

contagious, usually fatal, virus infection of rabbits which causes much suffering. It has been deliberately introduced in the UK and Australia since the 1950s to reduce the rabbit population.

N

abbreviation for **north**; newton, a unit of force; the chemical symbol for **nitrogen**.

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nacre

another name for mother-of-pearl.

Nadar (1820-1910)

adopted name of Gaspard-Félix Tournachon

French portrait photographer and caricaturist. He took the first aerial photographs (from a balloon in 1858) and was the first to take flash photographs (using magnesium bulbs).

nadir

point on the celestial sphere vertically below the observer and hence diametrically opposite the **zenith**.

naevus

mole, or patch of discoloration on the skin which has been present from birth. There are many different types of naevi, including those composed of a cluster of small blood vessels, such as the 'strawberry mark' (which usually disappears early in life) and the 'port-wine stain'.

A naevus of moderate size is harmless, and such marks can usually be disguised cosmetically unless they are extremely disfiguring, when they can sometimes be removed by cutting out, burning with an electric needle, freezing with carbon dioxide snow, or by argon laser treatment. In rare cases a mole may be a precursor of a malignant melanoma. Any changes in a mole, such as enlargement, itching, soreness, or bleeding, should be reported to a doctor.

nagana

sleeping sickness of African livestock, caused by a trypanosome and spread by the tsetse fly.

nail

in biology, a hard, flat, flexible outgrowth of the digits of primates (humans, monkeys, and apes). Nails are composed of keratin.

NAND gate

in electronics, a type of logic gate.

nano-

prefix used in SI units of measurement, equivalent to a one-billionth part (10^{-9}). For example, a nanosecond is one-billionth of a second.

nanotechnology

experimental technology using individual atoms or molecules as the components of minute machines, measured by the nanometre, or millionth of a millimetre. Nanotechnology research in the 1990s focused on testing molecular structures and refining ways to manipulate atoms using a scanning tunnelling microscope. The ultimate aim is to create very small computers and molecular machines which could perform vital engineering or medical tasks.

The scanning tunnelling microscope can be used to see and position single atoms and molecules, and to drill holes a nanometre (billionth of a metre) across in a variety of materials. The instrument can be used for ultrafine etching; the entire 28 volumes of the *Encyclopaedia Britannica* could be engraved on the head of a pin. In the USA, a complete electric motor has been built, which is less than 0.1 mm/0.004 in across with a top speed of 600,000 rpm. It is etched out of silicon, using the ordinary methods of chip manufacturers.

Nansen, Fridtjof (1861-1930)

Norwegian explorer and scientist. In 1893 he sailed to the Arctic in the *Fram*, which was deliberately allowed to drift north with an iceflow. Nansen, accompanied by F Hjalmar Johansen (1867-1923), continued north on foot and reached 86° 14' N, the highest latitude then attained. After World War I, Nansen became League of Nations high commissioner for refugees. He was awarded the Nobel Prize for Peace in 1922 for his relief work after World War I.

naphtha

mixtures of hydrocarbons obtained by destructive distillation of petroleum, coal tar, and shale oil. It is a raw material for the petrochemical and plastics industries. The term was originally applied to naturally occurring liquid hydrocarbons.

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naphthalene

$C_{10}H_8$

solid, white, shiny, aromatic hydrocarbon obtained from coal tar. The smell of moth balls is due to their naphthalene content. It is used in making indigo and certain azo dyes, as a mild disinfectant, and as a pesticide.

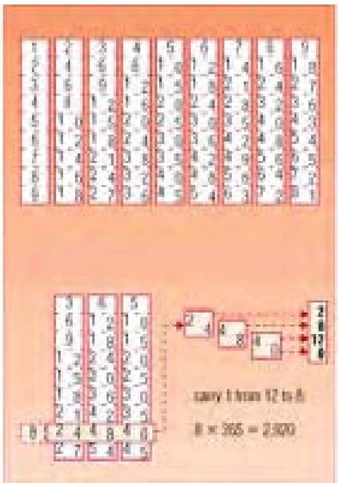
Napier, John (1550-1617)

8th Laird of Merchiston

Scottish mathematician who invented logarithms in 1614 and 'Napier's bones', an early mechanical calculating device for multiplication and division.

It was Napier who first used and then popularized the decimal point to separate the whole number part from the fractional part of a number.

Napier



(Image © Research Machines plc)

In 1617 Scottish mathematician John Napier published his description of what was arguably the first mechanical calculator – a set of numbered rods, usually made of bone or ivory and therefore known as Napier's bones. Using them, multiplication became merely a process of reading off the appropriate figures and making simple additions.

Napier, John

Go to site

Devoted to the life and contributions of John Napier. In addition to biographical information, you will find a list of references about Napier and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Napier. There is also an image of him, which can be enlarged, and a map of his birthplace.

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nappy rash

in medicine, an inflamed skin condition that occurs on the buttocks of infants. It is usually due to changing nappies too infrequently and the use of tightly fitting plastic pants. Nappy rash can be avoided by careful washing and drying of skin creases and folds in the area, followed by the application of a barrier cream.

If nappy rash does develop, it may clear if it is left exposed to the air. Creams containing dimethicone or zinc oxide can be used and, if the rash is associated with a fungal infection, creams containing the fungicide clotrimazole can be applied. It appears to occur less frequently in breast-fed infants and when disposable nappies are used.

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narcissism

in psychology, an exaggeration of normal self-respect and self-involvement which may amount to mental disorder when it precludes relationships with other people.

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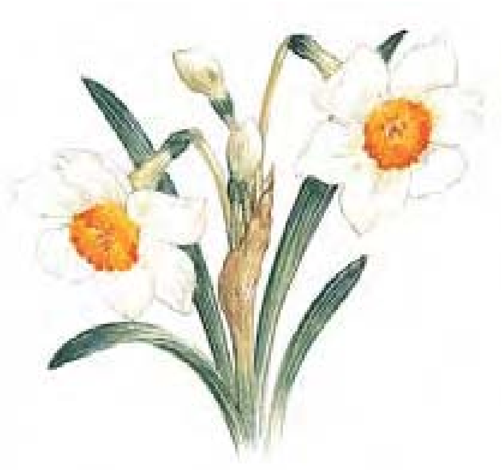
narcissus

any of a group of bulbous plants belonging to the amaryllis family. Species include the daffodil, jonquil, and narcissus. All have flowers with a cup or trumpet projecting from the centre. (Genus *Narcissus*, family Amaryllidaceae.)

narcissus



(Image © Research Machines plc)

In the true narcissus, the petals form a small bowl rather than the long trumpet of the daffodil.

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narcosis

in medicine, condition that can be produced by opioid drugs. It is characterized by deep sleep from which the affected individual can be roused only with great difficulty.

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narcotic

pain-relieving and sleep-inducing drug. The term is usually applied to heroin, morphine, and other opium derivatives, but may also be used for other drugs which depress brain activity, including anaesthetic agents and hypnotics.

Narmada Valley Project

controversial US$5 billion project to build more than 3,000 dams on the Narmada River, which runs for 1,245 km/778 mi through western India, to supply water to irrigate farmland for 30 million people and provide hydroelectric power. The project has been fiercely opposed by environmentalists in India and abroad. They believe it will lead to the displacement of 300,000 people, chiefly from small tribal communities; disrupt downstream fisheries; increase the risk of earthquakes; submerge forest land; increase the spread of insect-borne diseases; and threaten the fragile regional ecosystem through reducing, by two-thirds, the flow of water from the Narmada into the Arabian Sea.

The Narmada Valley Project was first envisaged in the 1940s by India's first prime minister, Jawaharlal Nehru. Its start was delayed until 1979 as a result of legal arguments and disputes among the various states it affects (Gujarat, Madhya Pradesh, Maharashtra, and Rajasthan). The project involves construction of two huge dams: the Sardar Sarovar, on the east edge of Gujarat, which will submerge 40,000 hectares of land and be the world's second largest dam; and the Narmada Sagar, in Madhya Pradesh. There will be a further 28 large dams, 135 medium ones, and 3,000 small dams, used to channel water into thousands of miles of irrigation canals. Protest against the project has been coordinated since the mid-1980s by the Narmada Bachhao Andolan (Save the Narmada Movement), and was influential in persuading Japan, in 1990, and the World Bank, in 1993, following an independent review, to end funding of the project.

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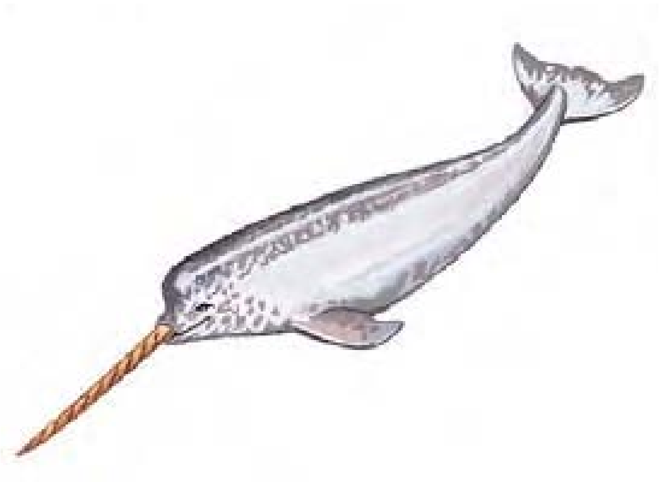
narwhal

toothed whale found only in the Arctic Ocean. It grows to 5 m/16 ft long, has a grey and black body, a small head, and short flippers. The male has a single spiral tusk growing straight out in front of its upper lip that can measure up to 2.7 m/9 ft long. (Species *Monodon monoceros*, family Monodontidae.)

narwhal



(Image © Research Machines plc)

The male narwhal, a toothed whale, has a spiral tusk up to 2.7 m/9 ft long. The tusk is actually an extended tooth which grows out of a hole in the upper lip. The tusk is not used as a weapon, although it may be used to dominate other males and to impress females.

NASA

acronym for National Aeronautics and Space Administration

US government agency for space flight and aeronautical research, founded in 1958 by the National Aeronautics and Space Act. Its headquarters are in Washington, DC, and its main installations include the Kennedy Space Center on Merritt Island in Florida, the Johnson Space Center in Houston, Texas, the Jet Propulsion Laboratory in Pasadena, California, the Goddard Space Flight Center in Beltsville, Maryland, and the Marshall Space Flight Center in Huntsville, Alabama. NASA's early planetary and lunar programmes included the Pioneer probes, from 1958, which gathered data for the later crewed missions, and the *Apollo* project, which took the first astronauts to the Moon in *Apollo 11* on 16–24 July 1969.

NASA launched the first space shuttle in 1981. In the early 1990s, the agency moved towards lower-budget missions, such as the Near-Earth Asteroid Rendezvous craft and the Lunar Prospector. It also established a **New Millennium Program** to identify, develop, and fly advanced technologies at lower costs. The programme's first launch was Deep Space 1 in 1998, and its Space Technology 6 (ST6) series has been developing new technologies for future flights. A notable success was the Mars Exploration Rover mission which in January 2004 landed two rovers on that planet. However, the break-up of the *Columbia* shuttle on 1 February 2003, killing all seven astronauts, led to all shuttles being grounded until 2005, as well as an extensive investigation and upgrade of safety. In January 2004, US president George W Bush announced plans to send astronauts back to the Moon in 2020 and later to Mars.

Its other recent major project, in partnership with 15 other nations, is the US$60 billion *International Space Station*, scheduled for completion in 2006. The first crew arrived at ISS in November 2000 under the command of NASA astronaut Bill Shepherd; by September 2001, six habitable modules had been added to the ISS.

NASA

Go to site

Latest news from NASA, plus the most recent images from the Hubble Space Telescope. The site also contains answers to questions about NASA resources and the space programme, and a gallery of video and audio clips and still images.

NASA Breakthrough Propulsion Physics Program

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Provides links to news of NASA activities and space-related news stories worldwide, with excerpts from articles and editorial comment. Interesting alternative to NASA's own news service. The Web site is regularly updated and has an easily accessible archive of previously featured material.

Neurolab Space Trivia

Go to site

NASA site that answers all the questions you might have about the history of space exploration, including a section on 'Firsts'.

nastic movement

plant movement that is caused by an external stimulus, such as light or temperature, but is directionally independent of its source, unlike tropisms. Nastic movements occur as a result of changes in water pressure within specialized cells or differing rates of growth in parts of the plant.

Examples include the opening and closing of crocus flowers following an increase or decrease in temperature (**thermonasty**), and the opening and closing of evening primrose *Oenothera* flowers on exposure to dark and light (**photonasty**).

The leaf movements of the Venus flytrap *Dionaea muscipula* following a tactile stimulus, and the rapid collapse of the leaflets of the sensitive plant *Mimosa pudica* are examples of **haptonasty**. Sleep movements, where the leaves or flowers of some plants adopt a different position at night, are described as **nyctinasty**. Other movement types include **hydronasty**, in response to a change in the atmospheric humidity, and **chemonasty**, in response to a chemical stimulus.

nasturtium

any of a group of plants that includes watercress (*N. officinale*), a perennial aquatic plant of Europe and Asia, grown as a salad crop. Belonging to a different family altogether, the South American trailing nasturtiums include the cultivated species *T. majus*, with orange, scarlet, or yellow flowers, and *T. minus*, which has smaller flowers. (Genus *Nasturtium*, family Cruciferae; South American genus *Tropaeolum*, family Tropaeolaceae.)

National Aeronautics and Space Administration

full name of NASA.

national park

land set aside and conserved for public enjoyment. National parks include not only the most scenic places, but also places distinguished for their historic, prehistoric, or scientific interest, or for their superior recreational assets. They range from areas the size of small countries to pockets of just a few acres. The first such designated area in the USA was Yellowstone National Park, established in 1872, although Yosemite National Park, originally a state reserve, predates it.

All elements of the National Park System are under the control of the Department of the Interior. For the most part, they were created from public lands, although since 1925 the government has been empowered to accept donations of land from other sources.

native companion

another name for the brolga, so called because these birds are often seen in pairs.

native metal

or free metal

any of the metallic elements that occur in nature in the chemically uncombined or elemental form (in addition to any combined form). They include bismuth, cobalt, copper, gold, iridium, iron, lead, mercury, nickel, osmium, palladium, platinum, ruthenium, rhodium, tin, and silver. Some are commonly found in the free state, such as gold; others occur almost exclusively in the combined state, but under unusual conditions do occur as native metals, such as mercury. Examples of native non-metals are carbon and sulphur.

natural frequency

frequency at which a mechanical system will vibrate freely. A pendulum, for example, always oscillates at the same frequency when set in motion. More complicated systems, such as bridges, also vibrate with a fixed natural frequency. If a varying force with a frequency equal to the natural frequency is applied to such an object the vibrations can become violent, a phenomenon known as resonance.

---

natural gas

mixture of flammable gases found in the Earth's crust (often in association with petroleum). It is one of the world's three main fossil fuels (with coal and oil).

Natural gas, a non-renewable resource, is formed from the remains of dead plants and animals. As these plants and animals died they were buried with mud near the sea floor. Over millions of years, heat from the Earth's interior and pressure from overlying rocks slowly changed the dead remains into hydrocarbons (substances containing hydrogen and carbon). The hydrocarbons, being light molecules, moved upwards and became trapped beneath impermeable rocks.

Natural gas is a mixture of hydrocarbons, chiefly methane (80%), with ethane, butane, and propane. Natural gas reservoirs are often found beneath the seabed and drilling technology is used to locate these supplies. The gas is usually transported from its source by pipeline, although it may be liquefied for transport and storage and is, therefore, often used in remote areas where other fuels are scarce and expensive. Prior to transportation, butane and propane are removed and liquefied to form 'bottled gas'.

Methane combusts in air to form products with the release of heat energy:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + heat energy

Another source of gas is from the cracking of crude oil into simpler molecules. Methane, propane, and butane are all gases that can be produced from the cracking process. The gases are liquefied and stored under pressure. Propane and butane also undergo combustion when ignited in air. Large amounts of heat energy are released in the reaction. The reaction for the combustion of propane is:

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ + heat energy

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natural logarithm

in mathematics, the exponent of a number expressed to base e, where e represents the irrational number 2.71828... . Natural logarithms are also called Napierian logarithms, after their inventor, the Scottish mathematician John Napier.

---

natural radioactivity

radioactivity generated by those radioactive elements that exist in the Earth's crust. All the elements from polonium (atomic number 84) to uranium (atomic number 92) are radioactive. Radioisotopes of some lighter elements are also found in nature (for example potassium-40). See background radiation.

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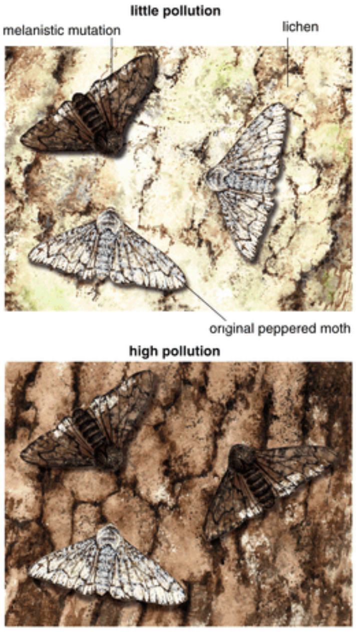
natural selection

process by which gene frequencies in a population change through certain individuals producing more descendants than others because they are better able to survive and reproduce in their environment. The accumulated effect of natural selection is to produce adaptations such as the insulating coat of a polar bear or the spadelike forelimbs of a mole. The process is slow, relying firstly on random variation in the genes of an organism being produced by mutation and secondly on the genetic recombination of sexual reproduction. It was recognized by Charles Darwin and English naturalist Alfred Russel Wallace as the main process driving evolution.

Natural selection results in evolution in a way that was described by Charles Darwin: individual organisms within a particular species may show a wide range of variation because of differences in their genes; predation, disease, and competition cause individuals to die; individuals with characteristics most suited to the environment are more likely to survive and breed successfully; and the genes which have enabled these individuals to survive are then passed on to the next generation, and if the environment is changing, the result is that some genes are more abundant in the next generation and the organism has evolved.

natural selection



(Image © Research Machines plc)

Industrial melanism in the peppered moth, first noticed by English geneticist Henry Kettlewell. He observed that whereas in rural areas peppered moths were light in colour to camouflage them against the lichens, in industrial areas where the tree trunks were dirtied with soot, peppered moths were darker. Natural selection favoured the darker mutation in industrial areas because it offered better camouflage there, so it had become widespread, whereas in rural areas the darker mutant was highly visible against the lighter tree trunks and so was easy prey to insect feeders.

Introduction to Evolutionary Biology

Go to site

Intelligent and readable explanation of the theory of evolution, the cornerstone of modern biology. Author Chris Colby presents the main aspects of evolutionary biology, and robustly confronts the 'evolution versus creation' debate. An interesting section dispels common misconceptions about evolution and demonstrates how changes to the environment can affect the way in which a species evolves.

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nature-nurture controversy

or environment-heredity controversy

long-standing dispute among philosophers and psychologists over the relative importance of environment, that is, upbringing, experience, and learning ('nurture'), and heredity, that is, genetic inheritance ('nature'), in determining the make-up of an organism, as related to human personality and intelligence.

One area of contention is the reason for differences between individuals; for example, in performing intelligence tests. The environmentalist position assumes that individuals do not differ significantly in their inherited mental abilities and that subsequent differences are due to learning, or to differences in early experiences. Opponents insist that certain differences in the capacities of individuals (and hence their behaviour) can be attributed to inherited differences in their genetic make-up.

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nature preserve

area set aside to protect a habitat and the wildlife that lives within it, with only restricted admission for the public. A nature preserve often provides a sanctuary for rare species, and rare habitats, such as marshlands. The world's largest is Etosha Reserve, Namibia; area 38,415 sq mi/99,520 sq km.

Many state and local preserves have been established in the USA since 1970. Some are called greenbelts and some are designated 'forever wild,' as well as those that are administered for limited or educational access.

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naturopathy

in alternative medicine, facilitating of the natural self-healing processes of the body. Naturopaths are the general practitioners (GPs) of alternative medicine and often refer clients to other specialists, particularly in manipulative therapies, to complement their own work of seeking, through diet, the prescription of natural medicines and supplements, and lifestyle counselling, to restore or augment the vitality of the body and thereby its optimum health.

nausea

in medicine, a feeling of sickness and a desire to vomit. It is a symptom of a wide range of diseases, such as gastrointestinal infections and motion sickness.

Nausea can occur as an adverse reaction to some drugs that irritate the gastrointestinal tract, such as ibuprofen, and can be very severe in patients receiving chemotherapy or radiotherapy to treat cancer. Nausea often occurs during the first three months of pregnancy when it should not be treated on a routine basis.

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nautical mile

unit of distance used in navigation, an internationally agreed standard (since 1959) equalling the average length of one minute of arc on a great circle of the Earth, or 1,852 m/6,076 ft. The term formerly applied to various units of distance used in navigation.

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nautilus

sea animal related to octopuses and squids, with many short, grasping tentacles surrounding a sharp beak, but different in that it has an outer shell. It is a cephalopod, a type of mollusc, and is found in the Indian and Pacific oceans. The well-known **pearly nautilus** (*N. pompilius*) has a chambered spiral shell about 20 cm/8 in in diameter. Its body occupies the outer chamber. (Genus *Nautilus*, class Cephalopoda.)

Nautiluses detect their prey by smell, using rhinopores, paired openings just below the eyes, according to US researchers in April 2000.
Paper nautilus is another name for the **argonaut**, a type of octopus.

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navel

or umbilicus

small indentation in the centre of the abdomen of mammals, marking the site of attachment of the umbilical cord, which connects the fetus to the placenta.

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navigation

the science and technology of finding the position, course, and distance travelled by a ship, plane, or other craft. Traditional methods include the magnetic compass and sextant. Today the gyrocompass is usually used, together with highly sophisticated electronic methods, employing beacons of radio signals, such as Decca, Loran, and Omega. Satellite navigation uses satellites that broadcast time and position signals.

The US global positioning system (GPS) was introduced in 1992. When complete, it will feature 24 Navstar satellites that will enable users (including eventually motorists and walkers) to triangulate their position (from any three satellites) to within 15 m/50 ft.

In 1992, 85 nations agreed to take part in trials of a new navigation system which makes use of surplus military space technology left over from the Cold War. The new system, known as FANS or Future Navigation System, will make use of the 24 Russian Glonass satellites and the 24 US GPS satellites. Small computers will gradually be fitted to civil aircraft to process the signals from the satellite, allowing aircraft to navigate with pinpoint accuracy anywhere in the world. The signals from at least three satellites will guide the craft to within a few metres of accuracy. FANS will be used in conjunction with four Inmarsat satellites to provide worldwide communications between pilots and air-traffic controllers.

Global Positioning System

satellites

The global positioning system, or GPS, has become indispensable as a tool for navigation and scientific discovery. It relies on 24 satellites that can be accessed for accurate positioning by users all over the world. GPS is funded and controlled by the United States Department of Defense. Essential to the satellites are on-board atomic clocks accurate to 3 billionths of one second.

A master control site at Falcon Air Force Base in Colorado Springs, USA, sends data to each satellite. Ephemeris data consist of satellite positions. Almanac data consist of the projected orbits of each satellite and information about their overall status. Clock corrections are also transmitted as necessary. In turn the satellites routinely send signals to five monitor stations so that their positions can be tracked. The monitor stations also 'downlink' the Almanac information sent to the satellites from the Master Control site.

GPS satellites transmit two microwave carrier signals. The first, a high-frequency signal, carries position and time data for civilian users worldwide. The US Department of Defense to limit horizontal and vertical accuracy to 100 and 156 m/30 and 46.8 ft respectively degrades this signal. A second, lower-frequency signal can be used to correct for the effects of the ionosphere for more precise positioning by authorized users, including allied military, government agencies, and approved civilian users.

receivers

GPS receivers search for the coded high-frequency radio signals transmitted by the satellites. Once located, complete transmission from a satellite takes 12.5 minutes. The signal includes the position of the satellite and time at which the signal was sent. Transit time of the satellite radio signal gives the distance, or range, of the satellite from the receiver because the speed of electromagnetic radiation (radio waves) is known. Time passes more quickly for the satellites than on Earth, as predicted by Einstein's theory of general relativity, and so 'relativistic' corrections to the transit time must be made. Signals from four satellites are required for precise positioning and time measurement.

applications

GPS receivers are used or navigation of ships, motor vehicles, aircraft, space vehicles, and persons on the ground. In addition, the precise time information and radio signals that carry the information are useful for scientific experiments.

Geodetics is one example of a scientific discipline benefiting from GPS technology. The relative motions of Earth's tectonic plates cause mountains and earthquakes. Plate tectonic motions are in the order of millimetres per year. The small displacements over long time periods makes measuring tectonic motions by traditional geodetic methods laborious and time consuming. Scientists are now using signals by GPS satellites to track Earth's tectonic plates and to establish how they deform to form mountains, depressions, and earthquakes as they move. Measurements that might have taken months or years to perform by traditional geodetic methods can be obtained in just a few days with greater accuracy using GPS. In this application, referred to as space geodesy, the characteristics of the satellite radio waves themselves are used rather than the data they transmit. Slight differences in the phase, or wave-crest positions, of GPS radio waves detected by two receiver stations can be converted into the distance between the stations. In this way distances between points can be measured with millimeter accuracy if receivers are within approximately 30 kilometers of one another.

As part of one space geodesy study, changing topography and relative motions measured by GPS reveal where strain is building in the tectonically active Aegean region. This information is helping scientists to identify potential earthquake hazards. In a similar study, GPS is being used to establish the ever-changing elevation and position of the worlds highest peak, Mount Everest.

port and starboard

To associate port/starboard, left/right and red/green navigation lights:

'There's no **red port** wine **left**'
(knowing this, you can work out that green, starboard, and right go together)

sailing and depth of water

If sailing in unfamiliar waters, remember:

Brown brown, run aground
White white, you might
Green green, nice and clean
Blue blue, run right through
This allows you to estimate the depth of the water from shallowest to deepest, based on its colour

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navigation, biological

ability of animals or insects to navigate. Although many animals navigate by following established routes or known landmarks, many animals can navigate without such aids; for example, birds can fly several thousand miles back to their nest site, over unknown terrain.

Such feats may be based on compass information derived from the position of the Sun, Moon, or stars, or on the characteristic patterns of Earth's magnetic field.

Biological navigation refers to the ability to navigate both in long-distance migrations and over shorter distances when foraging (for example, the honey bee finding its way from the hive to a nectar site and back). Where reliant on known landmarks, birds may home on features that can be seen from very great distances (such as the cloud caps that often form above isolated mid-ocean islands). Even smells can act as landmarks. Aquatic species like salmon are believed to learn the characteristic taste of the river where they hatch and return to it, often many years later. Brain cells in some birds have been found to contain magnetite and may therefore be sensitive to the Earth's magnetic field.

NDA

abbreviation for nondisclosure agreement.

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nearsightedness

alternative name for myopia.

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nebula

cloud of gas and dust in space. Nebulae are the birthplaces of stars, but some nebulae are produced by gas thrown off from dying stars (see planetary nebula; supernova). Nebulae are classified according to whether they emit, reflect, or absorb light.

An **emission nebula**, such as the Orion nebula, glows brightly because its gas is energized by stars that have formed within it. In a **reflection nebula**, starlight reflects off grains of dust in the nebula, such as surround the stars of the Pleiades cluster. A **dark nebula** is a dense cloud, composed of molecular hydrogen, which partially or completely absorbs light behind it. Examples include the Coalsack nebula in Crux and the Horsehead nebula in Orion.

neck

structure between the head and the trunk in animals. In the back of the neck are the upper seven vertebrae of the spinal column, and there are many powerful muscles that support and move the head. In front, the neck region contains the pharynx and trachea, and behind these the oesophagus. The large arteries (carotid, temporal, maxillary) and veins (jugular) that supply the brain and head are also located in the neck. The larynx (voice box) occupies a position where the trachea connects with the pharynx, and one of its cartilages produces the projection known as Adam's apple. The thyroid gland lies just below the larynx and in front of the upper part of the trachea.

necrosis

death or decay of tissue in a particular part of the body, usually due to bacterial poisoning or loss of local blood supply.

nectar

sugary liquid secreted by some plants from a nectary, a specialized gland usually situated near the base of the flower. Nectar often accumulates in special pouches or spurs, not always in the same location as the nectary. Nectar attracts insects, birds, bats, and other animals to the flower for pollination and is the raw material used by bees in the production of honey.

nectarine

smooth, shiny-skinned variety of peach, usually smaller than other peaches and with firmer flesh. It arose from a natural variation of the original form.

needlefish

any of a group of bony marine fishes with an elongated body and long jaws lined with many sharp teeth. They live in warm, tropical seas. (Family Belonidae.)

negative number

number less than zero. On a number line, any number to the left of zero is negative. Negative numbers are always written with a minus sign in front, for example, -6 is negative, 6 is positive. Scales often display negative numbers. On a temperature scale, 5°C below freezing is -5°C.

Positive and Negative Numbers

Go to site

Introduction to positive and negative numbers. Organized in a series of sections, this site explains the concept of positive and negative numbers before showing how to perform calculations with them.

negative/positive

in photography, a reverse image, which when printed is again reversed, restoring the original scene. It was invented by Fox Talbot in about 1834.

negative and positive

to remember the relationships between positive and negative:

'Minus times minus is plus, the reason for this we need not discuss'
W H Auden, *A Certain World* or Imagine you're in a town in the Wild West. You've got good guys (+) and bad guys (-), and they can either come to town (+) or leave town (-)
If the good guys (+) come to town (+), that's good (+)
If the bad guys (-) come to town (+), that's bad (-)
If the good guys (+) leave town (-), that's bad (-)

But if the bad guys (-) leave town (-), that's good (+) or Positive times negative is negative:
The friends of our enemies are our enemies
Negative times positive is negative:
The enemies of our friends are our enemies
Negative times negative is positive:
The enemies of our enemies are our friends
Positive times positive is positive:
The friends of our friends are our friends

---

nematode

any of a group of unsegmented worms that are pointed at both ends, with a tough, smooth outer skin. They include many free-living species found in soil and water, including the sea, but a large number are parasites, such as the roundworms and pinworms that live in humans, or the eelworms that attack plant roots. They differ from flatworms in that they have two openings to the gut (a mouth and an anus). The group includes *Caenorhabditis elegans* which is a model genetic organism and the first multicellular animal to have its complete genome sequenced. (Phylum Nematoda.)

Most nematode species are found in deep-sea sediment. Around 13,000 species are known, but a 1995 study by the Natural History Museum, London, based on the analysis of sediment from 17 seabed sites worldwide, estimated that nematodes may make up as much as 75% of all species, with there being an estimated 100 million species. Some are anhydrobiotic, which means they can survive becoming dehydrated, entering a state of suspended animation until they are rehydrated.

nematode

The nematode *Placentonema gigantissima* lives as a parasite in the placenta of sperm whales. It can reach 8 m/26 ft in length and 2.5 cm/1 in in diameter.

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neo-Darwinism

modern theory of evolution, built up since the 1930s by integrating the 19th-century English scientist Charles Darwin's theory of evolution through natural selection with the theory of genetic inheritance founded on the work of the Austrian biologist Gregor Mendel.

Neo-Darwinism asserts that evolution takes place because the environment is slowly changing, exerting a selection pressure on the individuals within a population. Those with characteristics that happen to adapt to the new environment are more likely to survive and have offspring and hence pass on these favourable characteristics. Over time the genetic make-up of the population changes and ultimately a new species is formed.

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neodymium

chemical symbol Nd

yellowish metallic element of the lanthanide series, atomic number 60, relative atomic mass 144.24. Its rose-coloured salts are used in colouring glass, and neodymium is used in lasers.

It was named in 1885 by Austrian chemist Carl von Welsbach, who fractionated it away from didymium (originally thought to be an element but actually a mixture of rare-earth metals consisting largely of neodymium, praesodymium, and cerium).

---

neon

chemical symbol Ne

(Greek neos 'new')

colourless, odourless, non-metallic, gaseous element, atomic number 10, relative atomic mass 20.183. It is grouped with the noble gases (rare gases) in Group 0 of the periodic table. Neon is nonreactive, and forms no compounds. It occurs in small quantities in the Earth's atmosphere.

Tubes containing neon are used in electric advertising signs, giving off a fiery red glow; it is also used in lasers. Neon was discovered by Scottish chemist William Ramsay and English chemist Morris Travers.

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neoplasm

(Greek 'new growth')

any lump or tumour, which may be benign or malignant (cancerous).

---

neoprene

synthetic rubber, developed in the USA in 1931 from the polymerization of chloroprene monomers, $CH_2{=}CCl.CH{=}CH_2$. The elastic properties of the polymer are enhanced by vulcanization. It is much more resistant to heat, light, oxidation, and petroleum than is ordinary rubber. It is used for making car tyres.

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neoteny

in biology, the retention of some juvenile characteristics in an animal that seems otherwise mature. An example is provided by the axolotl, a salamander that can reproduce sexually although still in its larval form.

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neper

unit used in telecommunications to express a ratio of powers and currents. It gives the attenuation of amplitudes as the natural logarithm of the ratio.

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nephritis

or Bright's disease

general term used to describe inflammation of the kidney. The degree of illness varies, and it may be acute (often following a recent streptococcal infection), or chronic, requiring a range of treatments from antibiotics to dialysis or transplant.

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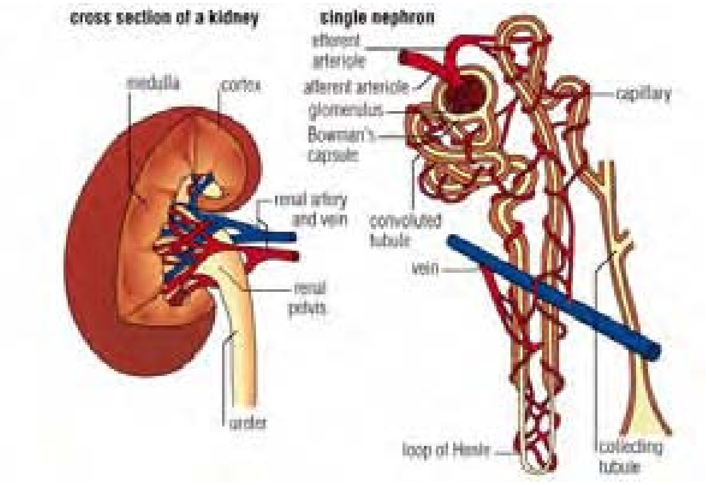
nephron

microscopic unit in vertebrate kidneys that forms **urine**. A human kidney is composed of over a million nephrons. Each nephron consists of a knot of blood capillaries called a glomerulus, contained in the Bowman's capsule, and a long narrow tubule enmeshed with yet more capillaries. Waste materials and water pass from the bloodstream into the tubule, and essential minerals and some water are reabsorbed from the tubule back into the bloodstream. The remaining filtrate (urine) is passed out from the body.

nephron



(Image © Research Machines plc)

The kidney (left) contains more than a million filtering units, or nephrons (right), consisting of the glomerulus, Bowman's capsule, and the loop of Henle. Blood flows through the glomerulus – a tight knot of fine blood vessels from which water and metabolic wastes filter into the tubule. This filtrate flows through the convoluted tubule and loop of Henle where most of the water and useful molecules are reabsorbed into the blood capillaries. The waste materials are passed to the collecting tubule as urine.

Neptune

eighth planet in average distance from the Sun. It is a giant gas (hydrogen, helium, methane) planet, with a mass 17.2 times that of Earth. It has the fastest winds in the Solar System.

mean distance from the Sun

4.4 billion km/2.794 billion mi

equatorial diameter

48,600 km/30,200 mi

rotation period

16 hours 7 minutes

year

164.8 Earth years

atmosphere

methane in its atmosphere absorbs red light and gives the planet a blue colouring. Consists primarily of hydrogen (85%) with helium (13%) and methane (1-2%)

surface

hydrogen, helium, and methane. Its interior is believed to have a central rocky core covered by a layer of ice

satellites

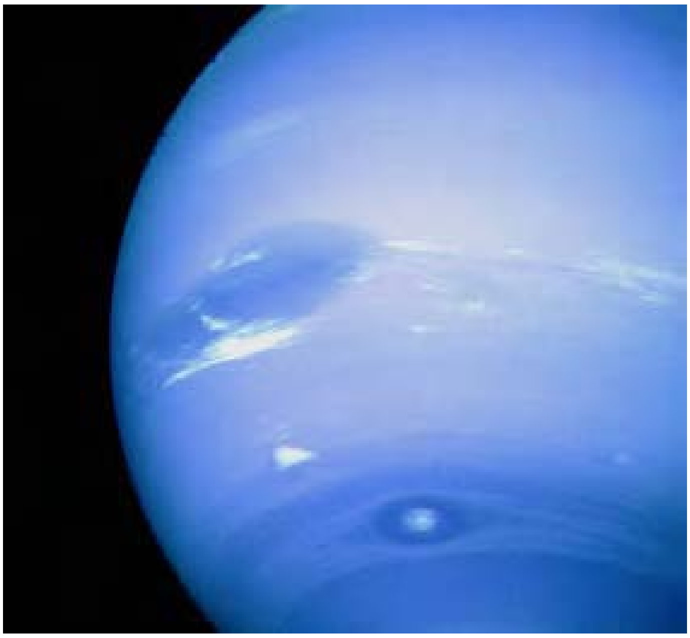
thirteen moons were known by the end of 2005. Of these, seven had been discovered with telescopes on Earth. The other six were discovered by the Voyager 2 probe in 1989. One of these, Proteus (diameter 415 km/260 mi), is larger than Nereid (300 km/200 mi), which had previously been discovered from Earth. Nereid orbits every 360 days on a highly elliptical path. The largest moon, Triton, is one of the four largest moons in the solar system. It orbits every 5.9 days in an east-to-west retrograde direction and is thought to be similar in nature to the planet Pluto

rings

there is a system of faint rings: Galle, Le Verrier, Lassell, Arago, and Adams (in order from Neptune). Galle is the widest at 1,700 km/1,060 mi.

Neptune was located in 1846 by German astronomers Johan Galle and Heinrich d'Arrest after calculations by English astronomer John Couch Adams and French mathematician Urbain Le Verrier had predicted its existence from disturbances in the movement of Uranus. Voyager 2, which passed Neptune in August 1989, revealed various cloud features, notably an Earth-sized oval storm cloud, the Great Dark Spot, similar to the Great Red Spot on Jupiter, but images taken by the Hubble Space Telescope in 1994 showed that the Great Dark Spot had disappeared. A smaller dark spot, DS2, has also gone. Neptune has also increased in brightness with the advance of spring in the planetseverals southern hemisphere. The seasons each last over 40 years on Neptune.

Neptune



(Image © NASA)

Neptune reconstructed from two images taken by the Voyager 2 probe in 1989. The Great Dark Spot is to the centre of the image, and the smaller dark spot DS2 (with its bright core) is to the bottom. Both features had disappeared by 1994. Between the two is the bright cloud feature known as the 'Scooter'.

Neptune: moons

To remember the moons of Neptune:

Neptune's **t**iny **d**ancing **g**irls **l**ook **p**retty **t**o**n**ight

Naiad, **T**halassa, **D**espina, **G**alatea, **L**arissa, **P**roteus, **T**riton, **N**ereid

Neptune's satellites

Satellite	Year of discovery	Diameter		Mean distance from Neptune	
		km	mi	km	mi
Triton	1846	2,700	1,678	355,000	221,000
Nereid	1949	340	211	5,513,000	3,426,000
Despina	1989	180	112	53,000	33,000
Galatea	1989	150	93	62,000	39,000
Larissa	1989	190	118	74,000	46,000
Naiad	1989	50	31	48,000	30,000
Proteus	1989	400	249	118,000	73,000
Thalassa	1989	80	50	50,000	31,000

Neptune

Go to site

Detailed description of the planet Neptune. The site includes a chronology of the exploration of the planet, along with statistics and information on its rings, moons, and satellites, supported by a good selection of images.

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neptunium

chemical symbol Np

silvery, radioactive metallic element of the actinide series, atomic number 93, relative atomic mass 237.048. It occurs in nature in minute amounts in pitchblende and other uranium ores, where it is produced from the decay of neutron-bombarded uranium in these ores. The longest-lived isotope, Np-237, has a half-life of 2.2 million years. The element can be produced by bombardment of U-238 with neutrons and is chemically highly reactive.

It was first synthesized in 1940 by US physicists Edwin McMillan and Philip Abelson (1913-), who named it after the planet Neptune (since it comes after uranium as the planet Neptune comes after Uranus).

Neptunium was the first transuranic element to be synthesized.

Nernst, (Walther) Hermann (1864-1941)

German physical chemist who was awarded the Nobel Prize for Chemistry in 1920 for work on heat changes in chemical reactions. He proposed in 1906 the principle known as the **Nernst heat theorem** or the third law of thermodynamics: chemical changes at the temperature of absolute zero involve no change of entropy (disorder).

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nerve

bundle of nerve cells enclosed in a sheath of connective tissue and transmitting impulses to and from the brain and spinal cord. A single nerve may contain both motor and sensory nerve cells, but they function independently.

brachial plexus nerves

To remember the construction of the brachial plexus nerves in the neck/shoulder region:

Robert **T**aylor **d**rinks **c**old **b**eer

Roots, **t**runks, **d**ivisions, **c**ords, **b**ranches

facial nerve: branches

To remember the branches of the facial nerve:

To **Z**anzibar **B**y **M**otor **C**ar

Temporal nerve, **z**ygomatic nerve, **b**uccal nerve, **m**arginal mandibular nerve, **c**ervical nerve

---

nerve cell

or neuron

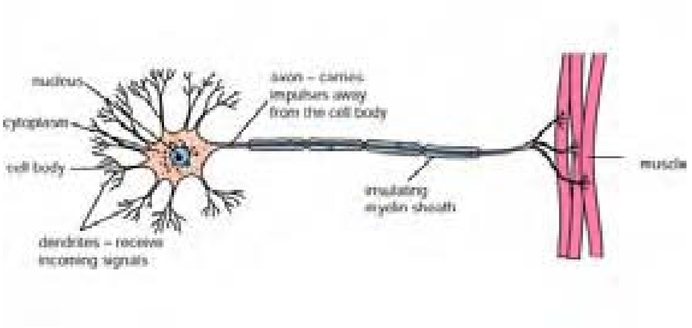
elongated cell that transmits information rapidly between different parts of the body, the basic functional unit of the nervous system. Each nerve cell has a cell body, containing the nucleus, from which trail processes called dendrites, responsible for receiving incoming signals. The unit of information is the nerve impulse, a travelling wave of chemical and electrical changes involving the membrane of the nerve cell. The cell's longest process, the axon, carries impulses away from the cell body. The brain contains many nerve cells.

A reflex arc is a simple example of how nerve cells help to control and coordinate processes in the body. It involves the use of three types of nerve cell. These are the sensory nerve cell, the intermediate (relay) nerve cell and the motor nerve cell. Where each nerve cell connects with the next there is a tiny gap called a synapse. Impulses can cross this gap.

The impulse involves the passage of sodium and potassium ions across the nerve-cell membrane. Sequential changes in the permeability of the membrane to positive sodium (Na^+) ions and potassium (K^+) ions produce electrical signals called action potentials. Impulses are received by the cell body and passed, as a pulse of electric charge, along the axon. The axon terminates at the synapse, a specialized area closely linked to the next cell (which may be another nerve cell or a specialized effector cell such as a muscle). On reaching the synapse, the impulse releases a chemical neurotransmitter, which diffuses across to the neighbouring cell and there stimulates another impulse or the action of the effector cell.

Nerve impulses travel quickly - in humans, they may reach speeds of 160 m/525 ft per second, although many are much slower.

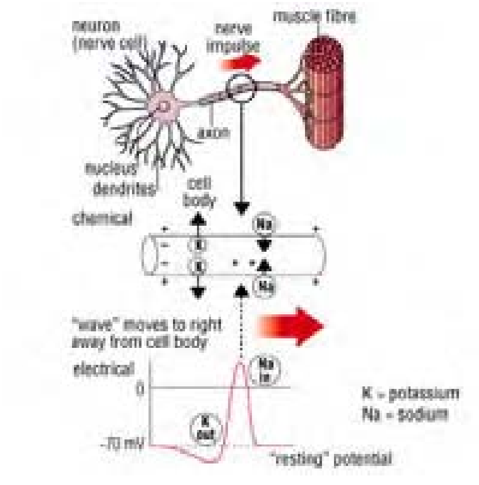
nerve cell


nucleus
cytoplasm
cell body
dendrites – receive incoming signals
axon – carries impulses away from the cell body
insulating myelin sheath
muscle

(Image © Research Machines plc)

The structure of a nerve cell. The nerve impulse enters the nerve cell by the dendrites and is then carried away from the cell body by the axon.

nerve cell


neuron (nerve cell)
nerve impulse
muscle fibre
axon
nucleus
dendrites
cell body
chemical
Na
K
K
Na
"wave" moves to right away from cell body
electrical
0
-70 mV
Na in
K out
"resting" potential
K = potassium
Na = sodium

(Image © Research Machines plc)

The anatomy and action of a nerve cell. The nerve cell or neuron consists of a cell body with the nucleus and projections called dendrites which pick up messages. An extension of the cell, the axon, connects one cell to the dendrites of the next. When a nerve cell is stimulated, waves of sodium (Na^+) and potassium (K^+) ions carry an electrical impulse down the axon.

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nervous breakdown

popular term for a reaction to overwhelming psychological stress. There is no equivalent medical term. People said to be suffering from a nervous breakdown may be suffering from a neurotic illness, such as depression or anxiety, or a psychotic illness, such as schizophrenia.

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nervous system

system of interconnected nerve cells of most invertebrates and all vertebrates. It is composed of the central and autonomic nervous systems. It may be as simple as the nerve net of coelenterates (for example, jellyfishes) or as complex as the mammalian nervous system, with a central nervous system comprising brain and spinal cord and a peripheral nervous system connecting up with sensory organs, muscles, and glands.

In a nervous system, specialized cells called nerve cells or neurones carry messages as nerve impulses quickly from one part of the body to another. These impulses may be carrying information about the outside world (stimuli) which allows the body to respond quickly to them. However, much of the information being carried around is to do with organizing processes inside the body (nervous coordination).

In mammals, some examples of processes regulated by the nervous system are changes in heart rate, changes in ventilation rate (breathing rate), the movement of food along the alimentary canal, and changes in the size of the iris which alter the amount of light entering the eye.

The nervous system includes the brain, the area in which collected information is used to make decisions and from where responses are initiated. Information is collected from all over the body, including from specialized sense organs such as the eye. The rest of the nervous system includes the spinal cord and nerve cells carrying information to and from the brain. For example, responses to stimuli involve nerve impulses which are carried along nerve cells from the brain, through part of the spinal cord, and then to muscles or other cells of the body.

Nervous System

Go to site

Interactive diagram of the nervous system with pop-ups describing the role of the various organs and nerves within the human body.

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nest

place chosen or constructed by a bird or other animal for incubation of eggs, hibernation, and shelter. Nests vary enormously, from saucerlike hollows in the ground, such as the scrapes of hares, to large and elaborate structures, such as the 4-m/13-ft diameter mounds of the megapode birds.

birds' nests

Birds that nest in slight depressions in the ground, such as terns and plovers, lay eggs that so closely resemble the ground that they generally escape detection. A slightly more elaborate nest is the burrow, such as that occupied by the sand martin, kingfisher, or puffin. In many cases these underground nests are made in burrows left by rabbits or voles.

Many birds and some animals make their nests in the hollows of trees; the female of the Bornean rhinoceros hornbill is sealed up by the male for many weeks, until her chicks are almost ready to leave the nest. The mud nests of the swallow family and other birds are built mainly with mud; some of these weigh over 2 kg/4.5 lb. Among the crudest nests that are made with collected material, such as sticks, leaves, blades of grass or hair, are those of the wood pigeon, which are so loosely put together that the eggs are visible through them.

Swallows, martins, sparrows, and flycatchers prefer houses as nesting sites; the thrushes, finches, and linnets use evergreen bushes and hedges. Most species construct nests that are highly distinctive.

other nest-builders

Among the fish, good examples of nest-builders are the three-spined stickleback *Gasterosteus aculeatus* and the Siamese fighting fish *Betta splendens*. The stickleback's nest is anchored to the river bed and constructed of algae and other aquatic plants stuck together by a secretion from the fish's kidneys. The nest of fighting fish is a floating bubble nest anchored to a piece of plant material into which the eggs are placed by the male after courtship.

Among the insects, nest-builders include the social insects, the ants, bees, and wasps, and their nests or hives, and the huge termite nests, up to 3 m/10 ft tall, found in the tropics.

Of the mammals, good examples are those of the harvest mouse *Micromys minutus* and the red squirrel *Sciurus vulgaris*. The harvest mouse nest is a kind of ball made of interlaced leaves of grass that generally belong to the same plants that support it above the ground. The red squirrel's nest is composed of a layer of twigs with a layer of moss or bark fragments. The whole thing is usually placed at the base of a large branch.

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nettle

any of a group of weedy plants with stinging hairs on oval, tooth-edged leaves; the hairs contain nerve poisons that penetrate the skin and cause a rash. The flowers are small and greenish, carried on spikes emerging at the same point where the leaves join the stem. The common nettle (*U. dioica*) grows on waste ground in Europe and North America, where it was introduced. (Genus *Urtica*, family Urticaceae.)

nettle

The hairs on stinging nettle leaves operate like mini hypodermic syringes. When the leaf is touched, the pressure in the hair falls as the fragile tip is broken away and a dose of nerve toxin is released.

Nettles

Go to site

Complete guide to nettles, covering six types of this plant: greater, lesser, white dead, purple dead, and yellow dead. There are detailed descriptions of all these types of nettles, including, where relevant, recipes that include them as an ingredient, notes on their constituents, and also information about medicinal uses.

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nettle rash

popular name for the skin disorder urticaria.

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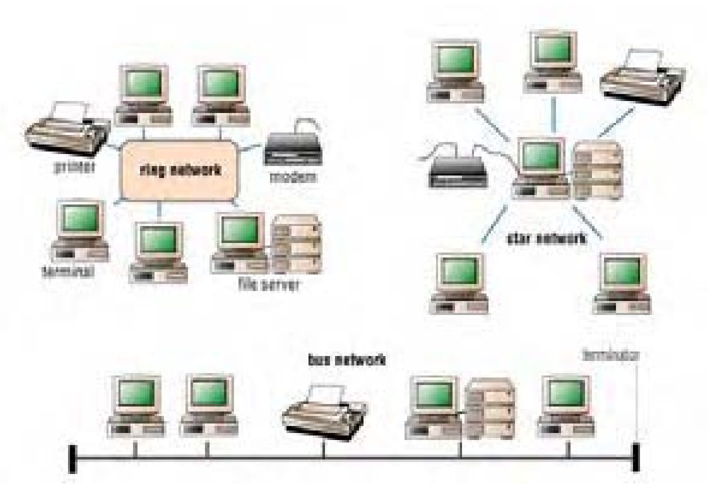
network

in computing, a method of connecting computers so that they can share data and peripheral devices, such as printers. The main types are classified by the pattern of the connections - star or ring network, for example - or by the degree of geographical spread allowed; for example, local area networks (LANs) for communication within a room or building, and wide area networks (WANs) for more remote systems.
The Internet is the linking of computer networks of institutions throughout the world: by 2006, there were about 1 billion users.

JANET (joint academic network) is used in the UK. SuperJANET, launched in 1992, is an extension of this, whose speed was upgraded to 10 gigabits per second (Gbps) in 2002.

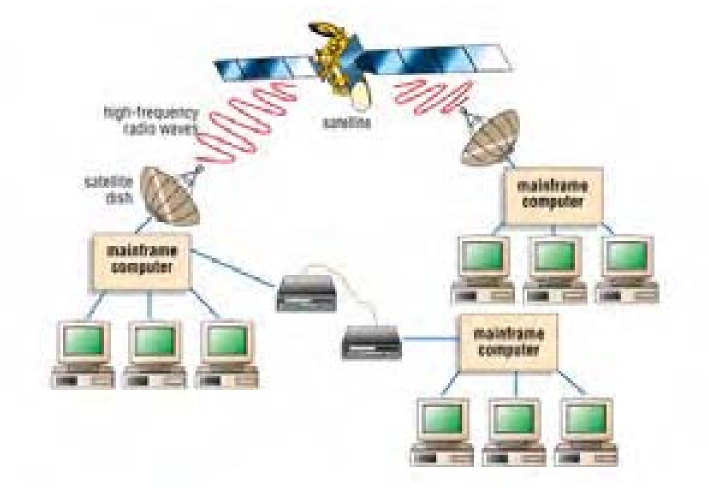
network


printer
ring network
modem
terminal
file server
star network
bus network
terminator

(Image © Research Machines plc)

Local area networks can be connected together in a ring circuit or in a star arrangement. In the ring arrangement, signals from a terminal or peripheral circulate around the ring to reach the terminal or peripheral addressed. In the star arrangement, signals travel via a central controller. In a bus network all elements are connected off a single cable that is terminated at each end.

network


high-frequency radio waves
satellite
satellite dish
mainframe computer
mainframe computer
mainframe computer

(Image © Research Machines plc)

A wide area network is used to connect remote computers via telephone lines or satellite links. The ISDN (Integrated Services Digital Network) telecommunications network allows high-speed transfer of digital data.

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neuralgia

sharp or burning pain originating in a nerve and spreading over its area of distribution. Trigeminal neuralgia, a common form, is a severe pain on one side of the face.

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neural network

in biology, a network of neurons, or nerve cells, in a human being or other animal; in computer technology, a network of processors that attempts to mimic a biological neural network.

A basic network has three layers of processors: an input layer, an output layer, and a 'hidden' layer in between. Each processor is connected to others in the network by a system of 'synapses'; each processor in the top layer connects to every one in the hidden layer, and each of these connects to every processor in the output layer. This means that each nerve cell in the middle and bottom layers receives input from several different sources; only when the amount of input exceeds a critical level does the cell fire an output signal. The chief characteristic of neural networks is their ability to sum up large amounts of imprecise data and decide whether they match a pattern or not. They can 'learn' to perform such tasks without needing to be explicitly programmed to do so. Networks of this type may be used in developing robot vision, matching fingerprints, and analysing fluctuations in stock-market prices.

Neural Networks

introduction

Neural networks - strictly artificial neural networks - represent a radically different approach to computing. They are called neural networks because they are loosely modelled on the networks of neurons - nerve cells - that make up brains. Neural networks are characterized by their ability to learn, and can be described as trainable pattern recognizers. The study and use of neural networks is sometimes called neurocomputing.

differences between brains and computers

Brains perform remarkable computational feats: recognizing music from just a few seconds of a recording, or faces seen only once before - accomplishments that defeat even the most modern computers. Yet brains stumble with arithmetic and make errors with simple logic. The reason for these anomalies might be found in the differences between brain and computer architecture - their internal structure and operating mechanisms. Conventional computers possess distinct processing and memory units, controlled by programs, but animal nervous systems and neural networks are instead made up of highly interconnected webs of simple processing units. They have no specific memory locations, information instead being stored as patterns of interconnections between the processing units. Neural networks are not programmed, but are trained by example. They can, therefore, learn things that cannot easily be stated in programs, making them invaluable in a wide range of applications.

early developments in neurocomputing

Although neurocomputing might seem a recent development, research started at around the same time as the early work on computers. In the 1940s scientists devised simple electrical networks, crudely modelled neural circuits, which could perform simple logical computations.

perceptrons

More sophisticated networks, called perceptrons, followed in the 1950s - the ancestors of modern neural networks. Perceptrons were just simple networks of amplifiers, but they could learn to recognize patterns. This generated tremendous excitement; however, significant limits to their abilities were soon discovered. Marvin Minsky and Seymour Papert of the Massachusetts Institute of Technology, USA, proved that certain problems could never be solved by perceptrons. When they published their results, research into neural networks effectively ceased for over a decade. At the end of the mid 1970s, however, theoretical breakthroughs made it possible for more complex neural networks to be developed, and by the mid 1980s they had become sufficiently sophisticated for general applications.

why neural networks?

Neural networks are of interest to computer technologists because they have the potential to offer solutions to a range of problems that have proved difficult to solve using conventional computing approaches. These problems include pattern recognition, machine learning, time-series forecasting, machine vision, and robot control. Underpinning all this is their ability to learn. In a famous example, a neural network was trained to recognize speech - with eerily realistic results. The network, called NET-talk, was developed by T J Sejnowski and C R Rosenberg at Johns Hopkins University in the USA. It was linked to a computer that could produce synthetic speech, so its progress could be heard. After producing formless noise for a few hours, it started babbling like a baby. Overnight training improved its performance so that it could read text with a 95% accuracy. No conventionally programmed computer could do this.

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neurasthenia

obsolete term for nervous exhaustion, covering mild depression and various symptoms of neurosis. Formerly thought to be a bodily malfunction, it is now generally considered to be mental in origin. Dating from the mid-19th century, the term became widely used to describe the symptoms of soldiers returning from the front in World War I.

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neuritis

peripheral nerve inflammation caused by injury, poisoning, or disease, and accompanied by sensory and motor changes in the area of the affected nerve.

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neurology

medical speciality concerned with the study and treatment of disorders of the brain, spinal cord, and peripheral nerves.

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neuron

another name for a nerve cell.

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neurosis

in psychology, a general term referring to emotional disorders, such as anxiety, depression, and phobias. The main disturbance tends to be one of mood; contact with reality is relatively unaffected, in contrast to psychosis.

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neurotoxin

any substance that destroys nerve tissue.

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neurotransmitter

chemical that diffuses across a synapse, and thus transmits impulses between nerve cells or between nerve cells and effector organs (for example, muscles). Common neurotransmitters are the amino acids glutamate and GABA (gamma-amino butyric acid), as well as noradrenaline (which also acts as a hormone) and acetylcholine, the latter being most frequent at junctions between nerve and muscle. Nearly 50 different neurotransmitters have been identified.

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neutralization

in chemistry, a process occurring when the excess acid (or excess base) in a substance is reacted with added base (or added acid) so that the resulting substance is neither acidic nor basic.

In theory neutralization involves adding acid or base as required to achieve pH 7. When the colour of an indicator is used to test for neutralization, the final pH may differ from pH 7 depending upon the indicator used. It will also differ from pH 7 in reactions between strong acids and weak bases and weak acids and strong bases, because the salt formed will have acidic or basic properties respectively.

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neutral oxide

oxide that has neither acidic nor basic properties (see oxide). Neutral oxides are only formed by non-metals. Examples are carbon monoxide, water, and nitrogen(I) oxide.

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neutrino

in physics, any of three uncharged elementary particles (and their antiparticles) of the lepton class, having a mass that is very small. The most familiar type, the antiparticle of the electron neutrino, is emitted in the beta decay of a nucleus. The other two are the muon and tau neutrinos.

Neutrino: Discovery

discovering the neutrino

Most fundamental particles are discovered experimentally. Some are predicted by theory, but are often not taken seriously until detected. The neutrino is an exception. Postulated in 1930, its existence was taken as an act of faith for 25 years.

There were good reasons for predicting the neutrino's existence. Unexplained energy losses in certain radioactive decays (called beta decay) suggested the laws of conservation of energy and angular momentum were invalid at subatomic level. The great Danish theoretical physicist Niels Bohr maintained these laws held only on average, not for each individual process. Austrian physicist Wolfgang Pauli explained it more simply: in beta decay, there was a previously undiscovered neutral particle carrying away the missing energy and momentum. He called it a 'neutron'. Italian physicist Enrico Fermi introduced the alternative term 'neutrino': Italian for 'little neutral one'. He constructed a successful theory of beta decay based on the neutrino's existence.

Reines and Cowan's explosive suggestion

Experimental observation of neutrinos proved difficult. They pass easily through solid material, penetrating lead 965 million million km/600 million million mi thick without being absorbed. This makes them extremely hard to detect. In the 1950s, US physicists Frederick Reines and Clyde Cowan put forward a far-fetched scheme using a nuclear weapon as neutrino source. Cowan described the proposed scheme several years later:

'We would dig a shaft near the centre of the explosion about 10 ft in diameter and about 150 ft deep. We would put a tank, 10 ft in diameter and 75 ft long on end at the bottom of the shaft. We would then suspend a detector from the top of the tank, along with its recording apparatus, and back-fill the shaft about the tank.'

'As the time for the explosion approached, we would start vacuum pumps and evacuate the tank as highly as possible. Then, when the countdown reached zero, we would break the suspension with a small explosive, allowing the detector to fall freely in the vacuum. For about two seconds, the falling detector would be seeing neutrinos and recording the pulses from them while the earth shock from the blast passed harmlessly by, rattling the tank mightily but not disturbing our falling detector. When all was relatively quiet, the detector would reach the bottom of the tank, landing on a thick pile of foam rubber and feathers.'

'We would return to the site of the shaft in a few days (when surface radioactivity had died away sufficiently), dig down to the tank, recover the detector and discover the truth about neutrinos.'

the crucial experiment

Before the spectacular experiment could be set up, Reines and Cowan realized that, with suitable modifications, they could utilize the much smaller neutrino flux from a nuclear reactor. They set up their experiment next to the Savannah River nuclear plant's reactor. The detector comprised a tank containing cadmium chloride dissolved in water. A neutrino passing through the tank reacts with protons in the water, producing a positron and a neutron. The positron combines with electrons, producing gamma rays. The neutron also produces gamma rays by reacting with the cadmium. When a gamma ray falls on a scintillation detector it produces a flash of light, detected using a photomultiplier and showing that a neutrino has passed through the tank.

At first, there were about 1.63 'events' (or signals) per hour with the reactor operating and 0.4 with it shut down. Subsequent experiments with various adjustments raised the rate to nearly three events per hour. The next task was to confirm that these signals were produced by neutrinos. This involved eliminating all other possible sources: principally neutrons, gamma rays, electrons, and protons from the reactor.

The water was in two plastic tanks, holding 200 l/40 gal, between large scintillation counters, and surrounded by 110 photomultipliers, with lead walls and floor 10 cm/4 in thick, and roof and doors 20 cm/8 in thick to eliminate radiation from the reactor. To prove the lead's effectiveness, tests were done with additional shields. One experiment involved packing wet sawdust in bags round the detectors to reduce spurious neutron flow. There was no appreciable change in signal, and so it was concluded that it was not due to radiation produced outside the detectors. The neutrino had indeed been detected.

modern neutrino detection

Nowadays, neutrinos from space are routinely detected by underground 'telescopes' similar to the Reines and Cowan set-up. Some modern neutrino telescopes comprise large tanks of ultrapure water, weighing up to 3000 tonnes. The tank, in a mine, has walls lined with photoelectric detectors. An alternative type of telescope uses dry-cleaning fluid (carbon tetrachloride); when it captures a neutrino, it produces radioactive argon whose presence may be detected by analysis of the liquid. There are large-scale neutrino detectors in Japan, Russia, Italy, and the USA. In Feb 1987, when a supernova exploded in the Large Magellanic Cloud, these instruments detected neutrinos from the explosion 170,000 light-years away.

Physics: Neutrinos and Optical Molasses

the missing neutrinos, and optical molasses

Progress in physics can be expected or unexpected. Particle physicists fully expect to detect the top quark, with one of their existing accelerators. Yet the discovery of superconductivity in thin films of potassium-doped carbon-60 molecules was completely unexpected. Sometimes physicists can only hope for progress: high-temperature superconductivity was discovered over five years ago, but physicists still cannot explain it theoretically.

solar neutrinos

The scarcity of solar neutrinos is a mystery. Neutrinos are particles without electric charge or mass, produced in processes such as radioactive beta decay. There are three types - electron, muon and tau. The Sun produces energy by combining four hydrogen nuclei into a helium nucleus - the process of thermonuclear fusion. It converts 600 tonnes of hydrogen every second in a web of reactions, several producing neutrinos. According to calculations, 65 billion solar electron neutrinos should penetrate every square centimetre of the Earth's surface every second. Detection of these neutrinos would confirm physicists' theories about the Sun. Neutrinos can travel unaffected through large objects, and are extremely difficult to detect.

The first experiment to detect solar neutrinos was set up in the Homestake Gold Mine in South Dakota, USA, in the 1960s. Despite running for 20 years, it only detected about a quarter of the predicted quantity; a second experiment in Japan detected less than half. Both experiments were sensitive to less than 10% of solar neutrinos. Neither could detect the neutrinos produced by protons fusing into heavy hydrogen (deuterium) at the start of the solar thermonuclear process. Physicists had hopes for two experiments (Gallex in Italy and SAGE in Russia) using detectors containing gallium, sensitive to most of these neutrinos. Both have now reported their first results: higher than the previous experiments, but not as high as predicted by theory.

Both experiments will be improved in the next few years; more sophisticated detectors are planned for 1996. If the shortage of neutrinos persists, perhaps neutrinos have mass after all, allowing electron neutrinos to change into muon or tau neutrinos on passing through the Sun. Proof of neutrino mass would be a significant development for particle physics, but the latest 'evidence' - reports of a neutrino with a mass of 17 kilo-electron-volts, found in beta decay - were due to experimental error.

laser cooling

When an atom absorbs a photon of light its velocity increases. This increase occurs in the direction of the light. The atom loses this velocity again when it emits a photon. Since this loss can occur in any direction, on average an atom travelling in the opposite direction to a laser beam will lose speed. With two opposed lasers, the atoms can be confined in a plane at right angles to the beams. With three pairs of lasers at right angles, some atoms will be trapped where all six beams overlap. Because temperature is related to velocity the atoms - now almost stationary - are 'cooled'. By making the laser wavelength slightly longer than the atom's normal absorption and emission wavelength, physicists can use the Doppler effect to make the atoms even cooler, in devices called 'optical molasses'.

Optical molasses have been used to cool sodium atoms to a few millionths of a degree above absolute zero. They are one of a variety of devices being used to trap and cool atoms and ions, to test the fundamentals of quantum mechanics and provide new standards for time and frequency. The power to manipulate and control atoms and large particles heralds new devices with colourful names like atomic fountains and trampolines, and optical tweezers. The latter can be used to study important biological molecules like DNA. There seems almost no limit to the temperatures and accuracy possible.

multilayer structures

Molecular beam epitaxy (MBE) allows scientists to grow layers only a few atoms thick, producing materials with completely new electronic, optical, and magnetic properties. The first semiconductor lasers to work at blue-green wavelengths were made with MBE, by growing layers of zinc selenide less than 10 nanometres (thousand millionths of a metre) thick, interspersed with layers containing cadmium or sulphur.

Most forms of information storage (audio and video tapes, computer disks) rely on thin magnetic films. Many recording and playback heads incorporate magnetoresistance (MR) sensors. MR is a property of most metals: their electrical resistance changes slightly in a magnetic field. In 1988 French researchers discovered that the resistance of MBE-grown thin films of alternate iron and chromium was halved in a magnetic field. They called them magnetic superlattices, and the effect 'giant magnetoresistance' (GMR). GMR could lead to the next generation of magnetic recording techniques. Higher values have been recorded in cobalt-copper superlattices grown by sputtering. The next challenge is to achieve GMR in much lower magnetic fields.

top quark

US physicists may have detected the elusive top quark at the Fermilab particle physics centre near Chicago. The particle, generated by the Tevatron particle collider on 29 Oct 1992, is only the second candidate for the sixth quark. Confirmation of the result is awaited.

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neutron

one of the three main subatomic particles, the others being the proton and the electron. Neutrons have about the same mass as protons but no electric charge, and occur in the nuclei of all atoms except hydrogen. They contribute to the mass of atoms but do not affect their chemistry.

For instance, the isotopes of a single element differ only in the number of neutrons in their nuclei but have identical chemical properties. Neutrons and protons have masses approximately 2,000 times those of electrons.

The neutron is a composite particle, being made up of three quarks, and therefore belongs to the baryon group of the hadrons. Outside a nucleus, a free neutron is unstable, decaying with a half-life of 11.6 minutes into a proton, an electron, and an antineutrino. The process by which a neutron changes into a proton is called beta decay.

The neutron was discovered by the British chemist James Chadwick in 1932.

Neutron: Lifespan

the short life of a neutron

In 1992 physicists finally agreed a value for the lifetime of the neutron. The neutron is one of the particles found in the atomic nucleus. Like most other subatomic particles, it spontaneously disintegrates, or decays, when outside the nucleus. The neutron lifetime is a measure of how long it takes for half of any sample of neutrons to decay.

Until recently, estimates of the average lifetime of the neutron varied widely. In the early 1960s, most physicists thought the neutron lifetime lay between 980 and 1040 seconds. Then a set of more accurate experiments indicated a value between 910 and 950 seconds. In the 1970s, expert opinion favoured the range between 900 and 950 seconds. In the 1980s, 870 to 910 seconds seemed to be indicated. Finally, in the early 1990s, data from several different sources converged on the now-accepted value of 889 seconds: 14 minutes 49 seconds.

does it matter how long a neutron lives?

Physicists are interested in having an exact value for the neutron lifetime because there is a relationship between the neutron lifetime and the lifetimes of other subatomic particles. If the decay rate of the neutron is known accurately the decay rate of other particles, such as the muon, can be calculated.

The neutron decays by a process called 'beta decay'. The neutron ejects an electron and an antineutrino when it decays, and turns into a proton (hydrogen nucleus). This process is responsible for some of the nuclear reactions that take place inside stars and the Sun. So astronomers need to understand neutron decay if they are to calculate the structure and energy output of the Sun and stars.

using the Big Bang theory

During the 1980s, cosmologists pointed out that our knowledge of the Big Bang - the explosion at the beginning of time - could be used to calculate the neutron lifetime. According to the Big Bang theory, when the universe was about a second old, it was a seething mass of protons and neutrons. The temperature was initially very high - over 10 billion degrees. At this temperature, neutrons constantly change into protons, and vice versa. The rapid interchange of protons and neutrons produced an approximate balance between the particles.

But as the universe expanded, and the temperature dropped, there was no longer enough energy to change protons into neutrons, and the proportion of neutrons dropped. When the universe was about 200 seconds old, the temperature had dropped to about 1 billion degrees. At this temperature, when neutrons and protons collide they combine to form nuclei, first of deuterium and then of helium-4. Once locked inside the nuclei, neutrons are stable, and have survived to the present day.

So the Big Bang theory tells us that there was a period of less than 200 seconds during which neutrons were decaying without being replaced. If neutrons had a very short lifetime, they would have all decayed during this period, and there would be no helium today. If neutrons had a very long lifetime, they would all have survived to become helium and there would be no hydrogen today. But today's universe contains about 75% hydrogen and 25% helium. This observation has been used to calculate the lifetime of the neutron. The resulting figure - 890 seconds - was lower than many physicists thought likely even in the late 1980s.

measuring the lifetime in the lab

Laboratory measurements of the neutron lifetime were successful in 1989. A team headed by Jim Byrne and Peter Dawber of Sussex University, England, monitored the decay of neutrons in a beam. They counted the number of protons produced by neutron decay at various points along the beam. To do this, the researchers had to collect the protons at various points using a device called a Penning trap. This device is a series of electrodes sitting in the neutron beam. As protons are produced by neutron decay, they are trapped by the electric and magnetic fields between the electrodes.

A typical neutron beam with 200 million neutrons passing along each square centimetre of the beam in a second will produce one proton every second. In Byrne's experiment, where 4000 million neutrons passed along the beam each second, there were just 10 decay protons produced each second. Byrne and Dawber's result was 893±15 seconds.

Another experiment undertaken at around the same time involved watching a collection of neutrons confined in magnetic storage rings or 'bottles'. Researchers measured the number of neutrons that survived during a given period, rather than the number that decayed. This experiment provided a valuable confirmation of Byrne and Dawber's result and allowed the neutron lifetime to be calculated even more precisely. The story ends, then, with evidence from several different sources all pointing to the same result.

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neutron beam machine

nuclear reactor or accelerator producing a stream of neutrons, which can 'see' through metals. It is used in industry to check molecular changes in metal under stress.

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neutron bomb

or enhanced radiation weapon

small hydrogen bomb for battlefield use that kills by radiation, with minimal damage to buildings and other structures.

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neutron star

very small, 'superdense' star composed mostly of neutrons. They are thought to form when massive stars explode as supernovae, during which the protons and electrons of the star's atoms merge, owing to intense gravitational collapse, to make neutrons. A neutron star has a mass two to three times that of the Sun, compressed into a globe only 20 km/12 mi in diameter.

If its mass is any greater, its gravity will be so strong that it will shrink even further to become a black hole. Being so small, neutron stars can spin very quickly. The rapidly flashing radio stars called pulsars are neutron stars. The flashing is caused by a rotating beam of radio energy similar in behaviour to a lighthouse beam.

neutron star

Neutron stars are so condensed that a fragment the size of a sugar cube would weigh as much as all the people on Earth put together.

Newfoundland

breed of large, gentle dog said to have originated in Newfoundland, Canada. Males can grow to 70 cm/27.5 in tall, and weigh 65 kg/145 lb; the females are slightly smaller. They have a dense, flat coat, usually dull black, and an oily, water-repellent undercoat, and they are excellent swimmers.

Newfoundlands that are black and white or brown and white are called **Landseers**.

New Madrid seismic fault zone

the largest system of geological faults in the eastern USA, centred on New Madrid, Missouri. There are several hundred earthquakes along the fault every year, more than anywhere else in the USA east of the Rocky mountains; but most of them are too small to be felt. A series of very severe earthquakes in 1811-12 created a lake 22 km/14 mi long and was felt as far away as Washington, DC, and Canada. Strong earthquakes would cause much damage because the solid continental rocks would transmit the vibrations over a wide area, and buildings in the region have not been designed with earthquakes in mind.

New Photography

German photographic movement of the 1930s, led by Albert Renger-Patzsch, that aimed to depict modern life in a direct and objective manner. In its anti-Pictorialism and emphasis on clarity, it paralleled the 'f/64' group in the USA.

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newt

small salamander found in Europe, Asia, northwestern Africa, and North America. (Family Salamandridae, order Urodela.)

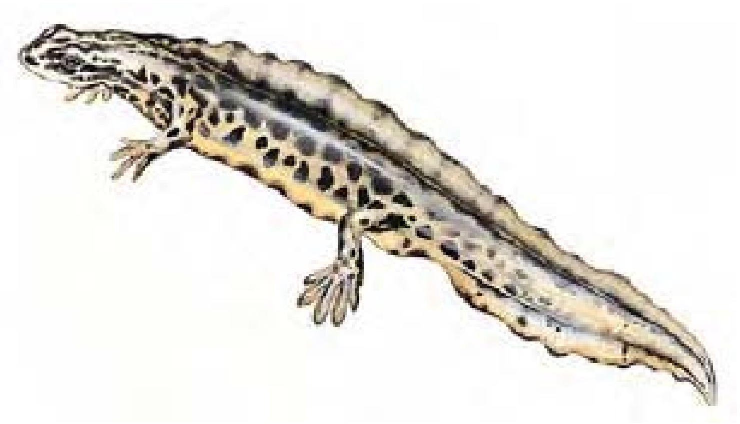
newt: limb loss

If a young newt loses one of its limbs it can grow another. Unfortunately, the ability to do this declines with age.

newt: skin

A newt may eat its own skin. As it grows, the newt has to shed its skin regularly; this is either discarded or eaten.

newt



(Image © Research Machines plc)

The crested newt, shown here, develops a crest of skin along the back in the spring mating season. All male newts are brightly coloured at this time. The European newts, such as the smooth newt, live on land for part of the year but enter a pond or lake to breed in the spring.

Tappaboy Newt Page

Go to site

Everything one could wish to know about these small salamanders can be found here. Contents include still and video footage of newts, newt art, the chance to chat with other newt addicts, practical tips on looking after them, and links to other newt sites.

New Technology Telescope

optical telescope that forms part of the European Southern Observatory, La Silla, Chile; it came into operation in 1990. It has a thin, lightweight mirror, 3.38 m/11.75 ft across, which is kept in shape by computer-adjustable supports to produce a sharper image than is possible with conventional mirrors. Such a system is termed **active optics**.

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newton

symbol N

SI unit of force. A newton is defined as the amount of force needed to move an object of 1 kg so that it accelerates at 1 metre per second per second. It is also used as a unit of weight. The weight of a medium size (100 g/3 oz) apple is one newton.

Newton, Isaac (1642-1727)

English physicist and mathematician who laid the foundations of physics as a modern discipline. During 1665-66, he discovered the binomial theorem, differential and integral calculus, and that white light is composed of many colours. He developed the three standard laws of motion (Newton's laws of motion) and the universal law of gravitation, set out in *Philosophiae naturalis principia mathematica* (1687), usually referred to as the *Principia*. He was knighted for his work in 1705.

Newton's greatest achievement was to demonstrate that scientific principles are of universal application. Using these principles, scientists could predict the results of their experiments when carried out in controlled conditions, enabling the more rapid development of new ideas. He clearly defined the nature of mass, weight, force, inertia, and acceleration.

In 1679 Newton calculated the Moon's motion on the basis of his theory of gravity and also found that his theory explained how the planets, including the Earth, orbited the Sun. The laws of planetary motion had been worked out by German astronomer Johannes Kepler on the basis of observations of the planets; Newton provided the scientific evidence to back up Kepler's theory.

Newton, Isaac

Among the lesser achievements of Isaac Newton were his career as a member of Parliament for Cambridge University – in which capacity his only recorded words were a request for a window to be opened – and his invention of the cat-flap (for a pet cat he kept at Woolsthorpe House).

Understanding the Universe: from Atoms to M Theory

introduction

At the end of the last millennium science as we know it did not exist. Today our lives have been transformed by its dazzling successes. Scarcely a single human activity does not depend in one way or another on its products. The scientific method seems like a golden path to truth, capable not only of explaining how the world works but, as a bonus, spawning countless technological marvels. Where will it all end? Is science a completable project, or will nature always present mysteries to baffle us?

understanding everything

The idea that humans could come to understand the world through rational reasoning began with the ancient Greek philosophers, two and a half millennia ago. They developed logic and mathematics, and pondered the great questions of existence, such as the nature of mind and matter, the organization of the heavens, and whether time had a beginning. True science, however, had to await the likes of Galileo Galilei and Isaac Newton in the 17th century. These early physicists believed that beneath the stunning richness and complexity of the natural world lay a simple and elegant unity, in the form of a set of universal laws that could be encapsulated in mathematical equations. By conducting experiments and observations, they supposed, scientists might tease out the rules on which the cosmos runs, and thus unveil deep principles that link all physical things.

a theory of everything?

Three hundred years on, as we move into the 21st century, the dream that science has the power to unify all knowledge remains a tantalizing lure. Some theoretical physicists think they can glimpse a system of mathematical equations that will finally expose the bedrock of physical reality. This ultimate 'theory of everything' promises to explain how the entire universe is put together. If it succeeds, it will represent the culmination of the so-called reductionist programme begun by the Greeks. Reductionism is the belief that the whole is nothing but the sum of its parts. For example, in the 5th century BC the philosopher Democritus conjectured that although the world might look complicated, all material things are actually composed of the same simple building blocks, or atoms. The universe, claimed the Greek atomists, consists of nothing but atoms moving in a void, so that all physical change is merely the rearrangement of atoms. It followed that if one could identify and catalogue the different species of atoms, and determine how they interact, then in a sense all of nature would be explained in one grand sweep. What we call atoms today are not, however, the fundamental, indestructible, elementary particles that the Greeks had in mind. They are composite bodies with components inside them. Still, the central notion remains valid. If we break atoms apart, and probe inside their constituents, we might eventually find truly primitive, indecomposable entities that go to make up everything in the cosmos.

particles

Belief that such a bottom level of structure exists has spurred a vast and expensive research programme called high-energy particle physics. This subject began with the discovery in the 1930s that the atomic nucleus contains protons and neutrons. In the decades that followed, many other particles were found too, most of them very unstable and short-lived. Today, scores of subatomic fragments have been created and studied in the laboratory using giant atom smashers. These gargantuan devices accelerate electrons and protons to enormous energies and then collide them. The debris from these violent encounters contains all manner of particles that exist only fleetingly. The jewel in the crown of this endeavour is the giant particle accelerator called the Large Electron Positron Collider (LEP) at the CERN Laboratory in Switzerland. A ring-shaped tube in a tunnel 3.8 m/12.5 ft wide and 27 km/16.7 mi long, it can be used to accelerate counter-rotating beams of electrons and their antimatter partners, positrons, to very near the speed of light, at which point they are brought into head-on collision. LEP will soon be converted to the Large Hadron Collider, which will whirl protons and antiprotons at each other, achieving collision energies millions of times those of familiar nuclear reactions. From accelerator experiments and the study of naturally occurring high-speed particles called cosmic rays, theorists have pieced together a detailed scheme of what structures lie buried in the deepest recesses of matter. So far, the smallest entities identified are the oddly named quarks, which cluster in triplets to make up nuclear particles such as protons. Together with electrons and neutrinos, which are collectively described as leptons, the total menagerie of apparently elementary particles runs to 12. Physicists suspect, however, that they have as yet glimpsed only a fraction of the full complement of fundamental entities. One reason concerns the existence of so-called dark matter in the universe. Astronomers are convinced that stars make up only a small percentage of the total mass of the cosmos. Our Milky Way galaxy, for example, spins far too fast to hold itself together if the stars and luminous gas clouds were the only material exerting a gravitational pull. Some unseen matter must exist to augment the gravity of the shining objects. The nature of this invisible stuff remains contentious. Theories vary from small black holes to unknown subatomic particles created in the Big Bang and left inhabiting the spaces between the stars. Experiments are in progress to track down these mystery particles. If they exist, they will have to be incorporated into any unified theory of physics, along with the quarks and leptons.

forces

Even if physicists finally identify all the basic particles of matter, both familiar and unfamiliar, the story does not end there. The universe would be dull indeed if particles simply sped through space ignoring each other. The rich diversity of material forms and physical phenomena depends upon the way these particles interact with each other through forces. At the time of Newton, three basic forces of nature were recognized: gravitation, electricity, and magnetism. In the 19th century, following the experiments of Michael Faraday and others, James Clerk Maxwell showed that electricity and magnetism were not, in fact, two separate forces, but deeply linked. He was able to demonstrate mathematically that they are actually two facets of a single electromagnetic force. Further understanding came in the 20th century. In the 1920s it became apparent that the atomic nucleus is also subject to two more forces, dubbed weak and strong. Physicists therefore decided that there are four fundamental forces of nature: gravitation, electromagnetism, and the two nuclear forces. However, in 1967 Abdus Salam and Steven Weinberg proposed that there is a subtle connection between the electromagnetic and weak nuclear forces. They predicted that at very high energies these two normally distinct forces would merge in identity to form a single electroweak force. Some years later their theory was confirmed by collider experiments at CERN. Following this triumph, theoretical physicists began to suspect that, at even higher energies, maybe the electroweak force would merge with the strong nuclear force, and perhaps even gravitation too. In other words, at the very highest energies, perhaps there is just one superforce. Cosmologists were quick to point out that, since the universe began with an ultra-high-energy Big Bang, for a brief instant the superforce would have reigned supreme. Then, as the universe expanded and cooled, so the four familiar forces of nature would have frozen out one by one. Our understanding of the unification of the forces of nature is incomplete. Although there is some evidence hinting at a connection between the strong force and the electroweak force, decisive experimental confirmation is still lacking, while gravitation remains something of a mystery. However, this has not prevented theorists from devising many imaginative mathematical models that seek to amalgamate all the forces and particles into a single scheme. In this quest they are guided by the fact that the forces of nature are transmitted between particles of matter by yet more particles, often called messengers, but technically known as bosons. Thus the familiar electrostatic force can be envisaged as acting across the space between two charged particles by virtue of the exchange of particles called photons, associated with light. Similarly, gravitation is transmitted by the exchange of gravitons. Taking into account all four forces, the total number of these messenger bosons plus particles of matter amounts to some dozens. The hope is that this small army of subatomic denizens can be grouped into families and combined into a unified mathematical system. If such a scheme exists, it will join quarks, leptons, and bosons into a common theme, thus unifying not only matter, but matter and force too.

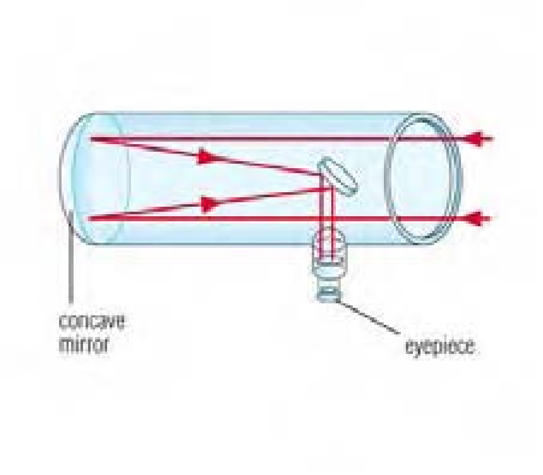
superstrings

It was always Albert Einstein's dream that he would be able to formulate some sort of unified field theory to achieve an amalgamation of all the forces and particles of nature. However, in spite of decades of work, he never came near to achieving his goal. One reason for this is because, until recently, all attempts at unification have been based on the assumption that the ultimate building blocks of matter are tiny particles. Now this assumption is being challenged by a bizarre set of ideas known as superstring theory. It takes as its starting point the notion that the smallest physical entities are not particles at all, but tiny loops of string, 20 powers of 10 smaller than an atomic nucleus. As the strings vibrate in different ways, so they present themselves to our instruments as different particles. Quarks, leptons, bosons – all are just alternative activities of the same basic stringy entities. String theory has been described by Ed Witten of Princeton University, one of its leading proponents, as a 21st century theory that has dropped by accident into the late 20th century. So abstract and weird are the properties of superstrings that the theorists are having to invent the mathematics to describe them as they go. One example of mathematical subtlety concerns the dimensions of space. In daily life we observe three space dimensions and one time dimension, making four dimensions of space-time in total. However, as long ago as the 1920s some theoretical physicists suggested that space might have additional unseen dimensions. To understand what this means, consider viewing a hosepipe from afar. It looks like a wiggly line, that is one-dimensional. On closer inspection, however, it is revealed to be a narrow tube. What one may have taken to be a point on a line turns out to be a tiny circle going around the tube. In the same way, perhaps what we normally take to be a point in three-dimensional space is actually a tiny circle going around a fourth space dimension. Physicists find that when extra space dimensions are added to their theoretical models, marvellous mathematical simplifications occur, and otherwise hidden connections appear between different forces. In one popular version of string theory, space has nine dimensions, six of them being 'rolled up' (like the hosepipe) to a diameter of only about a billion-trillion-trillionth of a centimetre, which is why even our most powerful instruments cannot directly detect these extra dimensions. If string theory is on the right track, then at the most fundamental level of structure, the physical universe would consist of nothing but string and space. The superstrings themselves are supposed to be absolutely elementary and primitive: they cannot be pulled apart to reveal interior parts. In that respect at least, they resemble the atoms of ancient Greece. But in terms of abstractness and mathematical elegance, we have come a long way since the first philosophical musings of Democritus. At the time of writing, many technical obstacles obscure a full understanding of superstring theory, and there is much bewilderment that not only one but several contending string theories exist. Recently there has been a significant advance, with the development of something called M theory, where M stands for Mother, or Master or Membrane. This theory treats the basic entities not as strings, but two-dimensional sheets or membranes moving in an 11-dimensional spacetime. There are suggestions that all the various string theories are in fact contained in the abstract mathematics of M theory.

conclusion

Nobody knows whether these arcane investigations will finally realize the ancients' dream of yielding a fully unified description of reality, or whether they will peter out in intractable mathematical complexities. But even if M theory, or some yet more exotic variant, does succeed in giving us the master formula for the cosmos, it will not be the end of science. Reductionism is, after all, only half the story. A complete description of nature at the ultra-microscopic level will not explain sunspots or snowflakes, for example. And it certainly will not help us to understand life and consciousness, or why people fall in love.

Newton



(Image © Research Machines plc)

In about 1670 Isaac Newton constructed the first reflecting telescope, which uses a concave mirror to collect and focus incoming light.

Newton's birthplace: Woolsthorpe Manor, Lincolnshire

Go to site

Tour of Isaac Newton's birthplace, with biographical detail and pictures of the interior of the house. There are also plenty of hyperlinks within the text to information about his scientific achievements, and to the rest of his life in sections entitled 'Newtonia', 'Places', 'Bibliography', 'Chronology', and 'Biographies'.

Newtonian physics

physics based on the concepts of the English scientist Isaac Newton, before the formulation of quantum theory or relativity theory.

Newtonian telescope

in astronomy, simple reflecting telescope in which light collected by a parabolic primary mirror is directed to a focus at the side of the tube by a flat secondary mirror placed at 45 degrees to the optical axis. It is named after English physicist and mathematician Isaac Newton, who constructed such a telescope in 1668.

Newton's laws of motion

in physics, three laws that form the basis of Newtonian mechanics, describing the motion of objects. (1) Unless acted upon by an unbalanced force, a body at rest stays at rest, and a moving body continues moving at the same speed in the same straight line. (2) An unbalanced force applied to a body gives it an acceleration proportional to the force (and in the direction of the force) and inversely proportional to the mass of the body. (3) When a body A exerts a force on a body B, B exerts an equal and opposite force on A; that is, to every action there is an equal and opposite reaction.

the first law

As an example, if a car is travelling at a certain speed in a certain direction, it will continue to travel at that speed in the same direction unless it is acted upon by an unbalanced force such as friction in the brake mechanism, which will slow down the car. A person in the car will continue to move forward (in accordance with the first law) unless acted upon by a force; for example, the restraining force of a seat belt.

the second law

This can be demonstrated using a ticker timer and a trolley with mass that can be varied. If the mass is kept constant and the amount of force applied in pulling the trolley varies, then the dots on the ticker timer tape become further apart; the trolley is changing velocity and therefore accelerating. The acceleration (a) is proportional to the force (F) applied. This can be expressed as acceleration/force = a constant, or a/F = a constant.

If the force applied in pulling the trolley is kept the same (constant), and the mass placed on the trolley is varied (from low to high), then the dots on the ticker timer tape become closer together as the mass gets larger; the acceleration decreases as mass increases. This can be expressed as acceleration being inversely proportional to mass (m), or $a \propto 1/m$.

The two equations can be combined to give an overall equation, expressing Newton's second law of motion. This is: force = mass × acceleration, or $F = ma$.

the third law

As an example, a book placed on a table will remain at rest. The force of gravity acting on the book pulls the book towards the ground. The table opposes the force (weight) exerted on the book by gravity. The table exerts the same amount of force in an upward direction. Hence the book remains at rest on the table.

Newton's rings

in optics, an interference phenomenon seen (using white light) as concentric rings of spectral colours where light passes through a thin film of a transparent medium, such as the wedge of air between a large-radius convex lens and a flat glass plate. With monochromatic light (light of a single wavelength), the rings take the form of alternate light and dark bands. They are caused by interference (interaction) between light rays reflected from the plate and those reflected from the curved surface of the lens.

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niacin

one of the 'B group' vitamins; see nicotinic acid.

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niche

in ecology, the 'place' occupied by a species in its habitat, including all chemical, physical, and biological components, such as what it eats, the time of day at which the species feeds, temperature, moisture, the parts of the habitat that it uses (for example, trees or open grassland), the way it reproduces, and how it behaves.

It is believed that no two species can occupy exactly the same niche, because they would be in direct competition for the same resources at every stage of their life cycle.

Nichrome

trade name for a series of alloys containing mainly nickel and chromium, with small amounts of other substances such as iron, magnesium, silicon, and carbon. Nichrome has a high melting point and is resistant to corrosion. It is therefore used in electrical heating elements and as a substitute for platinum in the flame test.

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nickel

chemical symbol Ni

hard, malleable and ductile, silver-white, metallic element, atomic number 28, relative atomic mass 58.71. It occurs in igneous rocks and as a free metal (native metal), occasionally occurring in fragments of iron-nickel meteorites. It is a component of the Earth's core, which is held to consist principally of iron with some nickel. It has a high melting point, low electrical and thermal conductivity, and can be magnetized. It does not tarnish and therefore is much used for alloys, electroplating, and for coinage.

It was discovered in 1751 by Swedish mineralogist Axel Cronstedt (1722-1765) and the name given is an abbreviated form of *kopparnickel*, Swedish 'false copper', since the ore in which it is found resembles copper but yields none.

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nickel ore

any mineral ore from which nickel is obtained. The main minerals are arsenides such as chloanthite ($NiAs_2$), and the sulphides millerite (NiS) and pentlandite ($(Ni,Fe)_9S_8$), the commonest ore. The chief nickel-producing countries are Canada, Russia, Kazakhstan, Cuba, and Australia.

Nicolle, Charles Jules Henri (1866-1936)

French bacteriologist who was awarded a Nobel Prize for Physiology or Medicine in 1928 for his work on the role of the body louse in transmitting typhus. In 1909 he discovered that typhus is transmitted by the body louse and delousing was made a compulsory part of the military routine for the armies of World War I.

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nicotine

$C_{10}H_{14}N_2$

alkaloid (nitrogenous compound) obtained from the dried leaves of the tobacco plant *Nicotiana tabacum*. A colourless oil, soluble in water, it turns brown on exposure to the air. Nicotine is found in tobacco smoke. It can be described as a recreational drug. It stimulates the human body and produces feelings that cause people to carry on smoking. However, nicotine is usually addictive (see addiction). Regular smokers find that it is very difficult or impossible to give up smoking even though they may try to. This is a problem, in that other chemicals in smoke cause a wide range of diseases and increase the risk of dying early. Nicotine has also been used as an insecticide.

Nicotine in its pure form is one of the most powerful poisons known. It is named after a 16th-century French diplomat, Jacques Nicot, who introduced tobacco to France.

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nicotine patch

plastic patch impregnated with nicotine that is stuck onto the skin to help the wearer give up smoking tobacco. Nicotine seeps out at a controlled rate onto the skin and is absorbed into the blood, thereby relieving the wearer's physical craving for the drug. The amount administered is reduced over time as the wearer proceeds from high-dose to low-dose patches.

Nicotine patches are more effective when combined with counselling because, although they can alleviate physical dependence on nicotine, they do not alter the habits that can make the wearer yearn for a cigarette. Very high doses of nicotine, such as those produced when wearing more than one patch at a time, can produce side effects such as vomiting, disturbed vision, and - in extreme cases - heart attacks.

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nicotinic acid

or niacin

water-soluble vitamin ($C_5H_5N.COOH$) of the B complex, found in meat, fish, and cereals; it can also be formed in small amounts in the body from the essential amino acid tryptophan. Absence of nicotinic acid from the diet leads to the disease pellagra.

Niepce, Joseph Nicéphore (1765-1833)

French pioneer of photography. Niepce invented heliography, a precursor of photography that fixed images onto pewter plates coated with pitch and required eight-hour exposures. He produced the world's first photograph from nature in 1826 and later collaborated with Daguerre on the faster daguerreotype process.

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nightingale

songbird belonging to the thrush family; it sings with remarkable beauty by night as well as during the day. About 16.5 cm/6.5 in long, it is dull brown with a reddish-brown rounded tail; the breast is dull greyish-white, tinting to brown. It migrates in summer to Europe and winters in Africa. It feeds on insects, small animals, and occasionally fruit. It has a huge musical repertoire, built from about 900 melodic elements. (Species *Luscinia megarhyncos*, family Muscicapidae.)

The female is slightly smaller than the male, but the plumage is very similar. The nest is often built on the ground, made of dry grass and leaves, and four to six olive-green eggs are laid in it. The male's song continues until the young are hatched.

The **thrush nightingale** (*L. luscinia*) of eastern Europe, is a louder but less sweet songster. Both species also sing in their winter ranges in Africa.

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nightjar

any of about 65 species of night-hunting birds. They have wide, bristly mouths for catching flying insects. Their distinctive calls have earned them such names as 'whippoorwill' and 'church-will's-widow'. Some US species are called nighthawks. (Family Caprimulgidae, order Caprimulgiformes.)

The name 'nighthawk' most commonly refers to the Chordeiles species of North America, including *Chordeiles minor* which breeds widely as far north as southern Alaska, and migrates south to Argentina.

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nightshade

any of several plants in the nightshade family. They include the annual herbaceous black nightshade (*S. nigrum*), with white flowers similar to those of the potato plant and black berries; the perennial shrubby bittersweet or woody nightshade (*S. dulcamara*), with purple, potatolike flowers and scarlet berries; and, belonging to a different genus, deadly nightshade or belladonna (*A. belladonna*). (Genera *Solanum* and *Atropa*, family Solanaceae.)

Nightshade, Woody

Go to site

Detailed information about woody nightshade, including an informative description of the plant, its constituents, and its habitat. This site also features notes on the medicinal uses of the plant, which range from treating skin conditions to asthma.

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niobium

chemical symbol Nb

soft, grey-white, somewhat ductile and malleable, metallic element, atomic number 41, relative atomic mass 92.906. It occurs in nature with tantalum, which it resembles in chemical properties. It is used in making stainless steel and other alloys for jet engines and rockets and for making superconductor magnets.

Niobium was discovered in 1801 by the English chemist Charles Hatchett (1765–1847), who named it columbium (symbol Cb), a name that is sometimes still used in metallurgy. In 1844 it was renamed after Niobe by the German chemist Heinrich Rose (1795–1864) because of its similarity to tantalum (Niobe is the daughter of Tantalus in Greek mythology).

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nit

egg case of the louse, which is glued to the base of the host's hair.

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nitrate

salt or ester of nitric acid, containing the NO_3^- ion. Nitrates are used in explosives, in the chemical and pharmaceutical industries, in curing meat (as nitre), and as fertilizers. They are the most water-soluble salts known and play a major part in the nitrogen cycle. Nitrates in the soil, whether naturally occurring or from inorganic or organic fertilizers, can be used by plants to make proteins and nucleic acids. However, run-off from fields can result in nitrate pollution.

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nitrate pollution

contamination of water by nitrates. Increased use of artificial fertilizers and land cultivation means that higher levels of nitrates are being washed from the soil into rivers, lakes, and aquifers. There they cause an excessive enrichment of the water (eutrophication), leading to a rapid growth of algae, which in turn darkens the water and reduces its oxygen content. The water is expensive to purify and many plants and animals die. High levels are now found in drinking water in arable areas. These may be harmful to newborn babies, and it is possible that they contribute to stomach cancer, although the evidence for this is unproven.

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nitre

or saltpetre

potassium nitrate, KNO_3, a mineral found on and just under the ground in desert regions; used in explosives. Nitre occurs in Bihar, India, Iran, and Cape Province, South Africa. The salt was formerly used for the manufacture of gunpowder, but the supply of nitre for explosives is today largely met by making the salt from nitratine (also called Chile saltpetre, $NaNO_3$). Saltpetre is a preservative and is widely used for curing meats.

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nitric acid

or aqua fortis; HNO_3

fuming acid obtained by the oxidation of ammonia or the action of sulphuric acid on potassium nitrate. It is a highly corrosive acid, dissolving most metals, and a strong oxidizing agent. It is used in the nitration and esterification of organic substances, and in the making of sulphuric acid, nitrates, explosives, plastics, and dyes.

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nitric oxide

or nitrogen monoxide (NO)

colourless gas released when metallic copper reacts with nitric acid and when nitrogen and oxygen combine at high temperatures. It is oxidized to nitrogen dioxide on contact with air. Nitric oxide has a wide range of functions in the body. It is involved in the transmission of nerve impulses and the protection of nerve cells against stress. It is released by macrophages in the immune system in response to viral and bacterial infection or to the proliferation of cancer cells. It is also important in the control of blood pressure.

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nitrification

process that takes place in soil when bacteria oxidize ammonia, turning it into nitrates. Nitrates can be absorbed by the roots of plants, so this is a vital stage in the nitrogen cycle.

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nitrite

salt or ester of nitrous acid, containing the nitrite ion (NO_2^-). Nitrites are used as preservatives (for example, to prevent the growth of botulism spores) and as colouring agents in cured meats such as bacon and sausages.

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nitrocellulose

series of esters with two to six nitrate (NO_3) groups per molecule, made by the action of concentrated nitric acid on cellulose (for example, cotton waste) in the presence of concentrated sulfuric acid. Those with five or more nitrate groups are explosive (gun cotton), but those with less were once used in lacquers, rayon, and plastics, such as colored and photographic film, until replaced by nonflammable cellulose acetate. Celluloid is a form of nitrocellulose.

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nitrogen

chemical symbol N

(Greek nitron 'native soda', sodium or potassium nitrate)

colourless, odourless, tasteless, gaseous, non-metallic element, atomic number 7, relative atomic mass 14.0067. It forms almost 80% of the Earth's atmosphere by volume and is a constituent of all plant and animal tissues (in proteins and nucleic acids). Nitrogen is obtained for industrial use by the liquefaction and fractional distillation of air. Its compounds are used in the manufacture of foods, drugs, fertilizers, dyes, and explosives.

Nitrogen has been recognized as a plant nutrient, found in manures and other organic matter, from early times, long before the complex cycle of nitrogen fixation was understood. It was isolated in 1772 by the English chemist Daniel Rutherford (1749-1819) and named in 1790 by the French chemist Jean Chaptal (1756-1832).

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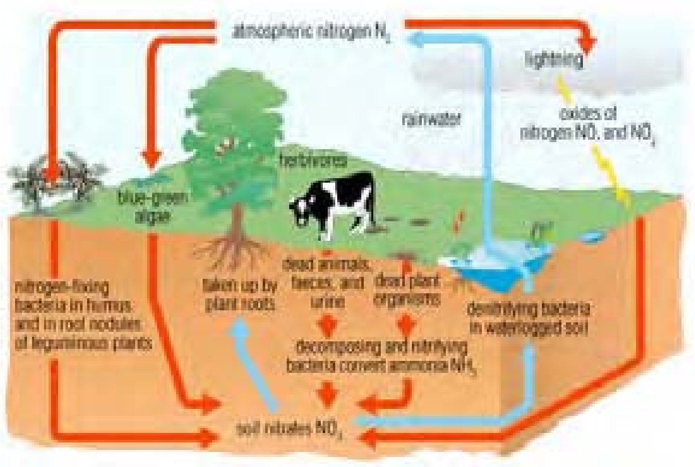
nitrogen cycle

process of nitrogen passing through the ecosystem. Nitrogen, in the form of inorganic compounds (such as nitrates) in the soil, is absorbed by plants and turned into organic compounds (such as proteins) in plant tissue. A proportion of this nitrogen is eaten by herbivores, with some of this in turn being passed on to the carnivores, which feed on the herbivores. The nitrogen is ultimately returned to the soil as excrement and when organisms die, and is converted back to inorganic forms by decomposers.

Although about 78% of the atmosphere is nitrogen, this cannot be used directly by most organisms. However, certain bacteria and cyanobacteria are capable of nitrogen fixation. Some nitrogen-fixing bacteria live mutually with leguminous plants (peas and beans) or other plants (for example, alder), where they form characteristic nodules on the roots. The presence of such plants increases the nitrate content, and hence the fertility, of the soil.

nitrogen cycle


atmospheric nitrogen N_2
lightning
rainwater
oxides of nitrogen NO_2 and NO_3
herbivores
blue-green algae
nitrogen-fixing bacteria in humus and in root nodules of leguminous plants
taken up by plant roots
dead animals, faeces, and urine
dead plant organisms
denitrifying bacteria in waterlogged soil
decomposing and nitrifying bacteria convert ammonia NH_3
soil nitrates NO_3

(Image © Research Machines plc)

The nitrogen cycle is one of a number of cycles during which the chemicals necessary for life are recycled. The carbon, sulphur, and phosphorus cycles are others. Since there is only a limited amount of these chemicals in the Earth and its atmosphere, the chemicals must be continuously recycled if life is to go on.

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nitrogen fixation

process by which nitrogen in the atmosphere is converted into nitrogenous compounds by the action of micro-organisms, such as cyanobacteria and bacteria, in conjunction with certain legumes (see root nodule). Several chemical processes duplicate nitrogen fixation to produce fertilizers; see nitrogen cycle. The key enzyme in natural nitrogen fixation is nitrogenase.

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nitrogen oxide

any chemical compound that contains only nitrogen and oxygen. All nitrogen oxides are gases. Nitrogen monoxide and nitrogen dioxide contribute to air pollution. See also nitrous oxide.

nitrogen monoxide

NO, or nitric oxide, is a colourless gas released when metallic copper reacts with concentrated nitric acid. It is also produced when nitrogen and oxygen combine at high temperature. On contact with air it is oxidized to nitrogen dioxide.

Nitrogen monoxide was discovered during the 1980s to act as a chemical messenger in small quantities within the human body, despite being toxic at higher concentrations and its rapid reaction with oxygen. The medical condition of septic shock is linked to overproduction by the body of nitrogen monoxide. Nitrogen monoxide has an unpaired electron, which can be removed to produce the nitrosyl ion, NO^+.

nitrogen dioxide

nitrogen(IV) oxide, NO_2, is a brown, acidic, pungent gas that is harmful if inhaled and contributes to the formation of acid rain, as it dissolves in water to form nitric acid. It is the most common of the nitrogen oxides and is obtained by heating most nitrate salts (for example lead(II) nitrate, $Pb(NO_3)_2$). If liquefied, it gives a colourless solution (N_2O_4). It has been used in rocket fuels.

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nitroglycerine

or glycerol trinitrate; $C_3H_5(ONO_2)_3$

flammable, explosive oil produced by the action of nitric and sulphuric acids on glycerol. Although poisonous, it is used in cardiac medicine. It explodes with great violence if heated in a confined space and is used in the preparation of dynamite, cordite, and other high explosives.

It was synthesized by the Italian Ascanio Soberro in 1846, and is unusual among explosives in that it is a liquid. Nitroglycerine is an effective explosive because it has low activation energy, and produces little smoke when burned. However, it was initially so reactive it was virtually unusable. Alfred Nobel's innovation was to purify nitroglycerine (using water, with which it is immiscible, to dissolve the impurities), and thereby make it more stable, and absorb it into wood flour to make dynamite.

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nitrous acid

HNO_2

weak acid that, in solution with water, decomposes quickly to form nitric acid and nitrogen dioxide.

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nitrous oxide

or dinitrogen oxide; N_2O

colourless, nonflammable gas that, used in conjunction with oxygen, reduces sensitivity to pain. In higher doses it is an anaesthetic. Well tolerated, it is often combined with other anaesthetic gases to enable them to be used in lower doses. It may be self-administered; for example, in childbirth. It is a greenhouse gas; about 10% of nitrous oxide released into the atmosphere comes from the manufacture of nylon. It used to be known as 'laughing gas'.

nitrous oxide

Earthworms produce nitrous oxide as a by-product from digesting soil nitrates and nitrites. Soil with earthworms contains five times as much nitrous oxide as soil without.

Nobel, Alfred Bernhard (1833-1896)

Swedish chemist and engineer. He invented dynamite in 1867, gelignite in 1875, and ballistite, a smokeless gunpowder, in 1887. Having amassed a large fortune from the manufacture of explosives and the exploitation of the Baku oilfields in Azerbaijan, near the Caspian Sea, he left this in trust for the endowment of five Nobel prizes.

Alfred Nobel - His Life and Work

Go to site

Presentation of the life and work of Alfred Nobel. The site includes references to Nobel's life in Paris, as well as his frequent travels; his industrial occupations; his scientific discoveries; and especially his work on explosives, which led to the patenting of dynamite. Also covered are his numerous chemical inventions, which included materials such as synthetic leather and artificial silk, his interest in literature and in social and peace-related issues, and of course the Nobel prizes, which came as a natural extension of his lifelong interests.

Excerpt from the Will of Alfred Nobel

Go to site

Excerpt from the will of Alfred Nobel delineating his vision in regards to the Nobel Prizes. The excerpt clearly defines those areas of knowledge and human excellence that Nobel wished to be rewarded through the Nobel Prizes. We also learn about the people assigned the task of deciding on the awards.

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nobelium

chemical symbol No

synthesized, radioactive, metallic element of the actinide series, atomic number 102, relative atomic mass 259. It is synthesized by bombarding curium with carbon nuclei.

It was named in 1957 after the Nobel Institute in Stockholm, Sweden, where it was claimed to have been first synthesized. Later evaluations determined that this was in fact not so, as the successful 1958 synthesis at the University of California at Berkeley produced a different set of data. The name was not, however, challenged. In 1992 the International Unions for Pure and Applied Chemistry and Physics (IUPAC and IUPAP) gave credit to Russian scientists in Dubna for the discovery of nobelium.

Nobel Prize

annual international prize, first awarded in 1901 under the will of Alfred Nobel, Swedish chemist, who invented dynamite. The interest on the Nobel endowment fund is divided annually among the persons who have made the greatest contributions in the fields of physics, chemistry, medicine, literature, and world peace. The first four are awarded by academic committees based in Sweden, while the Nobel Prize for Peace is awarded by a committee of the Norwegian parliament. A sixth prize, for economics, financed by the Swedish National Bank, was first awarded in 1969. The prizes have a large cash award and are given to organizations – such as the United Nations peacekeeping forces, which received the Nobel Prize for Peace in 1988 – as well as individuals.

Nobel Prize for Chemistry

Year	Winner(s)[1]	Awarded for
1901	Jacobus van't Hoff (Netherlands)	laws of chemical dynamics and osmotic pressure
1902	Emil Fischer (Germany)	sugar and purine syntheses

1903	Svante Arrhenius (Sweden)	theory of electrolytic dissociation
1904	William Ramsay (UK)	discovery of rare gases in air and their locations in the periodic table
1905	Adolf von Baeyer (Germany)	work in organic dyes and hydroaromatic compounds
1906	Henri Moissan (France)	isolation of fluorine and adoption of electric furnace
1907	Eduard Buchner (Germany)	biochemical research and discovery of cell-free fermentation
1908	Ernest Rutherford (UK)	work in atomic disintegration and the chemistry of radioactive substances
1909	Wilhelm Ostwald (Germany)	work in catalysis and principles of equilibria and rates of reaction
1910	Otto Wallach (Germany)	work in alicyclic compounds
1911	Marie Curie (France)	discovery of radium and polonium, and the isolation and study of radium
1912	Victor Grignard (France)	discovery of Grignard reagents
	Paul Sabatier (France)	finding method of catalytic hydrogenation of organic compounds
1913	Alfred Werner (Switzerland)	work in bonding of atoms within inorganic molecules
1914	Theodore Richards (USA)	accurate determination of the atomic masses of many elements
1915	Richard Willstätter (Germany)	research into plant pigments, especially chlorophyll
1916	no award	
1917	no award	
1918	Fritz Haber (Germany)	synthesis of ammonia from its elements
1919	no award	
1920	Walther Nernst (Germany)	work in thermochemistry
1921	Frederick Soddy (UK)	work in radioactive substances, especially isotopes
1922	Francis Aston (UK)	work in mass spectrometry of isotopes of radioactive elements, and enunciation of the whole-number rule
1923	Fritz Pregl (Austria)	method of microanalysis of organic substances
1924	no award	
1925	Richard Zsigmondy (Austria)	elucidation of heterogeneity of colloids
1926	Theodor Svedberg (Sweden)	investigation of dispersed systems
1927	Heinrich Wieland (Germany)	research on constitution of bile acids and related substances
1928	Adolf Windaus (Germany)	research on constitution of sterols and related vitamins
1929	Arthur Harden (UK) and Hans von Euler-Chelpin (Sweden)	work on fermentation of sugar and fermentative enzymes
1930	Hans Fischer (Germany)	analysis of haem (the iron-bearing group in haemoglobin) and chlorophyll and the synthesis of haemin (a compound of haem)
1931	Carl Bosch (Germany) and Friedrich Bergius (Germany)	invention and development of chemical high-pressure methods
1932	Irving Langmuir (USA)	discoveries and investigations in surface chemistry
1933	no award	
1934	Harold Urey (USA)	discovery of deuterium (heavy hydrogen)
1935	Irène and Frédéric Joliot-Curie (France)	synthesis of new radioactive elements
1936	Peter Debye (Netherlands)	work in molecular structures by investigation of dipole moments and the diffraction of X-rays and electrons in gases
1937	Norman Haworth (UK)	work in carbohydrates and ascorbic acid (vitamin C)
	Paul Karrer (Switzerland)	work in carotenoids, flavins, retinol (vitamin A) and riboflavin (vitamin B_2)
1938	Richard Kuhn (Germany) (declined)	carotenoids and vitamins research
1939	Adolf Butenandt (Germany) (declined)	work in sex hormones
	Leopold Ruzicka (Switzerland)	polymethylenes and higher terpenes
1940	no award	
1941	no award	
1942	no award	
1943	Georg von Hevesy (Hungary)	use of isotopes as tracers in chemical processes
1944	Otto Hahn (Germany)	discovery of nuclear fission
1945	Artturi Virtanen (Finland)	work in agriculture and nutrition, especially fodder preservation
1946	James Sumner (USA)	discovery of crystallization of enzymes
	John Northrop (USA) and Wendell Stanley (USA)	preparation of pure enzymes and virus proteins
1947	Robert Robinson (UK)	investigation of biologically important plant products, especially alkaloids
1948	Arne Tiselius (Sweden)	researches in electrophoresis and adsorption analysis, and discoveries concerning serum proteins
1949	William Giauque (USA)	work in chemical thermodynamics, especially at very low temperatures
1950	Otto Diels (West Germany) and Kurt Alder (West Germany)	discovery and development of diene synthesis
1951	Edwin McMillan (USA) and Glenn Seaborg (USA)	discovery and work in chemistry of transuranic elements
1952	Archer Martin (UK) and Richard Synge (UK)	development of partition chromatography
1953	Hermann Staudinger (West Germany)	discoveries in macromolecular chemistry
1954	Linus Pauling (USA)	study of nature of chemical bonds, especially in complex substances
1955	Vincent Du Vigneaud (USA)	investigations into biochemically important sulphur compounds, and the first synthesis of a polypeptide hormone
1956	Cyril Hinshelwood (UK) and Nikolai Semenov (USSR)	work in mechanism of chemical reactions
1957	Alexander Todd (UK)	work in nucleotides and nucleotide coenzymes
1958	Frederick Sanger (UK)	determination of the structure of proteins, especially insulin

1959	Jaroslav Heyrovský (Czechoslovakia)	discovery and development of polarographic methods of chemical analysis
1960	Willard Libby (USA)	development of radiocarbon dating in archaeology, geology, and geography
1961	Melvin Calvin (USA)	study of assimilation of carbon dioxide by plants
1962	Max Perutz (UK) and John Kendrew (UK)	determination of structures of globular proteins
1963	Karl Ziegler (West Germany) and Giulio Natta (Italy)	chemistry and technology of producing high polymers
1964	Dorothy Crowfoot Hodgkin (UK)	crystallographic determination of the structures of biochemical compounds, notably penicillin and cyanocobalamin (vitamin B_{12})
1965	Robert Woodward (USA)	organic synthesis
1966	Robert Mulliken (USA)	molecular orbital theory of chemical bonds and structures
1967	Manfred Eigen (West Germany), Ronald Norrish (UK), and George Porter (UK)	investigation of rapid chemical reactions by means of very short pulses of light energy
1968	Lars Onsager (USA)	discovery of reciprocal relations, fundamental for the thermodynamics of irreversible processes
1969	Derek Barton (UK) and Odd Hassel (Norway)	concept and applications of conformation in chemistry
1970	Luis Federico Leloir (Argentina)	discovery of sugar nucleotides and their role in carbohydrate biosynthesis
1971	Gerhard Herzberg (Canada)	research on electronic structure and geometry of molecules, particularly free radicals
1972	Christian Anfinsen (USA), Stanford Moore (USA), and William Stein (USA)	work in amino-acid structure and biological activity of the enzyme ribonuclease
1973	Ernst Fischer (West Germany) and Geoffrey Wilkinson (UK)	work in chemistry of organometallic sandwich compounds
1974	Paul Flory (USA)	studies of physical chemistry of macromolecules
1975	John Cornforth (UK)	work in stereochemistry of enzyme-catalysed reactions
	Vladimir Prelog (Switzerland)	work in stereochemistry of organic molecules and their reactions
1976	William Lipscomb (USA)	study of structure and chemical bonding of boranes (compounds of boron and hydrogen)
1977	Ilya Prigogine (Belgium)	work in thermodynamics of irreversible and dissipative processes
1978	Peter Mitchell (UK)	formulation of a theory of biological energy transfer and chemiosmotic theory
1979	Herbert Brown (USA) and Georg Wittig (West Germany)	use of boron and phosphorus compounds, respectively, in organic syntheses
1980	Paul Berg (USA)	biochemistry of nucleic acids, especially recombinant DNA
	Walter Gilbert (USA) and Frederick Sanger (UK)	base sequences in nucleic acids
1981	Kenichi Fukui (Japan) and Roald Hoffmann (USA)	theories concerning chemical reactions
1982	Aaron Klug (UK)	determination of crystallographic electron microscopy: structure of biologically important nucleic-acid-protein complexes
1983	Henry Taube (USA)	study of electron-transfer reactions in inorganic chemical reactions
1984	Bruce Merrifield (USA)	development of chemical syntheses on a solid matrix
1985	Herbert Hauptman (USA) and Jerome Karle (USA)	development of methods of determining crystal structures
1986	Dudley Herschbach (USA), Yuan Lee (USA), and John Polanyi (Canada)	development of dynamics of chemical elementary processes
1987	Donald Cram (USA), Jean-Marie Lehn (France), and Charles Pedersen (USA)	development of molecules with highly selective structure-specific interactions
1988	Johann Deisenhofer (West Germany), Robert Huber (West Germany), and Hartmut Michel (West Germany)	discovery of three-dimensional structure of the reaction centre of photosynthesis
1989	Sidney Altman (USA) and Thomas Cech (USA)	discovery of catalytic function of RNA
1990	Elias James Corey (USA)	new methods of synthesizing chemical compounds
1991	Richard Ernst (Switzerland)	improvements in the technology of nuclear magnetic resonance (NMR) imaging
1992	Rudolph Marcus (USA)	theoretical discoveries relating to reduction and oxidation reactions
1993	Kary Mullis (USA)	invention of the polymerase chain reaction technique for amplifying DNA
	Michael Smith (Canada)	invention of techniques for splicing foreign genetic segments into an organism's DNA in order to modify the proteins produced
1994	George Olah (USA)	development of technique for examining hydrocarbon molecules
1995	F Sherwood Rowland (USA), Mario Molina (USA), and Paul Crutzen (Netherlands)	explaining the chemical process of the ozone layer
1996	Robert Curl Jr (USA), Harold Kroto (UK), and Richard Smalley (USA)	discovery of fullerenes
1997	John Walker (UK), Paul Boyer (USA), and Jens Skou (Denmark)	study of the enzymes involved in the production of adenosine triphosphate (ATP), which acts as a store of energy in bodies called mitochondria inside cells
1998	Walter Kohn (USA), John Pople (USA)	research into quantum chemistry
1999	Ahmed Zewail (USA)	studies of the transition states of chemical reactions using femtosecond spectroscopy
2000	Alan J Heeger (USA), Alan G MacDiarmid (New Zealand), and Hideki Shirakawa (Japan)	their roles in the development of electrically conductive polymers
2001	William S Knowles (USA) and Ryoji Noyori (Japan)	work on chirally catalysed hydrogenation reactions
	K Barry Sharpless (USA)	work on chirally catalysed oxidation reactions
2002	John B Fenn (USA) and Koichi Tanaka (Japan)	work on analyses of biological macromolecules
	Kurt Wüthrich (Switzerland)	development of nuclear magnetic resonance spectroscopy for the study of biological macromolecules
2003	Peter Agre (USA)	discovery of water channels

	Roderick Mackinnon (USA)	structural and mechanistic studies of ion channels
2004	Aaron Ciechanover (Israel), Avram Hershko (Israel), and Irwin Rose (USA)	discovery of ubiquitin-mediated protein degradation
2005	Yves Chauvin (France), Robert H Grubbs (USA), and Richard R Schrock (USA)	development of the metathesis method in organic synthesis

[1] Nationality given is the citizenship of recipient at the time award was made.

Nobel Prize for Economics

Year	Winner(s)[1]	Awarded for
1969	Ragnar Frisch (Norway) and Jan Tinbergen (Netherlands)	work in econometrics
1970	Paul Samuelson (USA)	scientific analysis of economic theory
1971	Simon Kuznets (USA)	research on the economic growth of nations
1972	John Hicks (UK) and Kenneth Arrow (USA)	contributions to general economic equilibrium theory
1973	Wassily Leontief (USA)	work on input analysis
1974	Gunnar Myrdal (Sweden) and Friedrich von Hayek (UK)	analysis of the interdependence of economic, social, and institutional phenomena
1975	Leonid Kantorovich (USSR) and Tjalling Koopmans (USA)	contributions to the theory of optimum allocation of resources
1976	Milton Friedman (USA)	consumption analysis, monetary theory, and economic stabilization
1977	Bertil Ohlin (Sweden) and James Meade (UK)	contributions to theory of international trade
1978	Herbert Simon (USA)	decision-making processes in economic organization
1979	Arthur Lewis (UK) and Theodore Schultz (USA)	analysis of economic processes in developing nations
1980	Lawrence Klein (USA)	development and analysis of empirical models of business fluctuations
1981	James Tobin (USA)	empirical macroeconomic theories
1982	George Stigler (USA)	work on the economic effects of governmental regulation
1983	Gerard Debreu (USA)	mathematical proof of supply and demand theory
1984	Richard Stone (UK)	development of a national income accounting system
1985	Franco Modigliani (USA)	analysis of household savings and financial markets
1986	James McGill Buchanan (USA)	political theories advocating limited government role in the economy
1987	Robert Solow (USA)	contributions to the theory of economic growth
1988	Maurice Allais (France)	contributions to the theory of markets and efficient use of resources
1989	Trygve Haavelmo (Norway)	testing fundamental econometric theories
1990	Harry Markowitz (USA), Merton Miller (USA), and William Sharpe (USA)	pioneering theories on managing investment portfolios and corporate finances
1991	Ronald Coase (USA)	work on value and social problems of companies
1992	Gary Becker (USA)	work linking economic theory to aspects of human behaviour, drawing on other social sciences
1993	Robert Fogel (USA) and Douglass North (USA)	creating a new method of studying economic history (cliometrics)
1994	John Nash (USA), John Harsanyi (USA), and Reinhard Selten (Germany)	work on 'game theory', which investigates decision-making in a competitive environment
1995	Robert Lucas (USA)	developing the 'rational expectations' school, which questions a government's ability to steer the economy
1996	James Mirrlees (UK) and William Vickrey (USA)	fundamental contributions to the economic theory of incentives under asymmetric information
1997	Robert Merton (USA) and Myron Scholes (USA)	pioneering contribution to economic sciences by developing a new method of determining the value of derivatives
1998	Amartya Sen (India)	research into the social and economic causes of famines
1999	Robert A Mundell (Canada)	analysis of monetary and fiscal policy under different exchange rate regimes and analysis of optimum currency areas
2000	James J Heckman (USA)	development of theory and methods for analysing selective samples
	Daniel L McFadden (USA)	development of theory and methods for analysing discrete choice
2001	George A Akerlof (USA), A Michael Spence (USA), and Joseph E Stiglitz (USA)	analyses of markets with asymmetric information
2002	Daniel Kahneman (USA)	integration of psychological research into economic science
	Vernon L Smith (USA)	establishment of laboratory experiments as a tool in empirical economic analysis
2003	Robert F Engle (USA)	methods of analyzing economic time series with time-varying volatility (ARCH)
	Clive W J Granger (USA)	methods of analyzing economic time series with common trends (cointegration)
2004	Finn E Kydland (Norway) and Edward C Prescott	contributions to dynamic macroeconomics
2005	Robert J Aumann (Israel) and Thomas C Schelling	research into conflict and cooperation through game-theory analysis

[1] Nationality given is the citizenship of recipient at the time award was made.

Nobel Prize for Literature

Year	Winner(s)[1]
1901	René Sully-Prudhomme (France)
1902	Theodor Mommsen (Germany)
1903	Bjørnstjerne Bjørnson (Norway)

1904	Frédéric Mistral (France); José Echegaray (Spain)
1905	Henryk Sienkiewicz (Poland)
1906	Giosuè Carducci (Italy)
1907	Rudyard Kipling (UK)
1908	Rudolf Eucken (Germany)
1909	Selma Lagerlöf (Sweden)
1910	Paul von Heyse (Germany)
1911	Maurice Maeterlinck (Belgium)
1912	Gerhart Hauptmann (Germany)
1913	Rabindranath Tagore (India)
1914	no award
1915	Romain Rolland (France)
1916	Verner von Heidenstam (Sweden)
1917	Karl Gjellerup (Denmark); Henrik Pontoppidan (Denmark)
1918	Erik Axel Karlfeldt (Sweden) (declined)
1919	Carl Spitteler (Switzerland)
1920	Knut Hamsun (Norway)
1921	Anatole France (France)
1922	Jacinto Benavente y Martínez (Spain)
1923	William Butler Yeats (Ireland)
1924	Wladyslaw Stanislaw Reymont (Poland)
1925	George Bernard Shaw (Ireland)
1926	Grazia Deledda (Italy)
1927	Henri Bergson (France)
1928	Sigrid Undset (Norway)
1929	Thomas Mann (Germany)
1930	Sinclair Lewis (USA)
1931	Erik Axel Karlfeldt (Sweden) (posthumous award)
1932	John Galsworthy (UK)
1933	Ivan Bunin (USSR)
1934	Luigi Pirandello (Italy)
1935	no award
1936	Eugene O'Neill (USA)
1937	Roger Martin du Gard (France)
1938	Pearl Buck (USA)
1939	Frans Eemil Sillanpää (Finland)
1940	no award
1941	no award
1942	no award
1943	no award
1944	Johannes V Jensen (Denmark)
1945	Gabriela Mistral (Chile)
1946	Hermann Hesse (Switzerland)
1947	André Gide (France)
1948	T S Eliot (UK)
1949	William Faulkner (USA)
1950	Bertrand Russell (UK)
1951	Pär Lagerkvist (Sweden)
1952	François Mauriac (France)
1953	Winston Churchill (UK)
1954	Ernest Hemingway (USA)
1955	Halldór Laxness (Iceland)
1956	Juan Ramón Jiménez (Spain)
1957	Albert Camus (France)
1958	Boris Pasternak (USSR) (declined)
1959	Salvatore Quasimodo (Italy)
1960	Saint-John Perse (France)
1961	Ivo Andric (Yugoslavia)
1962	John Steinbeck (USA)
1963	George Seferis (Greece)
1964	Jean-Paul Sartre (France) (declined)
1965	Mikhail Sholokhov (USSR)
1966	Shmuel Yosef Agnon (Israel); Nelly Sachs (Sweden)
1967	Miguel Ángel Asturias (Guatemala)
1968	Yasunari Kawabata (Japan)

1969	Samuel Beckett (Ireland)
1970	Alexander Solzhenitsyn (USSR)
1971	Pablo Neruda (Chile)
1972	Heinrich Böll (West Germany)
1973	Patrick White (Australia)
1974	Eyvind Johnson (Sweden); Harry Martinson (Sweden)
1975	Eugenio Montale (Italy)
1976	Saul Bellow (USA)
1977	Vicente Aleixandre (Spain)
1978	Isaac Bashevis Singer (USA)
1979	Odysseus Elytis (Greece)
1980	Czeslaw Milosz (USA)
1981	Elias Canetti (Bulgaria)
1982	Gabriel García Márquez (Colombia)
1983	William Golding (UK)
1984	Jaroslav Seifert (Czechoslovakia)
1985	Claude Simon (France)
1986	Wole Soyinka (Nigeria)
1987	Joseph Brodsky (USA)
1988	Naguib Mahfouz (Egypt)
1989	Camilo José Cela (Spain)
1990	Octavio Paz (Mexico)
1991	Nadine Gordimer (South Africa)
1992	Derek Walcott (Santa Lucia)
1993	Toni Morrison (USA)
1994	Kenzaburo Oe (Japan)
1995	Seamus Heaney (Ireland)
1996	Wislawa Szymborska (Poland)
1997	Dario Fo (Italy)
1998	José Saramago (Portugal)
1999	Günter Grass (Germany)
2000	Gao Xingjian (China)
2001	V S Naipaul (UK)
2002	Imre Kertész (Hungary)
2003	J M Coetzee (South Africa)
2004	Elfriede Jelinek (Austria)
2005	Harold Pinter (UK)

[1] Nationality given is the citizenship of recipient at the time award was made.

Nobel Prize for Physiology or Medicine

Year	Winner(s)[1]	Awarded for
1901	Emil von Behring (Germany)	discovery that the body produces antitoxins, and development of serum therapy for diseases such as diphtheria
1902	Ronald Ross (UK)	work on the role of the *Anopheles* mosquito in transmitting malaria
1903	Niels Finsen (Denmark)	discovery of the use of ultraviolet light to treat skin diseases
1904	Ivan Pavlov (Russia)	discovery of the physiology of digestion
1905	Robert Koch (Germany)	investigations and discoveries in relation to tuberculosis
1906	Camillo Golgi (Italy) and Santiago Ramón y Cajal (Spain)	discovery of the fine structure of the nervous system
1907	Charles Laveran (France)	discovery that certain protozoa can cause disease
1908	Ilya Mechnikov (Russia) and Paul Ehrlich (Germany)	work on immunity
1909	Emil Kocher (Switzerland)	work on the physiology, pathology, and surgery of the thyroid gland
1910	Albrecht Kossel (Germany)	study of cell proteins and nucleic acids
1911	Allvar Gullstrand (Sweden)	work on the refraction of light through the different components of the eye
1912	Alexis Carrel (France)	work on the techniques for connecting severed blood vessels and transplanting organs
1913	Charles Richet (France)	work on allergic responses
1914	Robert Bárány (Austria-Hungary)	work on the physiology and pathology of the equilibrium organs of the inner ear
1915	no award	
1916	no award	
1917	no award	
1918	no award	
1919	Jules Bordet (Belgium)	work on immunity
1920	August Krogh (Denmark)	discovery of the mechanism regulating the dilation and constriction of blood capillaries
1921	no award	

1922	Archibald Hill (UK)	work in the production of heat in contracting muscle
	Otto Meyerhof (Germany)	work in the relationship between oxygen consumption and metabolism of lactic acid in muscle
1923	Frederick Banting (Canada) and John Macleod (UK)	discovery and isolation of the hormone insulin
1924	Willem Einthoven (Netherlands)	invention of the electrocardiograph
1925	no award	
1926	Johannes Fibiger (Denmark)	discovery of a parasite *Spiroptera carcinoma* that causes cancer
1927	Julius Wagner-Jauregg (Austria)	use of induced malarial fever to treat paralysis caused by mental deterioration
1928	Charles Nicolle (France)	work on the role of the body louse in transmitting typhus
1929	Christiaan Eijkman (Netherlands)	discovery of a cure for beriberi, a vitamin-deficiency disease
	Frederick Hopkins (UK)	discovery of trace substances, now known as vitamins, that stimulate growth
1930	Karl Landsteiner (USA)	discovery of human blood groups
1931	Otto Warburg (Germany)	discovery of respiratory enzymes that enable cells to process oxygen
1932	Charles Sherrington (UK) and Edgar Adrian (UK)	discovery of function of neurons (nerve cells)
1933	Thomas Morgan (USA)	work on the role of chromosomes in heredity
1934	George Whipple (USA), George Minot (USA), and William Murphy (USA)	work on treatment of pernicious anaemia by increasing the amount of liver in the diet
1935	Hans Spemann (Germany)	organizer effect in embryonic development
1936	Henry Dale (UK) and Otto Loewi (Germany)	chemical transmission of nerve impulses
1937	Albert Szent-Györgyi (Hungary)	investigation of biological oxidation processes and of the action of ascorbic acid (vitamin C)
1938	Corneille Heymans (Belgium)	mechanisms regulating respiration
1939	Gerhard Domagk (Germany)	discovery of the first antibacterial sulphonamide drug
1940	no award	
1941	no award	
1942	no award	
1943	Henrik Dam (Denmark)	discovery of vitamin K
	Edward Doisy (USA)	chemical nature of vitamin K
1944	Joseph Erlanger (USA) and Herbert Gasser (USA)	transmission of impulses by nerve fibres
1945	Alexander Fleming (UK)	discovery of the bactericidal effect of penicillin
	Ernst Chain (UK) and Howard Florey (Australia)	isolation of penicillin and its development as an antibiotic drug
1946	Hermann Muller (USA)	discovery that X-ray irradiation can cause mutation
1947	Carl Cori (USA) and Gerty Cori (USA)	production and breakdown of glycogen (animal starch)
	Bernardo Houssay (Argentina)	function of the pituitary gland in sugar metabolism
1948	Paul Müller (Switzerland)	discovery of the first synthetic contact insecticide DDT
1949	Walter Hess (Switzerland)	mapping areas of the midbrain that control the activities of certain body organs
	Antonio Egas Moniz (Portugal)	therapeutic value of prefrontal leucotomy in certain psychoses
1950	Edward Kendall (USA), Tadeus Reichstein (Switzerland), and Philip Hench (USA)	structure and biological effects of hormones of the adrenal cortex
1951	Max Theiler (South Africa)	discovery of a vaccine against yellow fever
1952	Selman Waksman (USA)	discovery of streptomycin, the first antibiotic effective against tuberculosis
1953	Hans Krebs (UK)	discovery of the Krebs cycle
	Fritz Lipmann (USA)	discovery of coenzyme A, a nonprotein compound that acts in conjunction with enzymes to catalyse metabolic reactions leading up to the Krebs cycle
1954	John Enders (USA), Thomas Weller (USA), and Frederick Robbins (USA)	cultivation of the polio virus in the laboratory
1955	Hugo Theorell (Sweden)	work on the nature and action of oxidation enzymes
1956	André Cournand (USA), Werner Forssmann (West Germany), and Dickinson Richards (USA)	work on the technique for passing a catheter into the heart for diagnostic purposes
1957	Daniel Bovet (Italy)	discovery of synthetic drugs used as muscle relaxants in anaesthesia
1958	George Beadle (USA) and Edward Tatum (USA)	discovery that genes regulate precise chemical effects
	Joshua Lederberg (USA)	work on genetic recombination and the organization of bacterial genetic material
1959	Severo Ochoa (USA) and Arthur Kornberg (USA)	discovery of enzymes that catalyse the formation of RNA (ribonucleic acid) and DNA (deoxyribonucleic acid)
1960	Macfarlane Burnet (Australia) and Peter Medawar (UK)	acquired immunological tolerance of transplanted tissues
1961	Georg von Békésy (USA)	investigations into the mechanism of hearing within the cochlea of the inner ear
1962	Francis Crick (UK), James Watson (USA), and Maurice Wilkins (UK)	discovery of the double-helical structure of DNA and of the significance of this structure in the replication and transfer of genetic information
1963	John Eccles (Australia), Alan Hodgkin (UK), and Andrew Huxley (UK)	ionic mechanisms involved in the communication or inhibition of impulses across neuron (nerve cell) membranes
1964	Konrad Bloch (USA) and Feodor Lynen (West Germany)	work on the cholesterol and fatty-acid metabolism
1965	François Jacob (France), André Lwoff (France), and Jacques Monod (France)	genetic control of enzyme and virus synthesis
1966	Peyton Rous (USA)	discovery of tumour-inducing viruses
	Charles Huggins (USA)	hormonal treatment of prostatic cancer
1967	Ragnar Granit (Sweden), Haldan Hartline (USA), and George Wald (USA)	physiology and chemistry of vision
1968	Robert Holley (USA), Har Gobind Khorana (USA), and Marshall Nirenberg (USA)	interpretation of genetic code and its function in protein synthesis

1969	Max Delbrück (USA), Alfred Hershey (USA), and Salvador Luria (USA)	replication mechanism and genetic structure of viruses
1970	Bernard Katz (UK), Ulf von Euler (Sweden), and Julius Axelrod (USA)	work on the storage, release, and inactivation of neurotransmitters
1971	Earl Sutherland (USA)	discovery of cyclic AMP, a chemical messenger that plays a role in the action of many hormones
1972	Gerald Edelman (USA) and Rodney Porter (UK)	work on the chemical structure of antibodies
1973	Karl von Frisch (Austria), Konrad Lorenz (Austria), and Nikolaas Tinbergen (UK)	work in animal behaviour patterns
1974	Albert Claude (USA), Christian de Duve (Belgium), and George Palade (USA)	work in structural and functional organization of the cell
1975	David Baltimore (USA), Renato Dulbecco (USA), and Howard Temin (USA)	work on interactions between tumour-inducing viruses and the genetic material of the cell
1976	Baruch Blumberg (USA) and Carleton Gajdusek (USA)	new mechanisms for the origin and transmission of infectious diseases
1977	Roger Guillemin (USA) and Andrew Schally (USA)	discovery of hormones produced by the hypothalamus region of the brain
	Rosalyn Yalow (USA)	radioimmunoassay techniques by which minute quantities of hormone may be detected
1978	Werner Arber (Switzerland), Daniel Nathans (USA), and Hamilton Smith (USA)	discovery of restriction enzymes and their application to molecular genetics
1979	Allan Cormack (USA) and Godfrey Hounsfield (UK)	development of the computerized axial tomography (CAT) scan
1980	Baruj Benacerraf (USA), Jean Dausset (France), and George Snell (USA)	work on genetically determined structures on the cell surface that regulate immunological reactions
1981	Roger Sperry (USA)	functional specialization of the brain's cerebral hemispheres
	David Hubel (USA) and Torsten Wiesel (Sweden)	work on visual perception
1982	Sune Bergström (Sweden), Bengt Samuelsson (Sweden), and John Vane (UK)	discovery of prostaglandins and related biologically active substances
1983	Barbara McClintock (USA)	discovery of mobile genetic elements
1984	Niels Jerne (Denmark-UK), Georges Köhler (West Germany), and César Milstein (Argentina)	work on immunity and discovery of a technique for producing highly specific, monoclonal antibodies
1985	Michael Brown (USA) and Joseph L Goldstein (USA)	work on the regulation of cholesterol metabolism
1986	Stanley Cohen (USA) and Rita Levi-Montalcini (USA-Italy)	discovery of factors that promote the growth of nerve and epidermal cells
1987	Susumu Tonegawa (Japan)	work on the process by which genes alter to produce a range of different antibodies
1988	James Black (UK), Gertrude Elion (USA), and George Hitchings (USA)	work on the principles governing the design of new drug treatment
1989	Michael Bishop (USA) and Harold Varmus (USA)	discovery of oncogenes, genes carried by viruses that can trigger cancerous growth in normal cells
1990	Joseph Murray (USA) and Donnall Thomas (USA)	pioneering work in organ and cell transplants
1991	Erwin Neher (Germany) and Bert Sakmann (Germany)	discovery of how gatelike structures (ion channels) regulate the flow of ions into and out of cells
1992	Edmond Fischer (USA) and Edwin Krebs (USA)	isolating and describing the action of the enzyme responsible for reversible protein phosphorylation, a major biological control mechanism
1993	Phillip Sharp (USA) and Richard Roberts (UK)	discovery of split genes (genes interrupted by nonsense segments of DNA)
1994	Alfred Gilman (USA) and Martin Rodbell (USA)	discovery of a family of proteins (G-proteins) that translate messages - in the form of hormones or other chemical signals - into action inside cells
1995	Edward Lewis (USA), Eric Wieschaus (USA), and Christiane Nüsslein-Volhard (Germany)	discovery of genes which control the early stages of the body's development
1996	Peter Doherty (Australia) and Rolf Zinkernagel (Switzerland)	discovery of how the immune system recognizes virus-infected cells
1997	Stanley Prusiner (USA)	discoveries, including the 'prion' theory, that could lead to new treatments of dementia-related diseases, including Alzheimer's and Parkinson's diseases
1998	Robert Furchgott (USA), Ferid Murad (USA), and Louis Ignarro (USA)	discovery that nitric oxide (NO) acts as a key chemical messenger between cells
1999	Günter Blobel (USA)	discovery that proteins have intrinsic signals that govern their transport and localization in the cell
2000	Arvid Carlsson (Sweden), Paul Greegard (USA), and Eric Kandel (USA)	elucidation of how signals are transmitted between nerve cells
2001	Leland H Hartwell (USA), R Timothy Hunt (UK), Paul M Nurse (UK)	discoveries of key regulators of the cell cycle
2002	Sydney Brenner (UK), H Robert Horvitz (USA), and John E Sulston (UK)	discoveries concerning genetic regulation of organ development and programmed cell death
2003	Paul C Lauterbur (USA) and Peter Mansfield (UK)	discoveries concerning magnetic resonance imaging
2004	Richard Axel (USA) and Linda B Buck (USA)	discoveries of odorant receptors and the organization of the olfactory system
2005	Barry J Marshall (Australia) and J Robin Warren (Australia)	discovery of the bacterium *Helicobacter pylori* and its role in gastritis and peptic ulcer disease

[1] Nationality given is the citizenship of recipient at the time award was made.

Nobel e-Museum: The Nobel Prize in Physics - Laureates

Go to site

Fascinating directory of physics prize laureates. This site is part of the Nobel e-Museum, which includes portraits, biographies, and transcripts of Nobel prize speeches.

Nobel Prize Internet Archive

Go to site

Beautifully-designed archive with a wealth of information on all the Nobel prizewinners with biographies and bibliographies of each laureate. Alongside the mainstream information, there are other features such as why there is no prize in mathematics.

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noble gas

or rare gas or inert gas

any of a group of six elements (helium, neon, argon, krypton, xenon, and radon), originally named 'inert' because they were thought not to enter into any chemical reactions. This is now known to be incorrect: in 1962, xenon was made to combine with fluorine, and since then, compounds of argon, krypton, and radon with fluorine and/or oxygen have been described.

The extreme unreactivity of the noble gases is due to the stability of their electronic structure. All the electron shells (energy levels) of inert gas atoms are full and, except for helium, they all have eight electrons in their outermost (valency) shell. The apparent stability of this electronic arrangement led to the formulation of the octet rule to explain the different types of chemical bond found in simple compounds. The noble gases are in Group 0 of the periodic table of the elements.

noble gases

To remember the noble gases:

He neatly **ar**ranges **Kr**emlin e**xe**cutive **ra**nks

Helium, **ne**on, **ar**gon, **kr**ypton, **x**enon, **ra**don

---

noble gas structure

configuration of electrons in noble gases (rare gases): helium, neon, argon, krypton, xenon, and radon.

This is characterized by full electron shells around the nucleus of an atom, which render the element stable. Any ion, produced by the gain or loss of electrons, that achieves an electronic configuration similar to one of the noble gases is said to have a noble gas structure.

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node

in physics, a position in a standing wave pattern at which there is no vibration. Points at which there is maximum vibration are called **antinodes**. Stretched strings, for example, can show nodes when they vibrate. Guitarists can produce special effects (harmonics) by touching a sounding string lightly to produce a node.

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nodule

in geology, a lump of mineral or other matter found within rocks or formed on the seabed surface; mining technology is being developed to exploit them.

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noise

unwanted sound. Permanent, incurable loss of hearing can be caused by prolonged exposure to high noise levels (above 85 decibels). Over 55 decibels on a daily outdoor basis is regarded as an unacceptable level. In scientific and engineering terms, a noise is any random, unpredictable signal.

noise pollution

Noise is a recognized form of pollution, but is difficult to measure because the annoyance or discomfort caused varies between individuals. If the noise is in a narrow frequency band, temporary hearing loss can occur even though the level is below 85 decibels or exposure is only for short periods. Lower levels of noise are an irritant, but seem not to increase fatigue or affect efficiency to any great extent. Loss of hearing is a common complaint of people working on factory production lines or in the construction and road industry. Minor psychiatric disease, stress-related ailments including high blood pressure, and disturbed sleep patterns are regularly linked to noise, although the causal links are in most cases hard to establish. Loud noise is a major pollutant in towns and cities. The European Commission announced in 1998 that every EU city with a population of more than 250,000 will have to produce 'noise maps' by 2002, as part of its directive to reduce noise pollution. An estimated 80 million people suffer daily through excessive noise in the EU. Workers in noisy places should wear ear defenders. Barriers such as lines of trees, or walls, can be used as barriers to reduce noise levels near sources such as motorways.

electronic noise

Electronic noise takes the form of unwanted signals generated in electronic circuits and in recording processes by stray electrical or magnetic fields, or by temperature variations. In electronic recording and communication systems, **white noise** frequently appears in the form of high frequencies, or hiss. The main advantages of digital systems are their relative freedom from such noise and their ability to recover and improve noise-affected signals.

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nomadic pastoralism

farming system where animals (cattle, goats, camels) are taken to different locations in order to find fresh pastures. It is practised in the developing world; out of an estimated 30-40 million (1990) nomadic pastoralists worldwide, most are in central Asia and the Sahel region of West Africa. Increasing numbers of cattle may lead to overgrazing of the area and desertification.

The increasing enclosure of land has reduced the area available for nomadic pastoralism and, as a result, this system of farming is under threat. The movement of farmers in this way contrasts with sedentary agriculture.

nomadic pastoralism

(Image © Research Machines plc)

Cows in Dareda, Tanzania. With so little arable land available, many parts of the developing world practise nomadic pastoralism, where animals are moved around to find fresh pastures and grazing grounds.

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non-metal

one of a set of elements (around 20 in total) with certain physical and chemical properties opposite to those of metal elements. The division between metal and non-metal elements forms the simplest division of the periodic table of the elements. Common physical properties are that non-metals have low electrical conductivity, are brittle when solid, or are gases or liquids. Exceptions include graphite, a form of carbon, which is a good electrical conductor.

In structure the non-metals are very diverse. Hydrogen (H), oxygen (O), nitrogen (N), fluorine (F), chlorine (Cl), and the noble gases (rare gases), helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radioactive radon (Rn), are gases. Only bromine (Br) is a liquid at room temperature, and the rest are solids.

Non-metals are the chemical opposites of metals. Metals form positively charged ions or cations; non-metals form negatively charged ions or anions. The exceptions are the chemically unreactive noble gases (rare gases), although xenon does react under certain conditions. Non-metals are electronegative, which means that they are able to gain electrons when bonding with metals. Apart from the noble gases, the non-metal elements have incomplete outer electron shells, and so try to gain enough electrons to fill them. The noble gases do not react because they already have complete outer electron shells. The type of bonding where ions are formed is known as ionic bonding. Non-metals may also share electrons with other non-metal elements to complete their outer shell; this type of bonding is known as covalent bonding.

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non-renewable resource

natural resource, such as coal, oil, or natural gas, that takes millions of years to form naturally and therefore cannot be replaced once it is consumed; it will eventually be used up. The main energy sources used by humans are non-renewable; renewable resources, such as solar, tidal, wind, and geothermal power, have so far been less exploited.

Fossil fuels like coal, oil, and gas generate a considerable amount of energy when they are burnt (the process of combustion). Non-renewable resources have a high carbon content because their origin lies in the photosynthetic activity of plants millions of years ago. The fuels release this carbon back into the atmosphere as carbon dioxide. The rate at which such fuels are being burnt is thus resulting in a rise in the concentration of carbon dioxide in the atmosphere, a cause of the greenhouse effect.

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nonsteroidal anti-inflammatory drug

full name of NSAID.

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nonvolatile memory

in computing, memory that does not lose its contents when the power supply to the computer is disconnected.

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noradrenaline

in the body, a hormone that acts directly on specific receptors to stimulate the sympathetic nervous system. Released by nerve stimulation or by drugs, it slows the heart rate mainly by constricting arterioles (small arteries) and so raising blood pressure. It is used therapeutically to treat shock.

Norfolk terrier

breed of dog identical to the Norwich terrier except that the ears drop forward rather than being pricked.

NOR gate

in electronics, a type of logic gate.

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normal distribution curve

bell-shaped curve that results when a normal distribution is represented graphically by plotting the distribution $f(x)$ against x. The curve is symmetrical about the mean value.

North Atlantic Drift

warm ocean current in the North Atlantic Ocean; an extension of the Gulf Stream. It flows east across the Atlantic and has a mellowing effect on the climate of northwestern Europe, particularly the British Isles and Scandinavia.

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northern lights

common name for the aurora borealis.

Northrop, John Howard (1891-1987)

US chemist. He was awarded the Nobel Prize for Chemistry in 1946 for his work in the 1930s when he crystallized a number of enzymes, including pepsin and trypsin, showing conclusively that they were proteins. He shared the award with Wendell Stanley and James Sumner.

Norwich terrier

small compact breed of terrier. It has a hard and wiry coat, that is close-lying and straight, and is coloured red, black, and tan; red grizzle; or grizzle and tan. Its head is rather foxlike, the muzzle being rather short and the skull wide between the erect ears. The legs are short, straight, and strong; the tail is traditionally docked. The height is usually 25 cm/10 in and the weight 5-6 kg/11-13 lb.

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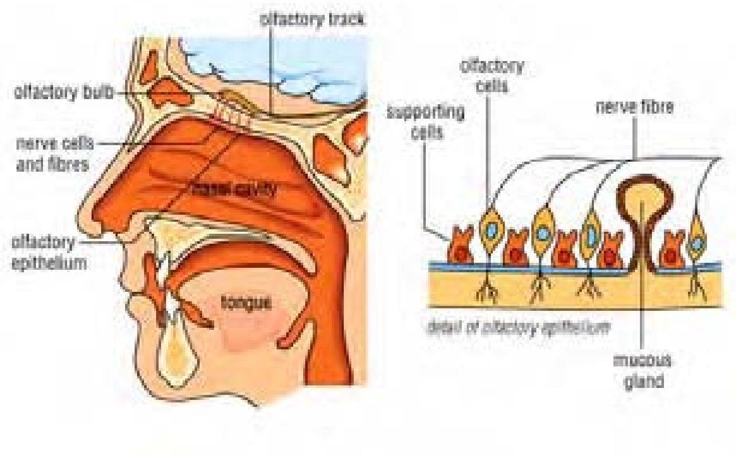
nose

in humans, the upper entrance of the respiratory tract; the organ of the sense of smell. The external part is divided down the middle by a septum of cartilage. The nostrils contain plates of cartilage that can be moved by muscles and have a growth of stiff hairs at the margin to prevent foreign objects from entering. The whole nasal cavity is lined with a mucous membrane that warms and moistens the air as it enters and ejects dirt. In the upper parts of the cavity the membrane contains 50 million olfactory receptor cells (cells sensitive to smell).

nose



(Image © Research Machines plc)

The structure of the nose. The organs of smell are confined to a small area in the roof of the nasal cavity. The olfactory cells are stimulated when certain molecules reach them. Smell is one of our most subtle senses: tens of thousands of smells can be distinguished. By comparison, taste, although closely related to smell, is a crude sensation. All the subtleties of taste depend upon smell.

nosebleed

or epistaxis

bleeding from the nose. It may be caused by injury, infection, high blood pressure, or some disorders of the blood. Although usually minor and easily controlled, the loss of blood may occasionally be so rapid as to be life-threatening, particularly in small children. Most nosebleeds can be stopped by simply squeezing the nose for a few minutes with the head held forwards, but in exceptional cases transfusion may be required and the nose may need to be packed with ribbon gauze or cauterized.

nosocomial

description of any infection acquired in a hospital or other medical facility, whether its effects are seen during the patient's stay or after discharge. Widely prevalent in some hospitals, nosocomial infections threaten patients who are seriously ill or whose immune systems have been suppressed. The threat is compounded by the prevalence of drug-resistant pathogens endemic to the hospital environment.

nostril

in vertebrates, the opening of the nasal cavity, in which cells sensitive to smell are located. (In fish, these cells detect water-borne chemicals, so they are effectively organs of taste.) In vertebrates with lungs, the nostrils also take in air. In humans, and most other mammals, the nostrils are located on the nose.

NOT gate

or inverter gate

in electronics, a type of logic gate.

notifiable disease

any disease of humans or animals that must be notified, by law, to a health officer or local authority. The majority of these diseases are serious infectious diseases, such as meningitis, tetanus, and whooping cough in humans and anthrax and foot and mouth in sheep and cows. Some industrial diseases, such as lung diseases related to the inhalation of asbestos, are also notifiable.

notochord

stiff but flexible rod that lies between the gut and the nerve cord of all embryonic and larval chordates, including the vertebrates. It forms the supporting structure of the adult lancelet, but in vertebrates it is replaced by the vertebral column, or spine.

nova

plural novae

faint star that suddenly erupts in brightness by 10,000 times or more, remains bright for a few days, and then fades away and is not seen again for very many years, if at all. Novae are believed to occur in close binary star systems, where gas from one star flows to a companion white dwarf. The gas ignites and is thrown off in an explosion at speeds of 1,500 kps/930 mps or more. Unlike a supernova, the star is not completely disrupted by the outburst. After a few weeks or months it subsides to its previous state; it may erupt many more times.

Although the name comes from the Latin 'new', photographic records show that such stars are not really new, but are faint stars undergoing an outburst of radiation that temporarily gives them an absolute magnitude in the range -6 to -10, at least 100,000 times brighter than the Sun. They fade away, rapidly at first and then more slowly over several years. Two or three such stars are detected in our Galaxy each year, but on average one is sufficiently close to us to become a naked-eye object only about once in ten years. Novae very similar to those appearing in our own Galaxy have also been observed in other galaxies.

Novocaine

trade name of **procaine**, the first synthetic local anaesthetic, invented in 1905. It is now seldom used, having been replaced by agents such as lignocaine. It is as effective as cocaine, formerly used as a painkiller, when injected, but only one third as toxic and not habit-forming.

NSAID

abbreviation for non-steroidal anti-inflammatory drug

any of a class of drugs used in the long-term treatment of rheumatoid arthritis and osteoarthritis; they act to reduce swelling and pain in soft tissues. Bleeding into the digestive tract is a serious side effect: NSAIDs should not be taken by persons with peptic ulcers.

NTP

abbreviation for **normal temperature and pressure**, the former name for **STP** (standard temperature and pressure).

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nuclear energy

or atomic energy

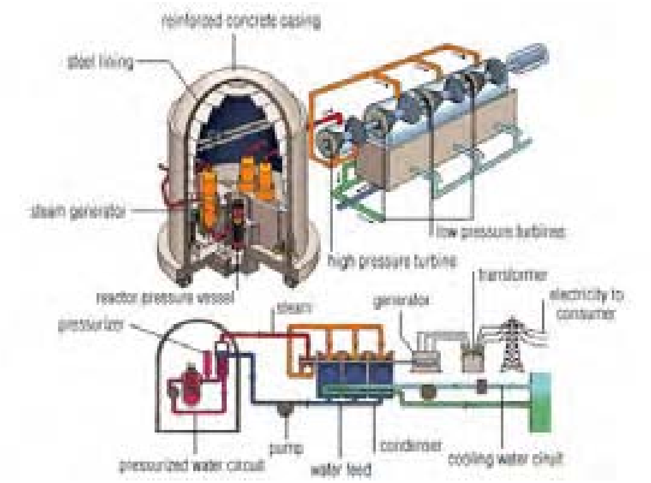
energy released from the inner core, or nucleus, of the atom. Energy produced by nuclear fission (the splitting of certain atomic nuclei) has been harnessed since the 1950s to generate electricity, and research continues into the possible controlled use of nuclear fusion (the fusing, or combining, of atomic nuclei).

In nuclear power stations, fission of radioactive substances (see radioactivity) takes place, releasing large amounts of heat energy. The heat is used to produce the steam that drives turbines and generators, producing electrical power.

Nuclear energy is produced from the transformation of matter into energy. The amount of energy can be calculated from Einstein's equation, $E = mc^2$, where E is the heat energy given out, m is the mass of radioactive substance, and c is the speed of light.

The Sun is an example of a natural nuclear reactor. Millions of atoms of hydrogen fuse together to form millions of atoms of helium, generating a continuous supply of heat and light energy. This is called a fusion reaction. A hydrogen bomb obtains its energy from a fusion reaction.

nuclear energy



(Image © Research Machines plc)

A pressurized water nuclear power station. Water at high pressure is circulated around the reactor vessel where it is heated. The hot water is pumped to the steam generator where it boils in a separate circuit; the steam drives the turbines coupled to the electricity generator. This is the most widely used type of reactor. More than 20 countries have pressurized water reactors.

Nuclear energy: key dates

1896	French physicist Henri Becquerel discovers radioactivity.
1905	In Switzerland, Albert Einstein shows that mass can be converted into energy.
1911	New Zealand physicist Ernest Rutherford proposes the nuclear model of the atom.
1919	Rutherford splits the atom, by bombarding a nitrogen nucleus with alpha particles.
1939	Otto Hahn, Fritz Strassman, and Lise Meitner announce the discovery of nuclear fission.
1942	Enrico Fermi builds the first nuclear reactor, in a squash court at the University of Chicago, USA.
1946	The first fast reactor, called Clementine, is built at Los Alamos, New Mexico.
1951	The Experimental Breeder Reactor, Idaho, USA, produces the first electricity to be generated by nuclear energy.
1954	The first reactor for generating electricity is built in the USSR, at Obninsk.
1956	The world's first commercial nuclear power station, Calder Hall, comes into operation in the UK.
1957	The release of radiation from Windscale (now Sellafield) nuclear power station, Cumbria, England, causes 39 deaths to 1977. In Kyshym, USSR, the venting of plutonium waste causes high but undisclosed casualties (30 small communities are deleted from maps produced in 1958).
1958	Experimental fast reactor built in Dounreay, northern Scotland.
1979	Nuclear-reactor accident at Three Mile Island, Pennsylvania, USA.
1986	An explosive leak from a reactor at Chernobyl, the Ukraine, results in clouds of radioactive material spreading as far as Sweden; 31 people are killed and thousands of square kilometres are contaminated.
1991	The first controlled and substantial production of nuclear-fusion energy (a two-second pulse of 1.7 megawatts) is achieved at JET, the Joint European Torus, at Culham, Oxfordshire, England.
1994	The world record for producing nuclear fusion energy is broken at the Tokamak Fusion Test Reactor at Princeton University, New Jersey. The Princeton tokamak produces 9 megawatts of power.
1995	Sizewell B, the UK's first pressurized-water nuclear reactor and the most advanced nuclear power station in the world, begins operating in Suffolk, England.
1996	British Nuclear Fuels is fined £25,000 after safety failures that result in a worker becoming contaminated with radioactivity.
1997	English physicists at JET (Joint European Torus) fuse isotopes of deuterium and tritium to produce a record 12 megawatts of nuclear-fusion power.
2006	An agreement to build the International Thermonuclear Experimental Reactor is agreed. The reactor will be built in France and aims to demonstrate the viability of nuclear fusion energy.

DOE: Division of Nuclear Physics

Go to site

Latest news from US Department of Energy's Division of Nuclear Physics. There are details of research programmes and – linking to the relevant centre – an interactive map of nuclear research facilities.

Nuclear Energy: Frequently Asked Questions

Go to site

Answers to the most commonly asked questions about nuclear energy, particularly with a view to sustaining human progress. It contains many links to related pages and is a personal opinion that openly asks for comment from visitors.

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nuclear fusion

process in which two atomic nuclei are fused, with the release of a large amount of energy. Very high temperatures and pressures are required for the process. Under these conditions the atoms involved are stripped of all their electrons so that the remaining particles, which together make up a **plasma**, can come close together at very high speeds and overcome the mutual repulsion of the positive charges on the atomic nuclei. At very close range the strong nuclear force will come into play, fusing the particles to form a larger nucleus. As fusion is accompanied by the release of large amounts of energy, the process might one day be harnessed to form the basis of commercial energy production. Methods of achieving controlled fusion are therefore the subject of research around the world.

Fusion is the process by which the Sun and the other stars produce their energy. Power generation by fusion would not produce the vast amounts of dangerous nuclear waste that are a by-product of nuclear fission.

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nuclear magnetic resonance

NMR

in medicine, scanning technique used to produce images of the organs in the body. It is another term for magnetic resonance imaging (MRI).

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nuclear medicine

in medicine, the use of radioactive isotopes in the diagnosis, investigation, and treatment of disease. See radioisotope scanning.

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nuclear notation

method used for labelling an atom according to the composition of its nucleus. The atoms or isotopes of a particular element are represented by the symbol ${}^{A}{}_{Z}X$ where A is the mass number of their nuclei, Z is their atomic number, and X is the chemical symbol for that element.

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nuclear physics

study of the properties of the nucleus of the atom, including the structure of nuclei; nuclear forces; the interactions between particles and nuclei; and the study of radioactive decay. The study of elementary particles is particle physics.

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nuclear reaction

reaction involving the nuclei of atoms. Atomic nuclei can undergo changes either as a result of radioactive decay, as in the decay of radium to radon (with the emission of an alpha particle):

$${}^{226}{}_{88}\mathrm{Ra} \rightarrow {}^{222}{}_{86}\mathrm{Rn} + {}^{4}{}_{2}\mathrm{He}$$

or as a result of particle bombardment in a machine or device, as in the production of cobalt-60 by the bombardment of cobalt-59 with neutrons:

$${}^{59}{}_{27}\mathrm{Co} + {}^{1}{}_{0}\mathrm{n} \rightarrow {}^{60}{}_{27}\mathrm{Co} + \gamma.$$

Nuclear fission and nuclear fusion are examples of nuclear reactions. The enormous amounts of energy released arise from the mass-energy relation put forward by Einstein, stating that $E = mc^2$ (where E is energy, m is mass, and c is the velocity of light).

In nuclear reactions the sum of the masses of all the products is less than the sum of the masses of the reacting particles. This lost mass is converted to energy according to Einstein's equation.

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nuclear reactor

device for producing nuclear energy in a controlled manner. There are various types of reactor in use, all using nuclear fission. In a **gas-cooled reactor**, a circulating gas under pressure (such as carbon dioxide) removes heat from the core of the reactor, which usually contains natural uranium. The efficiency of the fission process is increased by slowing neutrons in the core by using a moderator such as carbon. The reaction is controlled with neutron-absorbing rods made of boron. An **advanced gas-cooled reactor** (AGR) generally has enriched uranium as its fuel. A **water-cooled reactor**, such as the steam-generating heavy water (deuterium oxide) reactor, has water circulating through the hot core. The water is converted to steam, which drives turbo-alternators for generating electricity. The most widely used reactor is the **pressurized-water reactor** (PWR), which contains a sealed system of pressurized water that is heated to form steam in heat exchangers in an external circuit. The **fast reactor** has no moderator and uses fast neutrons to bring about fission. It uses a mixture of plutonium and uranium oxide as fuel. When operating, uranium is converted to plutonium, which can be extracted and used later as fuel. It is also called the fast breeder or breeder reactor because it produces more plutonium than it consumes. Heat is removed from the reactor by a coolant of liquid sodium.

Public concern over the safety of nuclear reactors has been intensified by explosions and accidental release of radioactive materials. The safest system allows for the emergency cooling of a reactor by automatically flooding an overheated core with water. Other concerns about nuclear power centre on the difficulties of reprocessing nuclear fuel and disposing safely of nuclear waste, and the cost of maintaining nuclear power stations and of decommissioning them at the end of their lives. The break up of the former USSR raised concerns about the ability of the new nation states to safely manage ageing reactors. In 1989 the UK government decided to postpone the construction of new nuclear power stations; in the USA, no new stations have been commissioned in over a decade. Rancho Seco, near Sacramento, California, was the first nuclear power station to be closed, by popular vote, in 1989. Sweden is committed to decommissioning its reactors. Some countries, such as France, are pressing ahead with their nuclear programmes. It was reported in 1997 that there were 443 nuclear power plants in 31 countries, representing a net growth of 15 since the 1992 Rio Earth Summit, and a further 36 were under construction. This compares with a total of just over 100 reactors generating electricity in 15 countries in 1972. Nuclear power generates around 17% of the world's electricity. Major accidents resulting in the release of large quantities of radiation occurred at Chernobyl, Ukraine, in 1986 and, on a far smaller scale, at Three Mile island in the USA in 1979.

Nuclear Reactor: The First

the first nuclear reactor

The world's first nuclear reactor was built in a squash court under Stagg Field football ground at the University of Chicago. On 2 Dec 1942 a team led by Italian physicist Enrico Fermi demonstrated a controlled self-sustaining nuclear chain reaction, opening the way to modern nuclear power and nuclear weapons.

the construction of the reactor

The reactor – or 'atomic pile' – comprised 400 tonnes of graphite made into 45,000 bricks and built in layers into a structure about 6 m/20 ft high. Sixty tonnes of uranium was pressed into 22,000 small cylinders fitted into slots in the graphite, which slowed the neutrons produced by the splitting of the uranium nuclei. Cadmium control rods in the pile soaked up excess neutrons to control the reaction.

The pile took less than a month to build, following intensive research starting with the discovery of nuclear fission in 1939. Fermi had worked on the design for six months, calculating the amount of uranium needed, and the best arrangement of the fuel and graphite. The work was dirty; black graphite dust got everywhere. The team was never free of it; even after showering, it continued to ooze out of their skin pores. They worked non-stop, knowing that the Nazis were also working to master nuclear power. Fermi, however, believed in regular routine. He always stopped at midday for lunch, and always went home at 5 p.m. Team member Albert Wattenberg recalls: 'He made everything look very logical and straightforward and he never made mistakes. It was eight years before I remember him making a mathematical mistake.'

time for lunch

During the morning of 2 Dec 1942, Fermi began fine-tuning the pile, measuring the neutrons being produced. A single cadmium control rod regulated the neutron flow. The task was to determine how far to withdraw the rod for a chain reaction to proceed. Shortly before noon, there was a loud bang. Alarm followed – until the team realized that the safety control rod had operated automatically to shut the reactor down. The cutoff had been set too low. Fermi decided it was time for a break. 'I'm hungry; let's go to lunch', he said. Lunch was quiet; no-one talked about the experiment. Fermi sat silent and preoccupied.

the first self-sustaining reaction

Back at work at 2 p.m., they eased the control rod out further. The instruments showing the reaction rate went off the scale and had to be reset; but the reaction was still not self-sustaining. Finally at 3.25 p.m., Fermi asked for the control rod to be withdrawn another foot. 'This is going to do it. Now it will become self-sustaining. The trace will climb and continue to climb – it will not level off.' The rod was withdrawn and the reaction rate climbed. Team member Harold Agnew remembers: 'Hearing the counters going faster and faster and seeing the pen recorders continue to rise was scary.' Fermi did rapid calculations on his sliderule. The reaction counters clicked increasingly rapidly until they became a continuous buzz. After a few minutes, Fermi looked up from his calculations with a broad smile. 'The reaction is self-sustaining', he announced.

The reactor was allowed to operate for 28 minutes; at 3.53 p.m. Fermi told Wally Zinn to insert the control rod. The neutron rate dropped immediately. The first controlled nuclear chain reaction had stopped. Agnew recalls: 'No smoke, no smell. It was over and we were back where we were that morning. And the outside world was unaware of what had happened.'

celebrations

The scientists applauded softly, aware of their work's implications. A bottle of Chianti was produced and the team drank to their success from paper cups. The wicker basket around the bottle was signed by several of the experimenters. All 43 people present knew what the future held. They fell silent and turned towards Fermi. Hungarian scientist Leo Szilard, an important team member, said, 'This will go down as a black day in the history of mankind.' Fermi's reply is not recorded.

Enrico sinks the admiral

The breakthrough was not announced publicly. Wartime secrecy prevailed; even Fermi's wife Laura did not learn of the success until after the war. At a party held after the successful experiment, she asked Leona Woods, the only woman in the team, what was being celebrated. 'Enrico has sunk a Japanese admiral', was the cryptic reply. The need for secrecy was paramount when Arthur Compton, in charge of the US nuclear weapons project, telephoned a colleague at Harvard with the news: 'The Italian navigator has landed in the New World', he said. 'How were the natives?' came the reply. 'Very friendly.' Compton answered.

The reactor did not operate again. In Feb 1943 it was dismantled and some of its parts used to make another reactor. The graphite blocks were eventually ground down to make ink to print invitations to the 40th anniversary celebrations, and to make into pencils given away as souvenirs.

Advanced Reactors

Go to site

Overview of the features of the next generation of nuclear reactors currently being developed around the world. This 'Nuclear issues briefing paper', from Australia, focuses on the reactors currently being developed in the USA, Japan, France, Germany, and Canada.

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nuclear safety

measures to avoid accidents in the operation of nuclear reactors and in the production and disposal of nuclear weapons and of nuclear waste. There are no guarantees of the safety of any of the various methods of disposal. Nuclear safety is a controversial subject – some governments do not acknowledge the hazards of atomic radiation and radiation sickness.

nuclear accidents

Windscale (now Sellafield), Cumbria, England. In 1957 fire destroyed the core of a reactor, releasing large quantities of radioactive fumes into the atmosphere. In 1990 a scientific study revealed an increased risk of leukaemia in children whose fathers had worked at Sellafield between 1950 and 1985.

Ticonderoga, 130 km/80 mi off the coast of Japan. In 1965 a US Navy Skyhawk jet bomber fell off the deck of this ship, sinking in 4,900 m/16,000 ft of water. It carried a one-megaton hydrogen bomb. The accident was only revealed in 1989.

Three Mile Island, Harrisburg, Pennsylvania, USA. In 1979 a combination of mechanical and electrical failure, as well as operator error, caused a pressurized water reactor to leak radioactive matter.

Church Rock, New Mexico, USA. In July 1979, 380 million litres/100 million gallons of radioactive water containing uranium leaked from a pond into the Rio Purco, causing the water to become over 6,500 times as radioactive as safety standards allow for drinking water.

Chernobyl, Ukraine. In April 1986 there was an explosive leak, caused by overheating, from a nonpressurized boiling-water reactor, one of the largest in Europe. The resulting clouds of radioactive material spread as far as the UK. Thirty-one people were killed in the explosion, and thousands of square kilometres of land were contaminated by fallout. By June 1992, seven times as many children in the Ukraine and Belarus were contracting thyroid cancer as before the accident, and the incidence of leukaemia was rising; it was estimated that more than 6,000 people had died as a result of the accident, and that the death toll in the Ukraine alone would eventually reach 40,000.

Tomsk, Siberia, Russia. In April 1993 a tank exploded at a uranium reprocessing plant, sending a cloud of radioactive particles into the air.

Nuclear Safety Department

Go to site

Presents the work of the International Atomic Energy Agency's Nuclear Safety Department. The Web site has documents under the three departmental sections: nuclear installation safety, safety coordination, and radiation protection and waste safety.

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nuclear waste

the radioactive and toxic by-products of the nuclear energy and nuclear weapons industries. Nuclear waste may have an active life of several thousand years. Reactor waste is of three types: **high-level** spent fuel, or the residue when nuclear fuel has been removed from a reactor and reprocessed; **intermediate**, which may be long-or short-lived; and **low-level**, but bulky, waste from reactors, which has only short-lived radioactivity. Disposal, by burial on land or at sea, has raised problems of safety, environmental pollution, and security.

The issue of nuclear waste is becoming the central controversy threatening the future of generating electricity by nuclear energy. The dumping of nuclear waste at sea officially stopped in 1983, when a moratorium was agreed by the members of the London Dumping Convention (a United Nations body that controls disposal of wastes at sea). Covertly, the USSR continued dumping, and deposited thousands of tonnes of nuclear waste and numerous faulty reactors in the sea during 1964-86. Russia has no way of treating nuclear waste and in 1993 announced its intention of continuing to dump it in the sea, in violation of international conventions, until 1997.

Nuclear Waste: Disposal of

what's to be done with nuclear waste?

Although it is over 50 years since scientists achieved controlled nuclear fission, the question of what to do about nuclear waste is as controversial as ever.

the dangers

Nuclear waste comes from nuclear power stations, nuclear weapons, uranium mines, and waste from medical and industrial uses of nuclear energy. It is one of the most hazardous of all waste products, because it releases dangerous forms of radiation, capable of causing a range of immediate and long-term health effects including radiation sickness, cancer, and birth defects. Some nuclear waste products can stay dangerously radioactive for many thousands of years, thus creating a disposal problem of a type and scale not met previously.

Nuclear waste can be categorized into three main types: high-, medium-, and low-level waste. The spent uranium rods from nuclear power stations are among the highest-level waste products, as are certain nuclear-weapon components. Less radioactive waste includes protective suits, cooling water used in power stations, and medical equipment.

nuclear waste in the environment

Radiation in nuclear waste cannot be destroyed by burning or industrial processes, and people regulating nuclear waste have a choice of storing it indefinitely, releasing it into the environment in the hope that it will disperse to nontoxic levels, or, in the case of some high-level wastes, reprocessing it to remove usable fuel.

In practice, all three options are used. When nuclear power was first used, far less was known about its hazards, and large amounts of low-level waste were simply discharged into the environment, ending up in the air, in rivers and oceans, and sometimes in the soil. Since then, there has been a steady decrease in what is judged 'acceptable' levels of radiation from the point of view of human health and a consequent tightening of controls over discharges.

the damage already caused

Unfortunately, a lot of damage has already been done. Despite some changes in regulations, low-level waste is still lost by accident or design. Evidence collected by the environmental organization Greenpeace confirmed suspicions that the Soviet navy used to dump reactors from nuclear submarines in Arctic seas, some of them with fuel still inside. Clusters of child leukaemia around some of the UK's nuclear facilities have caused a storm of controversy among researchers, with some believing that they point to a link with discharges of radiation, and others saying that the statistical probability of a link with the nuclear-power programme remains tenuous. Radiation from past and present uranium mines continues to cause problems in Namibia, the USA, and elsewhere.

storing nuclear waste

Many nuclear operations now choose to store their waste, until either the radioactivity has fallen to background levels or new disposal techniques are developed. The lowest-level waste, such as radioactive test tubes or tissue paper, are buried in metal containers in shallow trenches. Some countries have built concrete storage tanks for low- and intermediate-level waste, such as that in Drigg, Cumbria, in the UK. High-level waste – for example, used fuel rods or other components of a nuclear reactor – is sometimes stored underwater until the most intense radioactivity has dissipated.

Although many methods have been suggested for the long-term storage of waste, all these have their problems. Options include burial deep underground, with the waste vitrified (encased in glass), deposited in deep-sea trenches, or buried in polar icecaps. Some nuclear scientists even suggest blasting it off into space by rocket.

None of these alternatives is without serious problems. Space disposal would be extremely expensive and hazardous in case of accident. Sea dumping is banned by international treaty. Burial underground is the most favoured option at present but, given the enormous time scale involved, it is impossible for us to be sure that containers would not corrode, be displaced by earth movements, and otherwise leak their contents. Simply moving nuclear waste, by sea, air, road or rail, risks further accidents and escapes of radioactive material.

reprocessing: the most controversial option of all

The third disposal option, for high-level waste from spent fuel, includes reprocessing to extract remaining uranium and also another fissionable material, plutonium. The latter can be used to make nuclear weapons or nuclear fuel.

Reprocessing has long been favoured by the nuclear industry, partly because of greater fuel-use efficiency and partly because the close links between civilian and military nuclear programmes in many countries makes plutonium production an attractive option.

One of the best-known reprocessing facilities is Sellafield (once known as Windscale) in Cumbria, which processes nuclear waste from many parts of the world. The complex has long been the subject of intense controversy. It suffered a serious accident in 1957, and a continuing series of more minor leaks and emissions since. Although reprocessing recovers some of the most intensely radioactive material, it also produces large amounts of low-level waste, particularly cooling water and gases, which are released. Discharges from Sellafield have made the Irish Sea the world's most radioactive ocean.

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nucleic acid

complex organic acid made up of a long chain of nucleotides, present in the nucleus and sometimes the cytoplasm of the living cell and in viruses. The two types, known as DNA (deoxyribonucleic acid) and RNA (ribonucleic acid), form the basis of heredity. The nucleotides are made up of a sugar (deoxyribose or ribose), a phosphate group, and one of four purine or pyrimidine bases. In protein genes, the order of the bases along the nucleic acid strand contains the information that can be translated into an amino acid sequence according to the genetic code.

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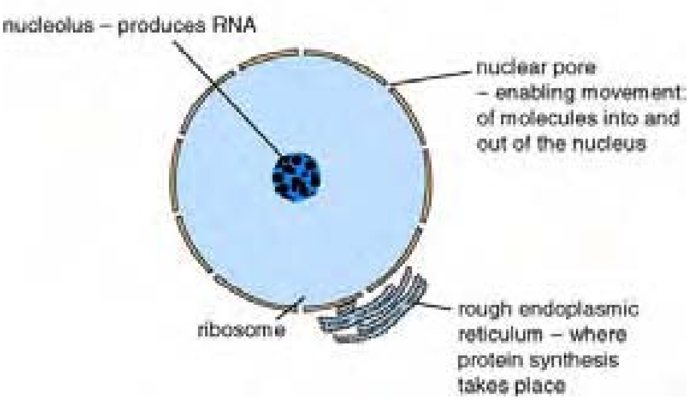
nucleolus

in biology, an RNA-rich structure found in the nucleus of eukaryotic cells. It produces the RNA that makes up the ribosomes, from instructions in the DNA.

nucleolus


nucleolus – produces RNA
nuclear pore – enabling movement of molecules into and out of the nucleus
ribosome
rough endoplasmic reticulum – where protein synthesis takes place

(Image © Research Machines plc)

The nucleolus is found in the nucleus. It contains the nucleolar organizers, the regions on some chromosomes containing genes that code for ribosome synthesis. An average, healthy cell can produce up to 10,000 ribosomes per minute.

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nucleon

in particle physics, either a proton or a neutron, when present in the atomic nucleus. **Nucleon number** is an alternative name for the mass number of an atom.

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nucleotide

organic compound consisting of a purine (adenine or guanine) or a pyrimidine (thymine, uracil, or cytosine) base linked to a sugar (deoxyribose or ribose) and a phosphate group. DNA and RNA are made up of long chains of nucleotides.

nucleotides

To remember classes of nucleotides:

In DNA there are four nucleotides (cytosine, thymine, adenine, guanine) divided into two classes (pyrimidines and purines). The easiest way to remember which class they belong to is that the p**y**rimidines contain the letter **y** (cytosine and thymine)

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nucleus

in astronomy, compact central core of a galaxy, often containing powerful radio, X-ray, and infrared sources. Active galaxies have extremely energetic nuclei.

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nucleus

in biology, the central, membrane-enclosed part of a eukaryotic cell, containing threads of DNA. It is found in both plant and animal cells. During cell division the threads of DNA coil up to form chromosomes. The nucleus controls the function of the cell by determining which proteins are produced within it. It is where inherited information is stored as genes. Because proteins are the chief structural molecules of living matter and, as enzymes, regulate all aspects of metabolism, it may be seen that the genetic code within the nucleus is effectively responsible for building and controlling the whole organism.

The nucleus contains the **nucleolus**, the part of the cell where ribosomes are produced. Movement of molecules into and out of the nucleus occurs through the nuclear pores. An average mammalian nucleus has approximately 3,000 pores.

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nucleus

plural nuclei

in physics, the positively-charged central part of an atom, which constitutes almost all its mass. Except for hydrogen nuclei, which have only one proton, nuclei are composed of both protons and neutrons. Surrounding the nucleus are electrons, of equal and opposite charge to that of the protons, thus giving the atom a neutral charge. Nuclei that are unstable may undergo radioactive decay or nuclear fission. In all stars, including our Sun, small nuclei join together to make more stable, larger nuclei. This process is called nuclear fusion.

The nucleus was discovered by the New Zealand-born British physicist Ernest Rutherford in 1911 as a result of experiments in firing alpha particles through very thin gold foil.

Nucleus: Early Experiments to Determine Structure

the most incredible event

What is an atom? Until about 100 years ago, scientists were pretty confident in regarding atoms as the permanent bricks of which the whole universe was built. All the changes of the universe amounted to nothing more drastic than simple rearrangements of permanent, indestructible atoms. Atoms seemed like the bricks in a child's box of toys, which could be used to build many different buildings in turn.

chipped bricks ..

This comfortable picture was changed by the investigations of British physicist Joseph John Thomson (1856-1940) into cathode rays. Thomson showed conclusively that not only could atomic 'bricks' be chipped, but that the fragments produced were identical, no matter what atom they came from. They were of equal weight or mass, and carried the same negative electrical charge. The fragments were called electrons.

Thomson's experiments enabled him to calculate the ratio of the mass of the electron to its charge: it was about 1,000 times smaller than the value that had already been calculated for a hydrogen ion in the electrolysis of liquids. This was the proof, announced in April 1897, that electrons were fundamental particles of matter, far smaller than any atom. But atoms could not consist of negatively charged electrons alone. Particles with like electrical charge repel one another and, anyway, atoms are electrically neutral.

Thomson, who built up the Cavendish Laboratory at Cambridge into a great research school, was succeeded as professor by New Zealand physicist Ernest Rutherford (1871-1937), his pupil and one of the greatest pioneers of subatomic physics. Rutherford, while professor of physics at Manchester University, had shown that α-particles were doubly ionized helium atoms, using a Geiger-Müller counter. His assistant, German physicist Hans Wilhelm Geiger (1882-1945), with a colleague Walther Müller, invented this instrument, which is still used to measure ionizing radiation.

... and indestructible tissue paper?

Rutherford's idea for attacking the problem of the nature of an atom was to study the scattering of α-particles passing through thin metal foils. This painstaking work was carried out by Geiger in 1910 with his colleague Marsden, with astonishing results. They found that most of the particles were only slightly deflected as they passed through the foil. But a very small proportion, about 1 in 8,000, were widely deflected. Rutherford described this result as ' ... quite the most incredible event that has ever happened to me in my life ... It was almost as if you fired a 15 inch shell at a piece of tissue paper and it came back and hit you.'

the nuclear atom

Rutherford concluded when he published the results in 1911 that almost all the mass of the atom was concentrated in a very small region and that most of the atom was 'empty space'. This crucial experiment established the idea of the nuclear atom. The obstacle that deflected the α-particles could only be the missing positive charges of the atom. These were carried by the minute central nucleus. The electrons, Rutherford supposed, must be in motion around the nucleus, otherwise they would be drawn to it.

The number of positive charges in the nucleus equalled the number of electrons, and so accounted for the electrical neutrality of the atom. The proton, later discovered as part of the nucleus, carried an equal but opposite charge to the electron. But on theoretical grounds, Rutherfords's planetary model of the atom was unstable. Since electrons are charged particles, an atom ought to radiate energy by virtue of their motion. Danish theoretical physicist Niels Bohr (1885-1962), who was Rutherford's pupil, provided the theory that accounted for the stability of the atom. He showed that electrons must reside in 'stationary' orbits, in which they did not radiate energy.

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nuclide

in physics, a species of atomic nucleus characterized by the number of protons (*Z*) and the number of neutrons (*N*). Nuclides with identical proton number but differing neutron number are called isotopes.

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nuée ardente

rapidly flowing, glowing white-hot cloud of ash and gas emitted by a volcano during a violent eruption. The ash and other pyroclastics in the lower part of the cloud behave like an ash flow. In 1902 a *nuée ardente* produced by the eruption of Mount Pelee in Martinique swept down the volcano in a matter of seconds and killed 28,000 people in the nearby town of St Pierre.

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numbat

or banded anteater

Australian marsupial anteater. It is brown with white stripes on the back and has a long tubular tongue to gather termites and ants. The body is about 25 cm/10 in long, and the tongue can be extended 10 cm/4 in. It is different from other marsupials in that it has no pouch. (Species *Myrmecobius fasciatus*.)

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number

symbol used in counting or measuring. In mathematics, there are various kinds of number. The everyday number system is the decimal ('proceeding by tens') system, using the base ten.

Real numbers include all rational numbers (integers, or whole numbers, and fractions) and irrational numbers (those not expressible as fractions). **Complex numbers** include the real and imaginary numbers (real-number multiples of the square root of -1). The **binary number system**, used in computers, has two as its base. The **natural numbers**, 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9, give a counting system that, in the **decimal number system**, continues 10, 11, 12, 13, and so on. These are whole numbers (integers), with fractions represented as, for example, 1/4, 1/2, 3/4, or as decimal fractions (0.25, 0.5, 0.75). They are also **rational numbers**.

Irrational numbers cannot be represented in this way and require symbols, such as $\sqrt{2}$, π, and e. They can be expressed numerically only as the (inexact) approximations 1.414, 3.142, and 2.718 (to three places of decimals), respectively. The symbols π and e are also examples of **transcendental numbers**, because they (unlike $\sqrt{2}$) cannot be derived by solving a polynomial equation (an equation with one variable quantity) with rational coefficients (multiplying factors). Complex numbers, which include the real numbers as well as imaginary numbers, take the general form $a + bi$, where $i = \sqrt{-1}$ (that is, $i^2 = -1$), and a is the real part and bi the imaginary part.

evolution of number systems

The ancient Egyptians, Greeks, Romans, and Babylonians all evolved number systems, although none had a zero, which was introduced from India by way of Arab mathematicians in about the 8th century and allowed a place-value system to be devised on which the decimal system is based. Other number systems have since evolved and have found applications. For example, numbers to base two (binary numbers), using only 0 and 1, are commonly used in digital computers to represent the two-state 'on' or 'off' pulses of electricity. Binary numbers were first developed by German mathematician Gottfried Leibniz in the late 17th century.

Large numbers

Nomenclature for large numbers varies in different countries: in the UK and Germany numbers have traditionally advanced by increments of a million, whereas in the USA and France numbers advance by increments of a thousand. The US usage is becoming prevalent in the UK and is now universally used by economists and statisticians.

UK and Germany		
million	1,000,000	1×10^{6}
billion	1,000,000,000,000	1×10^{12}
trillion	1,000,000,000,000,000,000	1×10^{18}
quadrillion	1,000,000,000,000,000,000,000,000	1×10^{24}
USA and France		
billion	1,000,000,000	1×10^{9}
trillion	1,000,000,000,000	1×10^{12}
quadrillion	1,000,000,000,000,000	1×10^{15}
Higher numbers		
Number	**UK**	**USA**
quintillion	1×10^{30}	1×10^{18}
sextillion	1×10^{36}	1×10^{21}
septillion	1×10^{42}	1×10^{24}
octillion	1×10^{48}	1×10^{27}
nonillion	1×10^{54}	1×10^{30}
decillion	1×10^{60}	1×10^{33}
vigintillion	1×10^{120}	1×10^{63}
centillion	1×10^{600}	1×10^{303}

Arabic Numerals

Go to site

Account of how numbers developed from their ancient Indian origins to the Modern Arabic numerals that are generally used today. There is a brief description of numbering systems used by the ancient Egyptians, Greeks, and Romans, and some of the problems these systems presented. The page also includes links to aspects of Islamic and Middle Eastern history.

First Use of Zero and Negative Numbers

Go to site

Page that describes how the concept of negative numbers became part of mathematical theory.

Googolplex

Go to site

Devoted to very large numbers, starting with a 'googol' (ten to the power of 100). This is a slightly quirky mathematics site, attempting to explain numbers that are so large as to defy comprehension. There is also a program to print out one of these numbers, should you wish.

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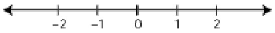
number line

in mathematics, a way of displaying consecutive numbers diagrammatically. A number line shows negative numbers to the left of zero and **positive numbers** to the right of zero, extending in each direction to infinity. A number line can be used to show integers, fractions, and/or decimal fractions.

For example:



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numerator

number or symbol that appears above the line in a vulgar fraction. For example, the numerator of 5/6 is 5. The numerator represents the fraction's dividend and indicates how many of the equal parts indicated by the denominator (number or symbol below the line) comprise the fraction.

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nursing

care of the sick, the very young, the very old, and the disabled. Organized training originated in 1836 in Germany, and was developed in Britain by the work of Florence Nightingale, who, during the Crimean War, established standards of scientific, humanitarian care in military hospitals. Nurses give day-to-day care and carry out routine medical and surgical duties under the supervision of doctors.

In ancient times very limited care was associated with some temples, and in Christian times nursing became associated with the religious orders until the Reformation brought it into secular hands in Protestant countries. Other early pioneers of nursing included the English prison reformer Elizabeth Fry, who set up the first training school for nurses in the UK; the Jamaican nurse Mary Seacole, who worked among the wounded of the Crimean War; and the US health worker Clara Barton, founder of the American Red Cross in 1881. Many specialities and qualifications now exist in Western countries, standards being maintained by professional bodies and boards.

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nut

any dry, single-seeded fruit that does not split open to release the seed, such as the chestnut. A nut is formed from more than one carpel, but only one seed becomes fully formed, the remainder aborting. The wall of the fruit, the pericarp, becomes hard and woody, forming the outer shell.

Examples of true nuts are the acorn and hazelnut. The term also describes various hard-shelled fruits and seeds, including almonds and walnuts, which are really the stones of drupes, and brazil nuts and shelled peanuts, which are seeds. The kernels of most nuts provide a concentrated, nutritious food, containing vitamins, minerals, and enzymes, about 50% fat, and 10-20% protein, although a few, such as chestnuts, are high in carbohydrates and have only a moderate protein content of 5%. Nuts also provide edible and industrial oils. Most nuts are produced by perennial trees and shrubs. Whereas the majority of nuts are obtained from plantations, considerable quantities of pecans and brazil nuts are still collected from the wild.

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nut and bolt

common method of fastening pieces of metal or wood together. The nut consists of a small block (usually metal) with a threaded hole in the centre for screwing on to a threaded rod or pin (bolt or screw). The method came into use at the turn of the 19th century, following Henry Maudslay's invention of a precision screw-cutting lathe.

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nutation

in astronomy, slight 'nodding' of the Earth in space, caused by the varying gravitational pulls of the Sun and Moon. Nutation changes the angle of the Earth's axial tilt (average 23.5°) by about 9 seconds of arc to either side of its mean position, a complete cycle taking just over 18.5 years.

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nutation

in botany, the spiral movement exhibited by the tips of certain stems during growth; it enables a climbing plant to find a suitable support. Nutation sometimes also occurs in tendrils and flower stalks.

The direction of the movements, clockwise or anticlockwise, is usually characteristic for particular species.

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nutcracker

either of two species of bird similar to a jay, belonging to the crow family. One species is found in the Old World and the other in the New World. (Genus *Nucifraga*, family Corvidae, order Passeriformes.)

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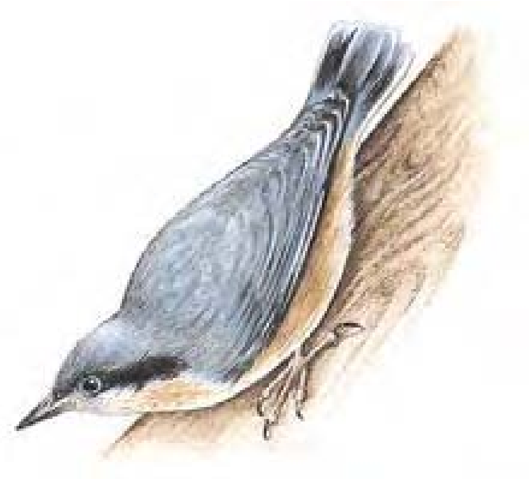
nuthatch

any of a group of small birds with short tails and pointed beaks. Nuthatches climb head first up, down, and around tree trunks and branches, foraging for insects and their larvae. (Family Sittidae, order Passeriformes.)

nuthatch



(Image © Research Machines plc)

The European nuthatch is one of about 25 species of nuthatch. They are robust little birds, with strong legs and sharp claws to help them climb. They run up and down branches and tree trunks, looking for food.

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nutmeg

kernel of the hard aromatic seed of the evergreen nutmeg tree, native to the Maluku Islands, Indonesia. Both the nutmeg and its secondary covering, known as **mace**, are used as spices in cookery. (*Myristica fragrans*, family Myristicaceae.)

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nutria

or **coypu** South American water rodent *Myocastor coypus*, about 2 ft/60 cm long and weighing up to 20 lb/9 kg. It has a scaly, ratlike tail, webbed hind feet, a blunt, muzzled head, and large, orange incisors. The fur is reddish brown. It feeds on vegetation and lives in burrows in river and lake banks.

Taken to Europe and then to North America to be farmed for their fur, many escaped or were released and became established, often to the detriment of native species. Escaped nutria in Louisiana were trapped for their fur, which controlled their numbers until trapping became unprofitable. Ecologists in 1993 developed a program to control the millions of nutria causing serious damage to Louisiana's coastal marsh.

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nutrition

strategy adopted by an organism to obtain the chemicals it needs to live, grow, and reproduce. These chemicals are nutrients that are absorbed from the environment, such as mineral salts, or chemicals made inside the body of a plant or animal. Nutrition is a term also used to describe the science of food, and its effect on human and animal life, health, and disease. Nutrition involves the study of the basic nutrients required to sustain life, their bioavailability in foods and overall diet, and the effects upon them of cooking and storage. It is also concerned with dietary deficiency diseases.

Plant nutrition is very different from animal nutrition in several ways. In a plant high-energy food (for example, carbohydrate) is made inside the plant by photosynthesis. An animal obtains high-energy food by eating a plant or another animal. Nutrients from the environment are absorbed by different parts of plant and animal bodies. In a plant, nutrients are absorbed from soil water by the roots (see root hair cell). In an animal, nutrients are absorbed from the gut by the epithelium cells lining it.

nutrition

To remember the classification of feeding methods:

All **c**ounty **p**layers **h**ave **h**undreds of **s**hots **p**erfected

Autotrophic (i. **c**hemosynthetic ii. **p**hotosynthetic), **h**eterotrophic (i. **h**olozoic ii. **s**aprophytic iii. **p**arasitic)

Reference Guide for Vitamins

Go to site

Quick reference guide to vitamins. After an overview of vitamins in general, the page describes the functions of common and obscure vitamins, and explains what happens when the body does not get enough of them.

Sports and Nutrition: The Winning Connection

Go to site

Divided into four main sections - 'Don't let your diet let you down', 'The pre-game meal planner', 'Keeping energy levels up', and 'Keeping fluid levels up' - this site contains lots of ideas and advice on eating healthily when undertaking lots of physical exercise. Each section contains a lengthy introduction to the topic, and then links to a quick summary of points to be aware of.

Types of Diet

Go to site

Examines the various types of nutrition, what they are and what they mean in nutritional terms. These range from 'Omnivorous' to 'Industrialized'.

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nylon

synthetic long-chain polymer similar in chemical structure to protein. Nylon was the first fully synthetic fibre. Made from petroleum, natural gas, air, and water, nylon was developed in 1935 by the US chemist W H Carothers and his associates, who worked for Du Pont. It is used in the manufacture of moulded articles, textiles, and medical sutures. Nylon fibres are stronger and more elastic than silk and are relatively insensitive to moisture and mildew. Nylon is used for a wide range of different textiles including carpets, and can be used in knitting or weaving. It is also used for simulating other fabrics such as silks and furs.

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nymph

in entomology, the immature form of insects that do not have a pupal stage; for example, grasshoppers and dragonflies. Nymphs generally resemble the adult (unlike larvae), but do not have fully formed reproductive organs or wings.

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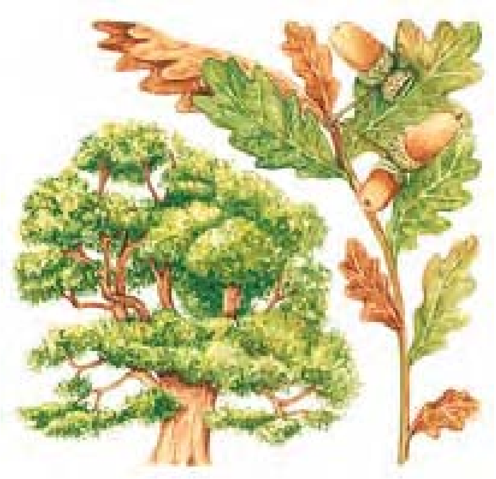
oak

any of a group of trees or shrubs belonging to the beech family, with over 300 known species widely distributed in temperate zones. Oaks are valuable for timber, the wood being durable and straight-grained. Their fruits are called acorns. (Genus *Quercus*, family Fagaceae.)

oak



(Image © Research Machines plc)

The English oak is the most common oak species in Northern Europe. Its lobed leaves and small acorns are characteristic of the deciduous oaks of cool temperate regions. Oaks from warmer regions are usually evergreen and often have unlobed leaves.

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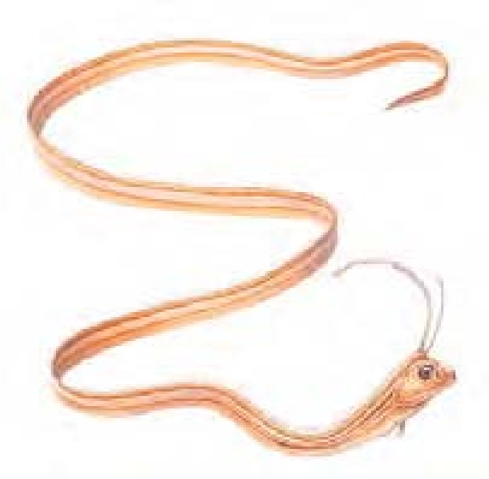
oarfish

any of a group of deep-sea bony fishes, found in warm parts of the Atlantic, Pacific, and Indian oceans. Oarfish are large, up to 9 m/30 ft long, elongated, and compressed, with a fin along the back and a manelike crest behind the head. They have a small mouth, no teeth or scales, and large eyes. They are often described as sea serpents. (Genus *Regalecidae*.)

oarfish



(Image © Research Machines plc)

The oarfish is a strange-looking deep-sea fish found in warm parts of the Atlantic, Pacific, and Indian oceans. It grows up to 9 m/30 ft long. Its silver body is compressed and the dorsal fin forms a manelike crest behind the head.

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oarweed

or tangleweed

any of several large, coarse, brown seaweeds found on the lower shore and below the low-tide mark, especially *L. digitata*. This species has fronds 1-2 m/3-6 ft long, a thick stalk, and a frond divided into flat fingers. In Japan and Korea it is cultivated and harvested commercially (especially genus *Laminaria*.)

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oasis

area of land made fertile by the presence of water near the surface in an otherwise arid region. The occurrence of oases affects the distribution of plants, animals, and people in the desert regions of the world.

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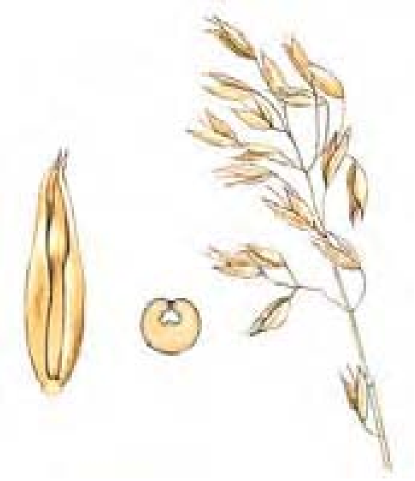
oat

type of annual grass, a cereal crop. The plant has long narrow leaves and a stiff straw stem; the panicles of flowers (clusters around the main stem), and later of grain, hang downwards. The cultivated oat (*A. sativa*) is produced for human and animal food. (Genus *Avena*.)

oat



(Image © Research Machines plc)

The oat plant has long, narrow leaves, with the grain hanging downwards. The grain has a high proportion of husk, not easily removed, and therefore relatively little is used as human food.

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obesity

condition of being significantly and unhealthily overweight. The body mass index (BMI) is commonly used to define obesity. People with a BMI between 25 and 30 are described as overweight, while those with a BMI over 30 count as obese. Obesity increases susceptibility to disease, strains the vital organs, and reduces life expectancy; it is usually remedied by controlled weight loss, healthy diet, and exercise.

Levels of obesity have risen significantly in many of the wealthier nations since the middle of the 20th century. In 2005, up to 30% of US adults (16% of children) and 22% of British adults (15% of children) were considered to be obese.

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object program

in computing, the machine code translation of a program written in a source language.

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observatory

site or facility for observing astronomical or meteorological phenomena. The modern observatory dates from the invention of the telescope. Observatories may be ground-based, carried on aircraft, or sent into orbit as satellites, in space stations, and on the space shuttle.

The pre-telescopic observatory built on the island of Hven (now Ven) in Denmark in 1576 for Tycho Brahe (1546–1601) was elaborate, but survived only to 1597. Later, observatories were built in Paris in 1667, Greenwich (the Royal Greenwich Observatory) in 1675, and Kew, England. Most early observatories were near towns, but with the advent of big telescopes, clear skies with little background light, and hence high, remote sites, became essential.

The most powerful optical telescopes covering the sky are at Mauna Kea, Hawaii; Mount Palomar, California; Kitt Peak National Observatory, Arizona; La Palma, Canary Islands; Cerro Tololo Inter-American Observatory, and the European Southern Observatory, Chile; Siding Spring Mountain, Australia; and Zelenchukskaya in the Caucasus.

A candidate for the worldseverals largest optical telescope is the European Southern Observatoryseverals VLT (Very Large Telescope) at the Paranal Observatory in Chile. It consists of four 8.2-m/325-inch reflecting telescopes and several smaller instruments, whose light can be combined to distinguish extremely fine detail in astronomical objects.

Radio astronomy observatories include Jodrell Bank, Cheshire, England; the Mullard Radio Astronomy Observatory, Cambridge, England; Socorro, New Mexico; Arecibo, Puerto Rico; Effelsberg, Germany; and Parkes, Australia. The Hubble Space Telescope was launched into orbit in 1990.

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obsession

persistently intruding thought, emotion, or impulse, often recognized by the sufferer as irrational, but nevertheless causing distress. It may be a brooding on destiny or death, or chronic doubts interfering with everyday life (such as fearing the gas is not turned off and repeatedly checking), or an impulse leading to repetitive action, such as continually washing one's hands.

In obsessive-compulsive neurosis, these intrusions compel the patient to perform rituals or ceremonies, albeit reluctantly, no matter how absurd or distasteful they may seem.

obsessive-compulsive disorder

OCD

in psychiatry, anxiety disorder that manifests itself in the need to check constantly that certain acts have been performed 'correctly'. Sufferers may, for example, feel compelled to wash themselves repeatedly or return home again and again to check that doors have been locked and appliances switched off. They may also hoard certain objects and insist in these being arranged in a precise way, or be troubled by intrusive and unpleasant thoughts. In extreme cases, normal life is disrupted through the hours devoted to compulsive actions. Treatment involves cognitive therapy and drug therapy with serotonin-blocking drugs such as Prozac.

There are approximately 1 million OCD sufferers in Britain and 5 million in the USA.

Obsessive-Compulsive Disorder

Go to site

Comprehensive resource on this psychiatric disorder. As well as containing a list of symptoms, the site explains in detail the problems an OCD sufferer might face, and discusses the kind of treatments available.

obsidian

black or dark-coloured glassy volcanic rock, chemically similar to granite, but formed by cooling rapidly on the Earth's surface at low pressure.

The glassy texture is the result of rapid cooling, which inhibits the growth of crystals. Obsidian was valued by the early civilizations of Mexico for making sharp-edged tools and ceremonial sculptures.

obstetrics

medical speciality concerned with the management of pregnancy, childbirth, and the immediate postnatal period.

obtuse angle

angle greater than 90° but less than 180°.

occluded front

weather front formed when a cold front catches up with a warm front. It brings clouds and rain as air is forced to rise upwards along the front, cooling and condensing as it does so.

occultation

in astronomy, the temporary obscuring of a star by a body in the Solar System. Occultations are used to provide information about changes in an orbit, and the structure of objects in space, such as radio sources.

The exact shapes and sizes of planets and asteroids can be found when they occult stars. The rings of Uranus were discovered when that planet occulted a star in 1977.

occupational psychology

study of human behaviour at work. It includes dealing with problems in organizations, advising on management difficulties, and investigating the relationship between humans and machines (as in the design of aircraft controls; see also ergonomics). Another area is psychometrics and the use of assessment to assist in selection of personnel.

ocean

great mass of salt water. Geographically speaking three oceans exist – the Atlantic, Indian, and Pacific – to which the Arctic is often added. They cover approximately 70% or 363,000,000 sq km/140,000,000 sq mi of the total surface area of the Earth. According to figures released in August 2001, the total volume of the world's oceans is 1,370 million cubic km/329 million cubic mi. Water levels recorded in the world's oceans have shown an increase of 10–15 cm/4–6 in over the past 100 years.

depth (average) 3,660 m/12,000 ft, but shallow ledges (continental shelves) 180 m/600 ft run out from the continents, beyond which the continental slope reaches down to the abyssal zone, the largest area, ranging from 2,000–6,000 m/6,500–19,500 ft. Only the deep-sea trenches go deeper, the deepest recorded being 11,034 m/36,201 ft (by the *Vityaz*, USSR) in the Mariana Trench of the western Pacific in 1957

features deep trenches (off eastern and southeastern Asia, and western South America), volcanic belts (in the western Pacific and eastern Indian Ocean), and ocean ridges (in the mid-Atlantic, eastern Pacific, and Indian Ocean).

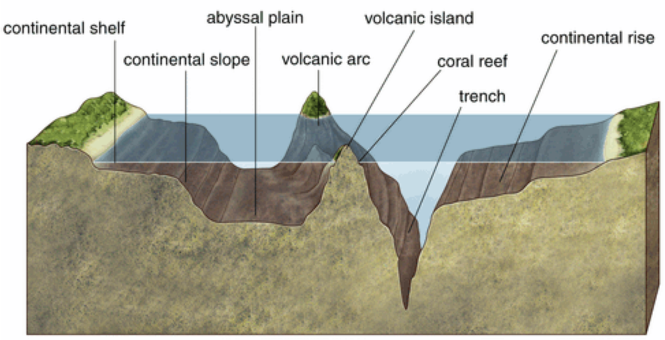
temperature varies on the surface with latitude (-2°C/28°F to +29°C)/84°F; decreases rapidly to 370 m/1,200 ft, then more slowly to 2,200 m/7,200 ft; and hardly at all beyond that

seawater contains about 3% dissolved salts, the most abundant being sodium chloride; salts come from the weathering of rocks on land; rainwater flowing over rocks, soils, and organic matter on land dissolves small amounts of substances, which pass into rivers to be carried to the sea. Salt concentration in the oceans remains remarkably constant as water is evaporated by the Sun and fresh water added by rivers. Positive ions present in sea water include sodium, magnesium, potassium, and calcium; negative ions include chloride, sulphate, hydrogencarbonate, and bromide

commercial extraction of minerals includes bromine, magnesium, potassium, salt (sodium chloride); those potentially recoverable include aluminium, calcium, copper, gold, manganese, silver.

pollution Oceans have always been used as a dumping area for human waste, but as the quantity of waste increases, and land areas for dumping diminish, the problem is exacerbated. Today ocean pollutants include airborne emissions from land (33% by weight of total marine pollution); oil from both shipping and land-based sources; toxins from industrial, agricultural, and domestic uses; sewage; sediments from mining, forestry, and farming; plastic litter; and radioactive isotopes. Thermal pollution by cooling water from power plants or other industry is also a problem, killing coral and other temperature-sensitive sedentary species.

ocean



(Image © Research Machines plc)

Profile of an ocean floor. The ocean trench is the deepest part of the ocean and the abyssal plains constitute most of the ocean bed.

oceans

To remember the four oceans:

I **A**m **A** **P**erson

Indian, **A**rctic, **A**tlantic, **P**acific

Major oceans and seas of the world

Ocean/sea	Area[1]		Average depth	
	sq km	sq mi	m	ft
Pacific Ocean	166,242,000	64,186,000	3,939	12,925
Atlantic Ocean	86,557,000	33,420,000	3,575	11,730
Indian Ocean	73,429,000	28,351,000	3,840	12,598
Southern Ocean	20,327,000	7,848,300	4,500	14,763
Arctic Ocean	13,224,000	5,106,000	1,038	3,407
South China Sea	2,975,000	1,149,000	1,464	4,802

Caribbean Sea	2,754,000	1,063,000	2,575	8,448
Mediterranean Sea	2,510,000	969,000	1,501	4,926
Bering Sea	2,261,000	873,000	1,491	4,893
Sea of Okhotsk	1,580,000	610,000	973	3,192
Gulf of Mexico	1,544,000	596,000	1,614	5,297
Sea of Japan	1,013,000	391,000	1,667	5,468
Hudson Bay	730,000	282,000	93	305
East China Sea	665,000	257,000	189	620
Andaman Sea	565,000	218,000	1,118	3,667
Black Sea	461,000	178,000	1,190	3,906
Red Sea	453,000	175,000	538	1,764
North Sea	427,000	165,000	94	308
Baltic Sea	422,000	163,000	55	180
Yellow Sea	294,000	114,000	37	121

[1] All figures are approximate as boundaries of oceans and seas cannot be exactly determined.

oceanarium

large display tank in which aquatic animals and plants live together much as they would in their natural environment. The first oceanarium was created by the explorer and naturalist W Douglas Burden in 1938 in Florida, USA.

ocean current

fast-flowing body of seawater forced by the wind or by variations in water density (as a result of temperature or salinity variations) between two areas. Ocean currents are partly responsible for transferring heat from the Equator to the poles and thereby evening out the global heat imbalance.

Ocean Drilling Program

ODP; formerly Deep-Sea Drilling Project (1968-85)

research project initiated in the USA to sample the rocks of the ocean crust. Initially under the direction of Scripps Institution of Oceanography, the project was planned and administered by the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). The operation became international in 1975, when Britain, France, West Germany, Japan, and the USSR also became involved.

Boreholes were drilled in all the oceans using the JOIDES ships *Glomar Challenger* and *Resolution*. Knowledge of the nature and history of the ocean basins was increased dramatically. The technical difficulty of drilling the seabed to a depth of 2,000 m/6,500 ft was overcome by keeping the ship in position with side-thrusting propellers and satellite navigation, and by guiding the drill using a radiolocation system. The project is intended to continue until 2005.

oceanography

study of the oceans. Its subdivisions deal with each ocean's extent and depth, the water's evolution and composition, its physics and chemistry, the bottom topography, currents and wind, tidal ranges, biology, and the various aspects of human use. Computer simulations are widely used in oceanography to plot the possible movements of the waters, and many studies are carried out by remote sensing.

Oceanography involves the study of water movements – currents, waves, and tides – and the chemical and physical properties of the seawater. It deals with the origin and topography of the ocean floor – ocean trenches and ridges formed by plate tectonics, and continental shelves from the submerged portions of the continents.

OceanLink

Go to site

Good site for finding out about many marine animals, with encyclopedic descriptions of selected animals. This site contains sections called 'Kidlinks', 'Ask a scientist', 'Spotlight on...', and 'Ocean news'.

Ocean Planet

Go to site

Oceans and the environmental issues affecting their health, based on the Smithsonian Institute's travelling exhibition of the same name. Use the exhibition floor plan to navigate around the different 'rooms' - with themes ranging from Ocean Science and Immersion to Heroes and Sea People.

Seawave Forecasts for California, Oregon, and Washington

Go to site

Maintained by NWS Marine Forecasts and Observations, this site displays wave and surf information for six locations along the Pacific Coast of the USA. Includes a link to bay, coastal, and offshore marine forecasts for selected cities, plus high seas forecasts, and surface observations.

Woods Hole Oceanographic Institution Home Page

Go to site

Site run by a Massachusetts-based oceanographic institute. As well as containing details of their research programmes and an overview of the organization, there is a gallery of marine pictures and videos, and contacts for their education programmes.

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ocean trench

submarine valley. Ocean trenches are characterized by the presence of a volcanic arc on the concave side of the trench. Trenches are now known to be related to subduction zones, places where a plate of oceanic lithosphere dives beneath another plate of either oceanic or continental lithosphere. Ocean trenches are found around the edge of the Pacific Ocean and the northeastern Indian Ocean; minor ones occur in the Caribbean and near the Falkland Islands.

Ocean trenches represent the deepest parts of the ocean floor, the deepest being the Mariana Trench which has a depth of 11,034 m/36,201 ft. At depths of below 6 km/3.6 mi there is no light and very high pressure; ocean trenches are inhabited by crustaceans, coelenterates (for example, sea anemones), polychaetes (a type of worm), molluscs, and echinoderms.

Deepest oceanic trenches in the world

Name	Location	Depth	
		m	ft
Mariana Trench	western Pacific	11,034	36,201
Tonga-Kermadec Trench[1]	southern Pacific	10,882	35,702
Kuril-Kamchatka Trench	western Pacific	10,542	34,587
Philippine Trench	western Pacific	10,539	34,577
Idzu-Bonin Trench	western Pacific	9,810	32,185
Puerto Rico Trench	western Atlantic	9,220	30,249
New Hebrides Trench	southern Pacific	9,165	30,069
Solomon Trench[2]	southern Pacific	9,140	29,987
Yap Trench	western Pacific	8,527	27,976
Japan Trench	western Pacific	8,412	27,598

[1] The Kermadec Trench is sometimes considered a separate feature with a depth of 10,047 m/32,963 ft.

[2] Also called New Britain Trench.

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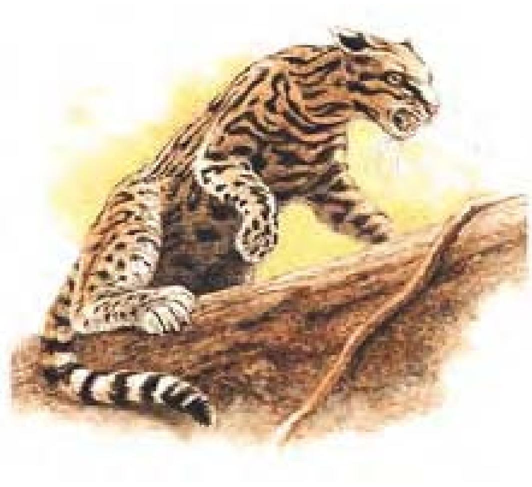
ocelot

wild cat of the southwestern USA, Mexico, and Central and South America. It is up to 1 m/3 ft long, with a 45 cm/1.5 ft tail, weighs about 18 kg/40 lb, and has a pale yellowish coat marked with horizontal stripes and blotches. As a result of being hunted for its fur, it is close to extinction. (Species *Felis pardalis*, family Felidae.)

ocelot



(Image © Research Machines plc)

In some parts of its range the beautifully marked ocelot has been hunted almost to extinction for its pelt. It inhabits the thick forests of the central Americas where it hunts mainly at night for small mammals and birds. It is a comparatively small cat reaching no more than 1 m/3.3 ft in length.

OCR

abbreviation for optical character recognition.

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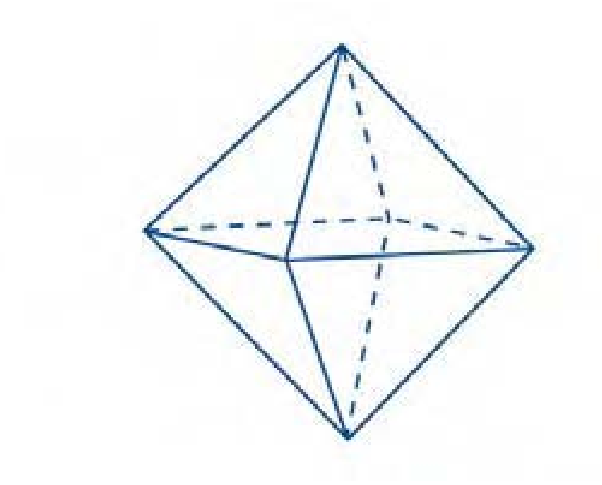
octahedron, regular

regular solid with eight faces, each of which is an equilateral triangle. It is one of the five regular polyhedra or Platonic solids. The figure made by joining the midpoints of the faces is a perfect cube and the vertices of the octahedron are themselves the midpoints of the faces of a surrounding cube. For this reason, the cube and the octahedron are called dual solids.

octahedron, regular



(Image © Research Machines plc)

A regular octahedron is a solid figure which has eight faces, each of which is an equilateral triangle.

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octal number system

number system to the base eight, used in computing. The highest digit that can appear in the octal system is seven. Whereas normal decimal, or base-ten, numbers may be considered to be written under column headings based on the number ten, octal, or base-eight, numbers can be thought of as written under column headings based on the number eight. The octal number 567 is therefore equivalent to the decimal number 375, since (5 × 64) + (6 × 8) + (7 × 1) = 375.

The octal number system is sometimes used by computer programmers as an alternative to the hexadecimal number system.

---

octane rating

numerical classification of petroleum fuels indicating their combustion characteristics.

The efficient running of an internal combustion engine depends on the ignition of a petrol-air mixture at the correct time during the cycle of the engine. Higher-rated petrol burns faster than lower-rated fuels. The use of the correct grade must be matched to the engine.

Octans

faint constellation in the southern hemisphere, represented as an octant. It contains the southern celestial pole. The closest naked-eye star to the south celestial pole is fifth-magnitude Sigma Octantis.

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octet rule

in chemistry, rule stating that elements combine in a way that gives them the electronic structure of the nearest noble gas (rare gas). The joining together of elements to form compounds is called bonding. All the noble gases except helium have eight electrons in their outermost shell, hence the term octet.

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octopus

soft-bodied sea animal with a round or oval body and eight slender arms (tentacles) in a ring surrounding its mouth. They are solitary creatures, living alone in rocky dens. They feed on crabs and other small animals. There are about 50 different species of octopus living in all the oceans of the world. Some are small, having bodies only 8 cm/3 in long, but the largest deep-sea species can grow to lengths of 20 m/64 ft.

behaviour

Octopuses can change colour to blend in with their surroundings and can swim using their arms or by a form of jet propulsion by squirting out water from their bodies. The octopus has rows of suckers along the length of each arm (or tentacle) which, as well as helping it swim and crawl around the ocean floor, allows it to search in cracks and crevices and grab prey. The octopus is a carnivore (flesh-eater), usually feeding on crabs, shrimps, and mussels, but the larger species of octopus have been known to hunt small sharks and dogfish. They trap the prey in their arms and drag it towards their powerful beaklike jaws. Once it has bitten its prey, the octopus injects it with a poisonous saliva to kill it. Sometimes, when frightened or to avoid enemies, they squirt out a black ink from their bodies which hides them and allows them to escape. If they lose an arm, they can grow another in its place. Octopuses are highly intelligent with two well developed eyes, similar to those of vertebrates (animals with backbones). They breathe using gills as fish do, but are unique in that they have three hearts.

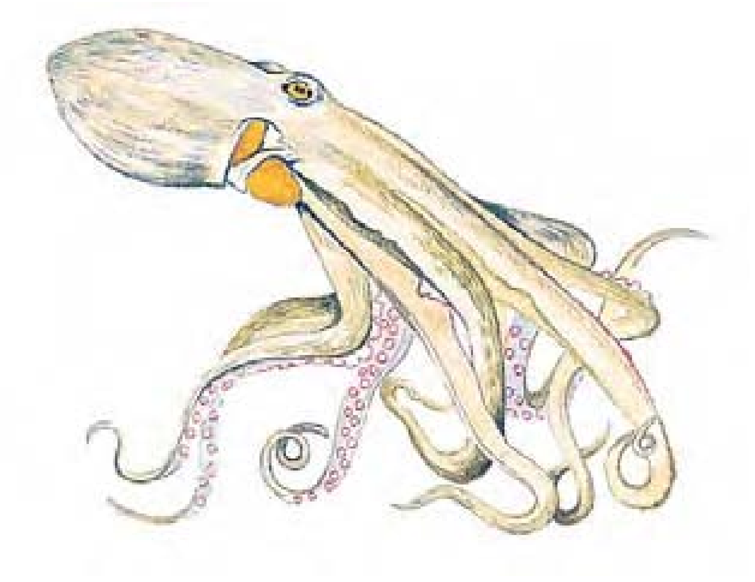
classification

Octopuses belong to the phylum Mollusca (molluscs), class Cephalopoda (cephalopods), subclass Coleoidea. They belong to the genus *Octopus* and there are about 50 known species including the **common octopus** (*O. vulgaris*), which may reach 2 m/6 ft in length; the Australian blue-ringed octopus (genus *Hapalochlaena*) that can kill a human being in 15 minutes as a result of its venomous bite; and the giant deep-sea octopus (*Architeuthis dux*) that can grow to 20 m/64 ft.

octopus

The octopus's brain lies between its eyes and encircles the oesophagus. This arrangement has some disadvantages; researchers have discovered spines lodged in octopus brains as a result of food 'going down the wrong way'.

octopus



(Image © Research Machines plc)

The octopus can swim by using its legs or by squirting water backwards to create a kind of jet propulsion. More often, however, it uses its eight suckered tentacles to crawl across rocks on the seabed.

Cephalopod Page

Go to site

Introduction to the world of cephalopods, the class that includes the squids, cuttlefish, and octopuses. As well as some images of marine life, this site also contains biological information about each subgroup.

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oedema

any abnormal accumulation of fluid in tissues or cavities of the body; waterlogging of the tissues due to excessive loss of plasma through the capillary walls. It may be generalized (the condition once known as dropsy) or confined to one area, such as the ankles.

Oedema may be mechanical - the result of obstructed veins or heart failure - or it may be due to increased permeability of the capillary walls, as in liver or kidney disease or malnutrition. Accumulation of fluid in the abdomen, a complication of cirrhosis, is known as **ascites**.

Oedipus complex

in psychology, the unconscious antagonism of a son to his father, whom he sees as a rival for his mother's affection. For a girl antagonistic to her mother as a rival for her father's affection, the term is **Electra complex**. The terms were coined by Sigmund Freud.

Freud saw this as a universal part of childhood development, which in most children is resolved during late childhood. Contemporary theory places less importance on the Oedipus/Electra complex than did Freud and his followers.

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oersted

symbol Oe

c.g.s. unit of magnetic field strength, now replaced by the SI unit ampere per meter. It is equal to a force of one dyne acting upon a unit magnetic pole in a vacuum. The Earth's magnetic field is about 0.5 oersted; the field near the poles of a small bar magnet is several hundred oersteds; and a powerful electromagnet can have a field strength of 30,000 oersteds.

Oersted, Hans Christian (1777-1851)

Danish physicist who founded the science of electromagnetism. In 1820 he discovered the magnetic field associated with an electric current. In 1825 he was the first to isolate aluminium.

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oesophagus

muscular tube through which food travels from the mouth to the stomach. The human oesophagus is about 23 cm/9 in long. It extends downwards from the pharynx, immediately behind the windpipe. It is lined with a mucous membrane made of epithelial cells (see epithelium), which secretes lubricant fluid to assist the downward movement of food. In its wall is muscle, which contracts to squeeze the food towards the stomach (peristalsis).

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oestrogen

any of a group of hormones produced by the ovaries of vertebrates; the term is also used for various synthetic hormones that mimic their effects. The principal oestrogen in mammals is oestradiol. Oestrogens control female sexual development, promote the growth of female secondary sexual characteristics at puberty, stimulate egg (ovum) production, and, in mammals, prepare the lining of the uterus for pregnancy. In other words, together with another hormone, progesterone, they regulate the growth and functioning of sex organs for sexual reproduction. Oestrogens are also used in female oral contraceptives, to inhibit the production of ova.

Oestrogens are used therapeutically for some hormone disorders and to inhibit lactation. US researchers in 1995 observed that oestrogen plays a role in the healing of damaged blood vessels. It has also been found that women recover more quickly from strokes if given a low oestrogen dose.

Contraceptive: Development of the Pill

lemons, crocodiles, and pigs

Birth control, in one form or another, has a long history. That well-known lover Casanova (1725-1798) is reputed to have used a lemon as a spermicide, with less than complete success. The ancient Egyptians used crocodile faeces. The sheath was probably introduced by Gabriel Fallopius, the famous Italian anatomist (1523-1562), but mainly as a prophylactic against venereal disease. Knowledge of human genital systems and their physiology, particularly the female system, remained rudimentary until the beginning of the 20th century. The most reliable form of birth control up to this point was simple abstinence.

The population of the world in 1830 was 1 billion; by 1929 it had increased to 2 billion. However, in the period following the carnage of World War I, people were more concerned to repopulate than to advance new methods of birth control. There were legal constraints on birth control as well. US social reformer Margaret Sanger (1883-1966) opened the first birth control advisory clinic in 1916 in Brooklyn, New York, USA, but it was closed by the police, and Sanger was imprisoned. So, in addition to the necessary scientific advances, before successful birth control could be practised there had to be changes both in the law and in social awareness.

preventing ovulation

The key step forward in scientific understanding came in the 1950s when US physiologist Gregory Pincus

(1903-) discovered that the steroid hormone progesterone, found in greater concentrations during pregnancy, is responsible for the prevention of ovulation at that time.

The way had been paved in the 1920s when German physiologist Ludwig Haberlandt (1885-1932) conducted a crucial experiment. Starting from the idea that pregnancy somehow triggered the secretion of anti-ovulatory substances, he demonstrated that by transplanting the ovaries from pregnant rabbits and rats to non-pregnant females, he could induce a temporary sterility. He also found that simple ovarian extracts could achieve the same result. He suggested that specific hormones secreted during pregnancy were responsible.

The modern study of sex hormones began with US endocrinologist Edgar Allen (1892-1943) who discovered oestrogen and showed experimentally that it induced the physiological changes normally found in the oestrous cycle. Allen and his colleagues extracted and crystallized a few milligrams of a hormone from the corpus luteum (part of the ovary) of the sow. To do this, they had to process the carcasses of several hundred sows. They suggested the name progesterone for the hormone.

a commercial source of progesterone

The story now moves to the Mexican jungle. In 1941, the US Bureau of Plant Industry, a branch of the Federal Bureau of Agronomy, received reports of the contraceptive properties of infusions used by the Indian women of Nevada. Like many indigenous tribes in different parts of the world, they made use of plant extracts. A US scientist, Russell Marker, found it difficult to pursue contraceptive studies in the prevailing climate of public opinion, and decided he would be better off in Mexico. Benefiting from local folklore, he investigated the wild yam as a possible source of progesterone.

After collecting considerable quantities of this tuber in the jungle, Marker succeeded in a remarkably short space of time in synthesizing 2 kg/4.4 lb of progesterone. It is related that he appeared one day in the offices of a small Mexican pharmaceutical firm and, placing four full 1 lb jars of progesterone on the manager's desk, enquired if he was interested in the industrial manufacture of the hormone!

the pill arrives

There the matter rested, until the work of Gregory Pincus made it possible to conduct a series of trials, one among the women of Port-au-Prince in Haiti, and two in Puerto Rico. The trials gave conclusive results, and the firm of Searle, in Chicago, USA, was then able to produce the first contraceptive pill, Enovid.

Progesterone is now known to play a vital role in maintaining the normal course of pregnancy. In high doses, however, it acts to prevent ovulation. By taking a contraceptive pill, in which the amounts of progesterone and oestrogen activity are carefully balanced, the female body behaves as if conception has occurred. Other types of pill operate only through progesterone activity.

The population of the world in 1961 was 3 billion; in 1975 4 billion and in the year 2000 it will top 6 billion. Most of the staggering 2 billion increase in the 25 years preceding the millennium will happen in countries other than North America and Europe. The population is relatively stable in the developed countries where, in some instances, the birth rate has been cut by up to 40%. This is attributable both to advances in the scientific knowledge of birth and its control made during this century and, equally, to an increase in overall wealth.

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oestrus

in mammals, the period during a female's reproductive cycle (also known as the oestrus cycle or menstrual cycle) when mating is most likely to occur. It usually coincides with ovulation, when egg cells are released from the ovary.

Offa's Dyke

defensive earthwork dyke along the English-Welsh border, of which there are remains from the mouth of the River Dee to that of the River Severn. It was built about AD 785 by King Offa of Mercia, England, and represents the boundary secured by his wars with Wales.

The dyke covered a distance of 240 km/149 mi, of which 130 km/81 mi are still standing. It consists of a large rampart and ditch, the latter usually on the Welsh side, and was laid out to take advantage of natural physical features.

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offset printing

the most common method of printing, which works on the principle of lithography: that is, that grease and water repel one another.

The printing plate is prepared using a photographic technique, resulting in a type image that attracts greasy printing ink. On the printing press the plate is wrapped around a cylinder and wetted and inked in turn. The ink adheres only to the type area, and this image is then transferred via an intermediate blanket cylinder, which is made of rubber, to the paper. Increasingly, new techniques are being used in offset printing, including chemical and digital techniques, which speeds up the process.

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ohm

symbol Ω

SI unit of electrical resistance (the property of a conductor that restricts the flow of electrons through it).

It was originally defined with reference to the resistance of a column of mercury, but is now taken as the resistance between two points when a potential difference of one volt between them produces a current of one ampere.

ohm

To remember the order of ohmic values in resistors:

Billy **B**rown **r**elies **o**n **y**our **g**in **b**ut **p**refers **g**ood **w**hiskey

Black, **b**rown, **r**ed, **o**range, **y**ellow, **g**reen, **b**lue, **p**urple, **g**rey, **w**hite

---

Ohm, Georg Simon (1789-1854)

German physicist who studied electricity and discovered the fundamental law that bears his name (see Ohm's law). The SI unit of electrical resistance, the **ohm**, is named after him, and the unit of conductance (the inverse of resistance) was formerly called the **mho**, which is 'ohm' spelled backwards.

Ohm's law

law that states that, for many materials over a wide range of conditions, the current flowing in a conductor maintained at constant temperature is directly proportional to the potential difference (voltage) between its ends. The law was discovered by German physicist Georg Ohm in 1827. He found that if the voltage across a conducting material is changed, the current flow through the material is changed proportionally (for example, if the voltage is doubled then the current also doubles).

If a current of I amperes flows between two points in a conductor across which the potential difference is V volts, then V/I is a constant called the resistance$R$ ohms between those two points. Hence: $V/I = R$ or $V = IR$. Not all conductors obey Ohm's law; those that do are called **ohmic conductors**.

Ohm's law

To remember one expression of this:

Vampires **a**re **r**are

volts = **a**mps × **r**esistance

---

oil

flammable substance, usually insoluble in water, and composed chiefly of carbon and hydrogen. Oils may be solids (fats and waxes) or liquids. Various plants produce vegetable oils; mineral oils are based on petroleum.

The crude oil (unrefined petroleum) found beneath the Earth's surface is formed from the remains of dead plants and animals. As these plants and animals died they were buried with mud near the sea floor. Over millions of years, heat from the Earth's interior and pressure from overlying rocks slowly changed the dead remains into hydrocarbons (substances containing hydrogen and carbon). The hydrocarbons, being light molecules, moved upwards and became trapped beneath impermeable rocks.

Oil reservoirs are often found beneath the seabed and drilling technology is used to locate these supplies of oil. Crude oil extracted from the ground is refined in fractional distillation columns to produce more useful products such as petrol, diesel, kerosene, plastics, and chemicals for pharmaceuticals.

Oil: Are we Looking in the Right Place?

a nonrenewable resource

Petroleum is perhaps the most important mineral resource in the world. Whole economies grow and collapse over variations in its price; 1991 saw a war – the Gulf War – waged over it, and while the 2003 Iraq War was ostensibly about weapons of mass destruction and the removal of Saddam Hussein, it is widely thought to have been about US greed for oil. Yet it is not an inexhaustible resource. Many pessimistic forecasts predict that the world's known supply will run out some time this century.

how is oil formed?

As a result there is a constant search for new deposits. An understanding of how oil is formed and how it is emplaced is essential in the hunt. The origins of oil have been understood for over a century. It is common knowledge that crude oil – petroleum – is formed from the organic remains of living creatures. Animals and plants are buried in the sediments of the sea bed. If they are buried quickly their organic substances may not oxidize and decay away.

When this sediment is compressed into sedimentary rock the organic chemicals – the hydrocarbons – may form droplets of petroleum, which can float upwards through the water contained in the rocks above. If they meet a layer that is impervious to the flow, the droplets gradually build up until the pores of the rocks are filled with oil, resulting in a reservoir. Hence the oil geologist looks for the source rocks – rocks that are likely to have produced oil - and then the reservoir rocks - rocks that have concentrated it and now contain it. Source rocks and reservoir rocks are both sedimentary, having formed from layers of sand, silt, and mud, and so oil geologists tend to be specialists in sedimentary rocks.

a different theory

However, back in the early 1980s, a single dissenting voice expressed a differing view. It was the voice of Dr Thomas Gold of Cornell University, Ithaca, New York. His theory was that hydrocarbons formed deep below the Earth's crust. The original matter of the Solar System was rich in carbon - as can be seen today in carbonaceous meteorites, and the black colour of the nucleus of Halley's Comet. This carbon was incorporated into the Earth's mantle as the planet solidified. For as long as the Earth has existed the carbon has been seeping out, oxidizing on the way up to form the gas carbon dioxide - an abundant product of volcanic eruptions.

It is theoretically possible that the great pressures inside the Earth can turn the carbon into methane and the other chemicals that constitute petroleum. Should these chemicals migrate towards the surface without oxidizing - and Gold's theory is that cracks in solid igneous rocks like granite would provide suitable pathways - then they may accumulate in sedimentary traps close to the surface as deposits of petroleum. The places to look for source rocks would then be in areas of very old broken igneous rocks close to sedimentary basins in which oil is known to have accumulated.

the theory is tested

His theories were dismissed out of hand by the petroleum industry but he did manage to obtain backing for an exploratory borehole from the Swedish State Power Board and the American Gas Research Institute. The site chosen was a geological structure called the Siljan Ring in central Sweden. It is an ancient meteorite crater punched into the Precambrian granitic rock that forms the core of the European continent. The site would provide the cracked igneous rock required by the theory, and was in the same general region as the North Sea oilfields. Drilling began in July 1986 and the whole project was all but dismissed and forgotten by the rest of the scientific world.

On 7 Oct 1991, when the eyes of the world were on the devastation of the Gulf War, and the oil industry was desperately trying to extinguish the blazing oil installations and cap the wrecked wells to prevent millions of gallons of oil from pouring into the desert and the sea, an announcement was made from the Siljan Ring project. Oil was struck at a depth of 2.8 km/1.7 mi.

oil

(Image © Corel)

An oil tanker leaving the British Petroleum Hamble terminal near Southampton, England. These huge ships are guided by small pilot boats out of the port and into the busy shipping lanes of the English Channel.

What Is Crude Oil?

Go to site

Beginning with a short history of the uses of crude oil, the text quickly moves on to an explanation of how crude oil is formed over millions of years. An explanation of more contemporary uses of oil, such as in the petrol industry, is then given. Spaced around the page are pictures of samples of oil from all around the world.

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oil, cooking

fat that is liquid at room temperature, extracted from the seeds or fruits of certain plants and used for frying, salad dressings, and sauces and condiments such as mayonnaise and mustard. Plants used for cooking oil include sunflower, olive, maize (corn), soya, peanut, and rape. Vegetable oil is a blend of more than one type of oil. Most oils are hot-pressed and refined, a process that leaves them without smell or flavour. Cold-pressed, unrefined oils keep their flavour. Oils are generally low in cholesterol and contain a high proportion of polyunsaturated or monounsaturated fatty acids, although all except soya and corn oil become saturated when heated.

---

oil crop

plant from whose seeds vegetable oils are pressed. Cool temperate areas grow rapeseed and linseed; warm temperate regions produce sunflowers, olives, and soybeans; tropical regions produce groundnuts (peanuts), palm oil, and coconuts.

Some of the major vegetable oils, such as soybean oil, peanut oil, and cottonseed oil, are derived from crops grown primarily for other purposes. Most vegetable oils are used as both edible oils and as ingredients in industrial products such as soaps, varnishes, printing inks, and paints.

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oil palm

African palm tree, the fruit of which yields valuable oils, used as food or processed into margarine, soaps, and livestock feeds. (*Elaeis guineensis*.)

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oil spill

oil discharged from an ocean-going tanker, pipeline, or oil installation, often as a result of damage. An oil spill kills shore life, clogging the feathers of birds and suffocating other creatures. At sea, toxic chemicals spread into the water below, poisoning sea life. Mixed with dust, the oil forms globules that sink to the seabed, poisoning sea life there as well. Oil spills are broken up by the use of detergents but such chemicals can themselves damage wildlife. The annual spillage of oil is 8 million barrels (280 million gallons) a year. At any given time tankers are carrying 500 million barrels (17.5 billion gallons).

The amount of oil entering oceans from shipping operations decreased by 60% 1981–91.

In March 1989 the *Exxon Valdez* (belonging to the Exxon Corporation) ran aground and spilled oil in Alaska's Prince William Sound, covering 12,400 sq km/4,800 sq mi and killing at least 34,400 sea birds, 10,000 sea otters, and up to 16 whales. The incident led to the US Oil Pollution Act of 1990, which requires tankers operating in US waters to have double hulls.

The world's largest oil spill was in the Gulf in 1991 as a direct result of hostilities during the Gulf War. Around 6–8 million barrels (210–280 million gallons) of oil were spilled, polluting 675 km/420 mi of Saudi coastline. In some places, the oil was 30 cm/12 in deep in the sand.

Sea Empress Oil Spill

Go to site

Overview of the *Sea Empress* oil spill on the coast of South Wales in February 1996. The site contains scientific information about the spill including its effect on the mammals, birds, and fish in the region. It also contains some good pictures of marine life.

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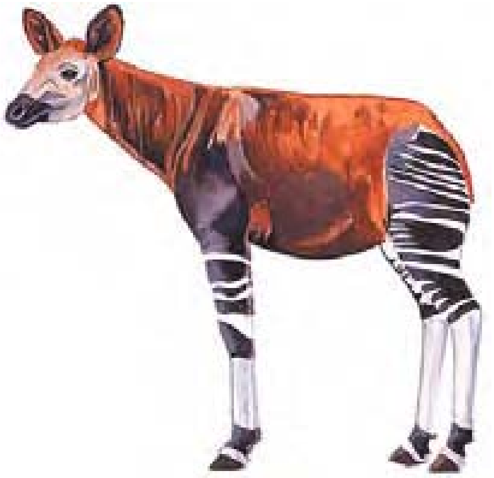
okapi

ruminant (cud-chewing) mammal related to the giraffe, although with a much shorter neck and legs, found in the tropical rainforests of central Africa. Its purplish brown body, creamy face, and black and white stripes on the legs and hindquarters provide excellent camouflage. Okapis have remained virtually unchanged for millions of years. (Species *Okapia johnstoni*, family Giraffidae.)

The okapi was unknown to Europeans until 1901; now only a few hundred are thought to survive.

okapi



(Image © Research Machines plc)

The okapi has a prehensile tongue that is used to pick tasty leaves. The tongue is so long that the animal uses it to clean its eyes and eyelids.

okra

plant belonging to the Old World hibiscus family. Its red-and-yellow flowers are followed by long, sticky, green fruits known as **ladies' fingers** or **bhindi**. The fruits are cooked in soups and stews. (*Hibiscus esculentus*, family Malvaceae.)

old age

later years of life. The causes of progressive degeneration of bodily and mental processes associated with it are still not precisely known, but every one of the phenomena of ageing can occur at almost any age, and the process does not take place throughout the body at an equal rate.
Geriatrics is the branch of medicine dealing with the diagnosis and treatment of disease in the elderly.

Normally, ageing begins after about 30. The arteries start to lose their elasticity, so that a greater strain is placed on the heart. The resulting gradual impairment of the blood supply is responsible for many of the changes, but between 30 and 60 there is a period of maturity in which ageing usually makes little progress. Research into the process of ageing (**gerontology**) includes study of dietary factors and the mechanisms behind structural changes in the tissues. Old age in itself is not a disease.

oleander

or rose bay

evergreen Mediterranean shrub belonging to the dogbane family, with pink or white flowers and aromatic leaves that produce and release the poison oleandrin. (*Nerium oleander*, family Apocynaceae.)

olefin

common name for alkene.

Oligocene epoch

third epoch of the Tertiary period of geological time, 35.5-3.25 million years ago. The name, from Greek, means 'a little recent', referring to the presence of the remains of some modern types of animals existing at that time.

oligosaccharide

carbohydrate comprising a few monosaccharide units linked together. It is a general term used to indicate that a carbohydrate is larger than a simple di- or trisaccharide but not as large as a polysaccharide.

olive

evergreen tree belonging to the olive family. Native to Asia but widely cultivated in Mediterranean and subtropical areas, it grows up to 15 m/50 ft high and has twisted branches and lance-shaped silvery leaves that grow opposite each other. The white flowers are followed by small green oval fruits that turn bluish-black when ripe. They are preserved in brine or oil, dried; or pressed to make olive oil. (*Olea europaea*, family Oleaceae.)

The oil, which is a pale, greenish yellow, is widely consumed; it is also used in soaps and ointments, and as a lubricant.

olivenite

basic copper arsenate, $Cu_2AsO_4(OH)$, occurring as a mineral in olive-green prisms.

Olivetti

Italian multinational office-machinery and information-services company, with headquarters in Ivrea, Italy. Formed in 1908 by Camillo Olivetti (1868-1943), the company is known for its high design standards, sustained through relationships with some of this century's leading designers. The company produced its first typewriter in 1908, and now produces a wide range of office technological equipment.

Adriano Olivetti (1901-1960), son of the founder, instigated the programme of employing consultant designers. Marcello Nizzoli was taken on in 1938, followed by Ettore Sottsass in 1958 and Mario Bellini in 1962. They each produced some seminal designs for the company while continuing to work for other clients. Sottsass's 'Valentine' typewriter in 1969 is among the best known, as is Bellini's series of 'Lexicon' typewriters. In the 1950s the company branched into electronic products, producing an electronic computer in 1959.

During the 1970s the company invested heavily in electronics, launching electronic typewriters and personal computers. In 1978, Carlo De Benedetti bought a shareholding and took over management of the company. In 1983 the company formed a business alliance with US telecommunications company AT&T. Further electronic products were developed including printers, fax machines, and photocopiers.

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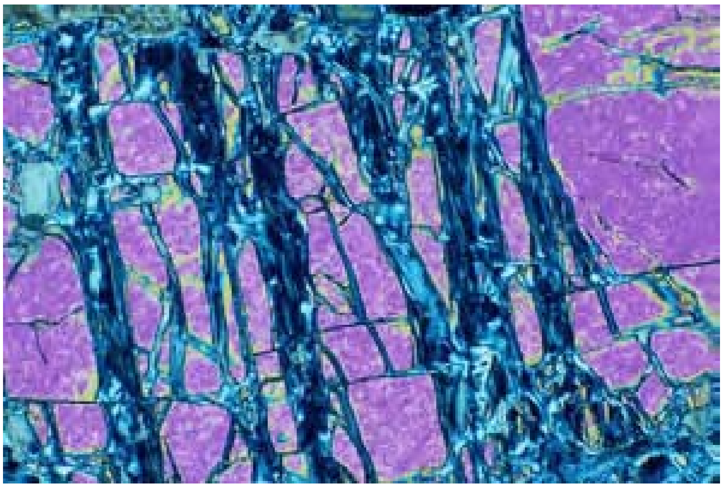
olivine

greenish mineral, magnesium iron silicate, $(Mg,Fe)_2SiO_4$. It is a rock-forming mineral, present in, for example, peridotite, gabbro, and basalt. Olivine is called **peridot** when pale green and transparent, and used in jewellery.

olivine



(Image © Corel)

Olivine under a polarized microscope. It is a rock-forming mineral abundant in gabbros and basalts.

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olm

cave-dwelling aquatic salamander. Olms are found in underground caves along the Adriatic seaboard in Italy, Croatia, and Serbia and Montenegro. The adult is permanently larval in form, about 25 cm/10 in long, almost blind, with external gills and underdeveloped limbs. See neoteny. (Species *Proteus anguinus*, family Proteidae.)

The olm is the only European member of its family; the other members are the North American mudpuppies.

The olm can survive for 12 years without eating. It can also withstand subzero temperatures.

Omar Khayyám (c. 1050-c. 1123)

Persian astronomer, mathematician, and poet. In the West, he is chiefly known as a poet through Edward Fitzgerald's version of 'The Rubaiyat of Omar Khayyám' (1859).

Khayyám was born in Nishapur. He founded a school of astronomical research and assisted in reforming the calendar. The result of his observations was the *Jalali* era, begun 1079. He wrote a study of algebra, which was known in Europe as well as in the East.

Khayyam, Omar

Go to site

Biography of the Persian astronomer, mathematician, and poet. The site contains a description of his weighty contribution to mathematics, in which he discovered a geometrical method to solve cubic equations by intersecting a parabola with a circle amongst many other works. Several literature references for further reading on the life and works of Omar Khayyam are listed, and his portrait is also shown.

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omnivore

animal that feeds on both plant and animal material. Omnivores have digestive adaptations intermediate between those of herbivores and carnivores, with relatively unspecialized digestive systems and gut micro-organisms that can digest a variety of foodstuffs. Omnivores include humans, the chimpanzee, the cockroach, and the ant.

onager

wild ass found in western Asia. Onagers are sandy brown, lighter underneath, and about the size of a small horse. (Species *Equus hemionus*.)

Onassis, Aristotle Socrates (1906-1975)

Greek shipping magnate who from 1932 built up one of the world's largest independent shipping lines. During the 1950s he was one of the first to construct supertankers, and was also the founder of the Greek national airline, Olympic Airways, in 1957. In 1968 he married Jacqueline Kennedy, widow of US president John F Kennedy.

Sent to Argentina in 1923, he first worked as a telephone operator on a nightshift while trying, during the daytime, to start a tobacco importing business. Capitalizing on the growing popularity of Turkish tobacco imports, he started to manufacture cigarettes. He negotiated a trade agreement with Argentina on behalf of the Greek government in 1928. In 1932, in the depths of the economic Depression, he bought six Canadian freighters for $20,000, a fraction of their actual value. After the war Onassis bought surplus wartime *Liberty* ships from the USA and, as the international freight market expanded, invested in oil tankers, going on to build supertankers in the 1950s.

onchocerciasis

or river blindness

disease found in tropical Africa and Central America. It is transmitted by bloodsucking black flies, which infect the victim with parasitic filarial worms (genus *Onchocerca*), producing skin disorders and intense itching; some invade the eyes and may cause blindness.

It is treated with antiparasitic drugs known as filaricides.

oncogene

gene carried by a virus that induces a cell to divide abnormally, giving rise to a cancer. Oncogenes arise from mutations in genes (proto-oncogenes) found in all normal cells. They are usually also found in viruses that are capable of transforming normal cells to tumour cells. Such viruses are able to insert their oncogenes into the host cell's DNA, causing it to divide uncontrollably. More than one oncogene may be necessary to transform a cell in this way.

In 1989 US scientists J Michael Bishop and Harold Varmus were jointly awarded the Nobel Prize for Physiology or Medicine for their concept of oncogenes, although credit for the discovery was claimed by a French cancer specialist, Dominique Stehelin.

oncology

medical speciality concerned with the diagnosis and treatment of neoplasms, especially cancer.

onco-mouse

mouse that has a human oncogene (gene that can cause certain cancers) implanted into its cells by genetic engineering. Such mice are used to test anticancer treatments and were patented within the USA by Harvard University in 1988, thereby protecting its exclusive rights to produce the animal and profit from its research.

onion

plant belonging to the lily family, whose bulb has a strong, distinctive smell and taste. Cultivated from ancient times, it may have originated in Asia. The bulb is edible; its pale concentric layers of leaf bases contain an oil that is released into the air when the onion is cut open, causing the eyes to water. Onions are used extensively in cooking. (*Allium cepa*, family Liliaceae.)

The onion is a biennial plant, the common variety producing a bulb in the first season and seeds in the second.

onion

(Image © Research Machines plc)

A Cornish onion grower with some of his produce. Onions are sensitive to the number of daylight hours during the growing season. By this measure they can be separated into three kinds: long-day, mid-day, and short-day. The amount of daylight they receive during the British summer favours the growing of long-day onions.

Onions, Garlic, and Shallots

Go to site

Informative guide to these closely related vegetables from the Virginia Cooperative Extension. There is a guide to planting them, as well as the types of soil, sunlight, and moisture that yield best results. This site also features solutions to common problems and information about harvesting and storage.

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online system

in computing, originally a system that allows the computer to work interactively with its users, responding to each instruction as it is given and prompting users for information when necessary. As almost all the computers used now work this way, 'online system' is now used to refer to large database, e-mail, and conferencing systems accessed via a modem or network connection. These often have tens or hundreds of users from different places – sometimes from different countries – 'online' at the same time.

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ontogeny

the process of development of a living organism, including the part of development that takes place after hatching or birth. The idea that 'ontogeny recapitulates phylogeny' (the development of an organism goes through the same stages as its evolutionary history), proposed by the German scientist Haeckel, has now been greatly modified.

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onyx

semi-precious variety of chalcedonic silica (SiO_2) in which the crystals are too fine to be detected under a microscope, a state known as cryptocrystalline. It has straight parallel bands of different colours: milk-white, black, and red.

Sardonyx, an onyx variety, has layers of brown or red carnelian alternating with lighter layers of onyx. It can be carved into cameos.

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oocyte

in medicine, an immature ovum. Only a fraction of the oocytes produced in the ovary survive until puberty and not all of these undergo meiosis to become an ovum that can be fertilized by a sperm.

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oolite

limestone made up of tiny spherical carbonate particles, called **ooliths**, cemented together. Ooliths have a concentric structure with a diameter up to 2 mm/0.08 in. They were formed by chemical precipitation and accumulation on ancient sea floors.

The surface texture of oolites is rather like that of fish roe. The late Jurassic limestones of the British Isles are mostly oolitic in nature.

Oort, Jan Hendrik (1900-1992)

Dutch astronomer. In 1927 he calculated the mass and size of our Galaxy, the Milky Way, and the Sun's distance from its centre, from the observed movements of stars around the Galaxy's centre. In 1950 Oort proposed that comets exist in a vast swarm, now called the Oort cloud, at the edge of the Solar System.

In 1944 Oort's student Hendrik van de Hulst (1918-) calculated that hydrogen in space would emit radio waves at 21 cm/8.3 in wavelength, and in the 1950s Oort's team mapped the spiral structure of the Milky Way from the radio waves given out by interstellar hydrogen.

Oort cloud

spherical cloud of comets beyond Pluto, extending out to about 100,000 astronomical units (approximately 1.6 light years) from the Sun. The gravitational effect of passing stars and the rest of our Galaxy disturbs comets from the cloud so that they fall in towards the Sun on highly elongated orbits, becoming visible from Earth. As many as 10 trillion comets may reside in the Oort cloud, named after Dutch astronomer Jan Oort who postulated its existence in 1950.

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oosphere

another name for the female gamete, or ovum, of certain plants such as algae.

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ooze

sediment of fine texture consisting mainly of organic matter found on the ocean floor at depths greater than 2,000 m/6,600 ft. Several kinds of ooze exist, each named after its constituents.

Siliceous ooze is composed of the silica shells of tiny marine plants (diatoms) and animals (radiolarians). **Calcareous ooze** is formed from the calcite shells of microscopic animals (foraminifera) and floating algae (coccoliths).

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opah

or moonfish

large marine bony fish. These fish may be up to 2 m/6.6 ft long and weigh approximately 200 kg/440 lb. They are widely distributed in warm seas, and feed on squids, crustaceans, and small fish.

classification

Opahs are genus *Lampris*, family Lampridae, order Lampriformes.

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opal

form of hydrous silica ($SiO_2.nH_2O$), often occurring as stalactites and found in many types of rock. The common opal is translucent, milk-white, yellow, red, blue, or green, and lustrous. Precious opal is opalescent, the characteristic play of colours being caused by close-packed silica spheres diffracting light rays within the stone.

Opal is cryptocrystalline, that is, the crystals are too fine to be detected under an optical microscope. Opals are found in Hungary; New South Wales, Australia (black opals were first discovered there in 1905); and Mexico (red fire opals).

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open cluster

or galactic cluster

loose cluster of young stars. More than 1,200 open clusters have been catalogued, each containing between a dozen and several thousand stars. They are also known as galactic clusters because of their abundance along the galactic plane. Examples include the Pleiades and the Hyades. Star clusters are of interest to astronomers because they represent samples of stars that have been formed at the same time from similar material. See also globular cluster and star cluster.

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open-hearth furnace

method of steelmaking, now largely superseded by the basic-oxygen process. It was developed in 1864 in England by German-born William and Friedrich Siemens, and improved by Pierre and Emile Martin in France in the same year. In the furnace, which has a wide, saucer-shaped hearth and a low roof, molten pig iron and scrap are packed into the shallow hearth and heated by overhead gas burners using preheated air.

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open source

computing term to describe the distribution of software with its source code, its original instructions. Anyone may examine open-source software's codes, make improvements, and pass these on to the open source community. Its use created one of the most adaptable systems for developing software, including powerful operating systems like GNU, the free UNIX-like software distributed by the Free Software Foundation, and the non-proprietary Linux operating system.

The distribution terms of open source software must comply with criteria laid down at the Open Source organization. This movement aimed to provide any tool or system free to those who wished to use it, and to engineer alternatives to commercial software. The rules allowed open source companies to charge a nominal fee for creating packages of applications and for customer support. Users may write their own commercial software provided that it does not use any sections of open source code.

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operating system

OS

in computing, a program that controls the basic operation of a computer. A typical OS controls the peripheral devices such as printers, organizes the filing system, provides a means of communicating with the operator, and runs other programs.

Many operating systems are written to run on specific computers, but some are available from third-party software houses and will run on machines from a variety of manufacturers. Examples include Apple's Macintosh OS X, Microsoft's Windows, and Unix.

Unix (developed at AT&T's Bell Laboratories) is the standard on workstations, minicomputers, and supercomputers; it is also used on desktop PCs and mainframes. The relatively recent Linux is rapidly increasing in popularity.

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operational amplifier

or op-amp

processor that amplifies the difference between two incoming electrical signals. It is a current gain device. Operational amplifiers have two inputs, an inverting input (-) and a noninverting input (+). The input signal from a sensor or switch, often as part of a potential divider, is compared with a similar signal at the other input. This then decides the type of output. If a positive signal is applied to the noninverting input, the output will be positive. If the input is negative, the output will be negative. If a positive signal is given to the inverting input, the output will be negative. A negative input will give a positive output. If the signals at the two inputs are the same, the output will be zero. Feedback loops are attached from the output to the input in order to control the amplification of the output.

Operational amplifiers usually come in an IC (integrated circuit) package. The output from the amplifier is attached to a transducer driver which in turn activates an output device.

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operon

group of genes that are found next to each other on a chromosome, and are turned on and off as an integrated unit. They usually produce enzymes that control different steps in the same biochemical pathway by a single operator gene. Operons were discovered in 1961 (by the French biochemists François Jacob and Jacques Monod) in bacteria.

They are less common in higher organisms where the control of metabolism is a more complex process.

Ophiuchus

large constellation along the celestial equator (see celestial sphere), known as the serpent bearer because the constellation Serpens is wrapped around it. The Sun passes through Ophiuchus each December, but the constellation is not counted as part of the zodiac. Ophiuchus contains Barnard's star. It was in the southeastern corner of this constellation that Kepler's star, the most recent supernova in our galaxy, appeared in 1604.

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ophthalmia neonatorum

form of conjunctivitis mostly contracted during delivery by an infant whose mother is infected with gonorrhoea. It can lead to blindness unless promptly treated.

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ophthalmology

medical speciality concerned with diseases of the eye and its surrounding tissues.

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opiate, endogenous

naturally produced chemical in the body which has effects similar to morphine and other opiate drugs; a type of neurotransmitter.

Examples include endorphins and encephalins.

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opioid analgesic

or narcotic analgesic

in medicine, pain relieving agent that acts at receptor sites in the central nervous system. Opiates are used to relieve moderate to severe pain. Drugs in this class include morphine, pethidine, and diamorphine (heroin). Dependence and tolerance to these drugs can develop.

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opium

drug extracted from the unripe seeds of the opium poppy (*Papaver somniferum*) of southwestern Asia. An addictive narcotic, it contains several alkaloids, including **morphine**, one of the most powerful natural painkillers and addictive narcotics known, and **codeine**, a milder painkiller.

Heroin is a synthetic derivative of morphine and even more powerful as a drug. Opium is still sometimes given as a tincture, dissolved in alcohol and known as **laudanum**. Opium also contains the highly poisonous alkaloid **thebaine**.

Opium Kings

Go to site

Companion site to the PBS television programme *Frontline*, this page includes information about opium and heroin, their effects on the brain, and the strategies that law enforcement agencies have developed to fight opium production and heroin addiction. Articles describe the process of turning poppies into heroin and an outline the history of opium going back to its initial cultivation in 3400 BC. You can also find interviews with US 'drug czars', a US Drug Enforcement Agency official, and a former ambassador to Burma. There are maps and charts of areas where opium is cultivated and maps that detail the heroin trade routes.

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opossum

any of a family of marsupials (mammals that carry their young in a pouch) native to North and South America. Most opossums are tree-living, nocturnal animals, with prehensile tails that can be used as an additional limb, and hands and feet well adapted for grasping. They range from 10 cm/4 in to 50 cm/20 in in length and are insectivorous, carnivorous, or, more commonly, omnivorous. (Family Didelphidae.)

The name is also popularly applied to some of the similar-looking phalangers found in Australia.

Oppenheimer, J(ulius) Robert (1904-1967)

US physicist. As director of the Los Alamos Science Laboratory 1943–45, he was in charge of the development of the atom bomb (the Manhattan Project). He objected to the development of the hydrogen bomb, and was alleged to be a security risk in 1953 by the US Atomic Energy Commission (AEC).

Investigating the equations describing the energy states of the atom, Oppenheimer showed in 1930 that a positively charged particle with the mass of an electron could exist. This particle was detected in 1932 and called the positron.

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opposition

in astronomy, moment at which a body in the Solar System lies opposite the Sun in the sky as seen from the Earth and crosses the meridian at about midnight.

Although the inferior planets cannot come to opposition, it is the best time for observation of the superior planets as they can then be seen all night.

opposition

(Image © NASA)

Mars at opposition (roughly in line with the Earth on one side of the Sun) on 13-14 June 2001. Mars is in opposition about every 26 months.

optical aberration

see aberration, optical.

optical activity

in chemistry, the ability of certain crystals, liquids, and solutions to rotate the plane of polarized light as it passes through them. The phenomenon is related to the three-dimensional arrangement of the atoms making up the molecules concerned. Only substances that lack any form of structural symmetry exhibit optical activity.

optical character recognition

OCR

in computing, a technique for inputting text to a computer by means of a document reader. First, a scanner produces a digital image of the text; then character-recognition software makes use of stored knowledge about the shapes of individual characters to convert the digital image to a set of internal codes that can be stored and processed by a computer.

OCR originally required specially designed characters but current devices can recognize most standard typefaces and even handwriting. OCR is used, for example, by gas and electricity companies to input data collected on meter-reading cards, and by personal digital assistants to recognize users' handwriting.

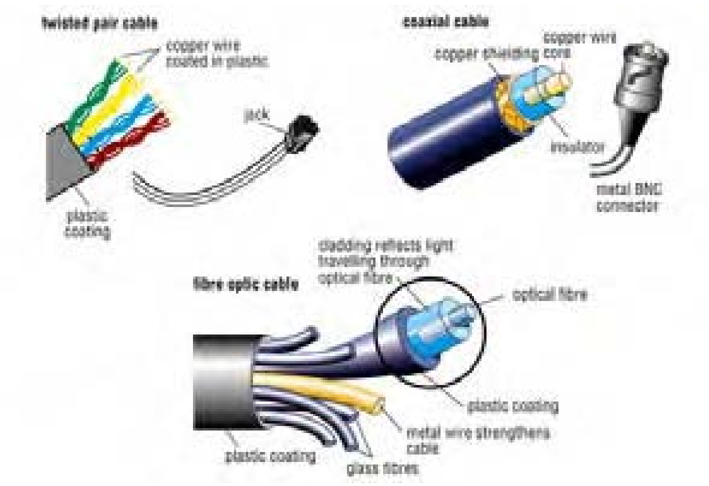
optical fibre

very fine, optically-pure glass fibre through which light can be reflected to transmit images or data from one end to the other. Although expensive to produce and install, optical fibres can carry more data than traditional cables, and are less susceptible to interference. Standard optical fibre transmitters can send up to 10 billion bits of information per second by switching a laser beam on and off.

Optical fibres are increasingly being used to replace metal communications cables, the messages being encoded as digital pulses of light rather than as fluctuating electric current. Research is investigating how optical fibres could replace wiring inside computers.

Bundles of optical fibres are also used in endoscopes to inspect otherwise inaccessible parts of machines or of the living body (see endoscopy).

optical fibre


twisted pair cable
copper wire coated in plastic
jack
plastic coating
coaxial cable
copper wire
copper shielding core
insulator
metal BNC connector
fibre optic cable
cladding reflects light travelling through optical fibre
optical fibre
plastic coating
metal wire strengthens cable
plastic coating
glass fibres

(Image © Research Machines plc)

The major differences in construction between twisted pair (telephone), coaxial, and fibre optic cable.

optical illusion

scene or picture that fools the eye. An example of a natural optical illusion is that the Moon appears bigger when it is on the horizon than when it is high in the sky.

optical instrument

instrument that makes use of one or more lenses or mirrors, or of a combination of these, in order to change the path of light rays and produce an image. Optical instruments such as magnifying glasses, microscopes, and telescopes are used to provide a clear, magnified image of the very small or the very distant. Others, such as cameras, photographic enlargers, and film projectors may be used to store or reproduce images.

optic nerve

large nerve passing from the eye to the brain, carrying visual information. In mammals, it may contain up to a million nerve fibres, connecting the sensory cells of the retina to the optical centres in the brain. Embryologically, the optic nerve develops as an outgrowth of the brain.

optics

branch of physics that deals with the study of light and vision – for example, shadows and mirror images, lenses, microscopes, telescopes, and cameras. On striking a surface, light rays are reflected or refracted, and the study of this is known as geometrical optics.

Online Photonics Resource

Go to site

News, features, and discussion of developments in optics research and technology. A powerful search facility makes this an invaluable starting point for the finding of optics resources on the Internet.

optoelectronics

branch of electronics concerned with the development of devices (based on the semiconductor gallium arsenide) that respond not only to the electrons of electronic data transmission, but also to photons ('particles' of light).

opuntia

any cactus belonging to the same group of plants as the prickly pear. They all have showy flowers and fleshy, jointed stems. (Genus *Opuntia*, family Cactaceae.)

oral contraceptive

in medicine, synthetic female hormones that are taken by mouth for contraception and commonly referred to as the pill.

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orange

round orange-coloured juicy citrus fruit of several species of evergreen trees, which bear white blossom and fruits at the same time. Thought to have originated in Southeast Asia, orange trees are commercially cultivated in Spain, Israel, the USA, Brazil, South Africa, and elsewhere. The sweet orange (*C. sinensis*) is commonly eaten fresh; the Jaffa, blood, and navel orange are varieties of this species. (Genus *Citrus*, family Rutaceae.)

Tangerines and mandarins belong to a related species (*C. reticulata*). The sour or Seville orange (*C. aurantium*) is the bitter orange used in making marmalade. Oranges yield several essential oils.

orange tree

(Image © Corel)

Orange tree bearing fruit and blossom. The fruit of the orange is rich in vitamin C, sugars, and acids.

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orang-utan

ape *Pongo pygmaeus*, found solely in Borneo and Sumatra. Up to 1.65 m/5.5 ft in height, it is covered with long, red-brown hair and mainly lives a solitary, arboreal life, feeding chiefly on fruit. Now an endangered species, it is officially protected because its habitat is being systematically destroyed by deforestation. In March 2001, there were estimated to be fewer than 25,000 orang-utans in the wild.

There are two subspecies: *P. p. pygmaeus* found in Borneo, and the smaller *P. p. abelli* on Sumatra. Their rate of reproduction is very slow, with an eight-year gap between births. Orang-utans are slow-moving and have been hunted for food, as well as by animal collectors. The name means 'man of the forest'.

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orbit

in mammals, one of two bony cavities on either side of the nose in which the eyes are situated. They protect the eyes from injury because of the thickness of the bone at the front of the orbit.

The optic canal, which is the route between the optic nerve and the brain, opens into the rear of the orbits and nerves and blood vessels pass through the optical fissures. The eyes are held within the orbits by the extra-ocular muscles and the orbital septum.

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orbit

path of one body in space around another, such as the orbit of the Earth around the Sun or of the Moon around the Earth. Both bodies move around their common centre of mass. The movement of objects in orbit follows Kepler's laws, which apply to artificial satellites as well as to natural bodies.

As stated by the laws, the orbit of one body around another is an ellipse. The ellipse can be highly elongated, as are comet orbits around the Sun, or it may be almost circular, as are those of some planets. The closest point of a planet's orbit to the Sun is called **perihelion**; the most distant point is **aphelion**. (For a body orbiting the Earth, the closest and furthest points of the orbit are called **perigee** and **apogee**.)

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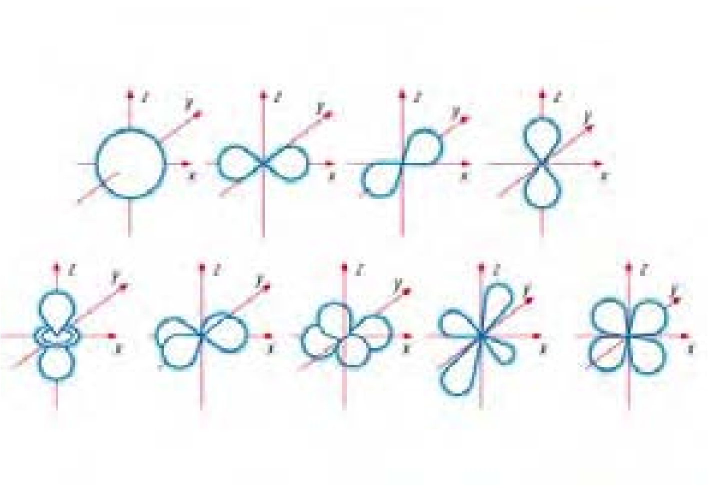
orbital, atomic

region around the nucleus of an atom (or, in a molecule, around several nuclei) in which an electron is likely to be found. According to quantum theory, the position of an electron is uncertain; it may be found at any point. However, it is more likely to be found in some places than in others, and this pattern of probabilities makes up the orbital.

An atom or molecule has numerous orbitals, each of which has a fixed size and shape. An orbital is characterized by three numbers, called quantum numbers, representing its energy (and hence size), its angular momentum (and hence shape), and its orientation. Each orbital can be occupied by one or (if their spins are aligned in opposite directions) two electrons.

orbital, atomic



(Image © Research Machines plc)

The shapes of atomic orbitals. An atomic orbital is a picture of the 'electron cloud' that surrounds the nucleus of an atom. There are four basic shapes for atomic orbitals: spherical, dumbbell, clover-leaf, and complex (shown at bottom left).

orbitals

To remember the order of atomic orbitals:

Spin **p**airs **d**on't **f**orm - **g**o **h**igher

The Pauli selection rule states that two electrons of like spin may not be present in any orbital if they have the same set of quantum numbers. Since the electronic orbitals in atoms are listed by the letters s, p, d, f, g, h, in order of ascending energy, this mnemonic acts as a useful reminder

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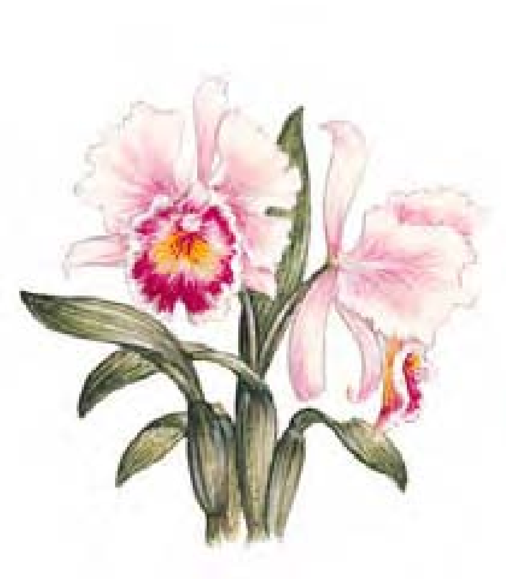
orchid

any plant of a large family that contains at least 15,000 species and 700 genera, distributed throughout the world except in the coldest areas, and most numerous in damp equatorial regions. The flowers are the most highly evolved of the plant kingdom; they have three sepals and three petals and sometimes grow singly, but more usually appear with other flowers on spikes, growing up one side of the main stem, or all around the main stem, which may be upright or drooping. (Family Orchidaceae.)

orchid

The flowers of bee orchids resemble female bees so completely that they have the same shape, the same smell, and even the same degree of hairiness.

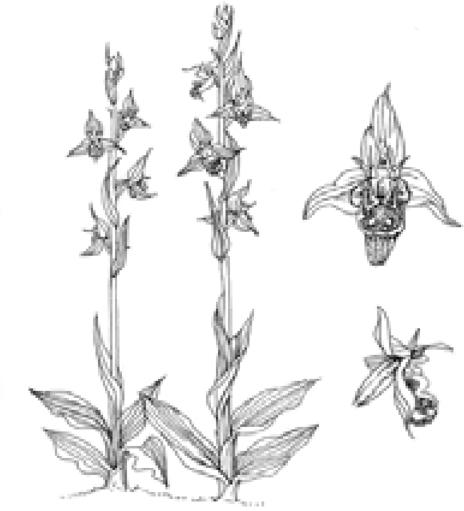
orchid



(Image © Research Machines plc)

The orchid belongs to one of the largest flowering-plant families: there are at least 15,000 species. They have evolved complex mechanisms and structures to ensure successful pollination by insects.

orchid



(Image © Research Machines plc)

The bee orchid (*Ophrys apifera*) is one of a number of species of orchid whose flowers resemble female insects or spiders. Male insects emerge before the females, in the early spring while the orchids are blooming. Tempted by the hairy, metallic purple flowers, the male insect attempts to mate with the orchid. In the process, the insect inadvertently picks up pollen, which he then transfers to his next 'mate'. The bee orchid grows primarily in the Mediterranean region.

Orchid House

Go to site

Everything you could ever want to know about orchids can be found here. There is a very good introductory 'Frequently Asked Questions' section, as well as information for the more experienced horticulturist. There is even an orchid-related short story and some pictures of orchids accompanied by soothing music.

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order

in biological classification, a group of related families. For example, the horse, rhinoceros, and tapir families are grouped in the order Perissodactyla, the odd-toed ungulates, because they all have either one or three toes on each foot. The names of orders are not shown in italic (unlike genus and species names) and by convention they have the ending '-formes' in birds and fish; '-a' in mammals, amphibians, reptiles, and other animals; and '-ales' in fungi and plants. Related orders are grouped together in a class.

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ordinal number

in mathematics, one of the series first, second, third, fourth, ... Ordinal numbers relate to order, whereas cardinal numbers (1, 2, 3, 4, ...) relate to quantity, or count.

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ordinate

in coordinate geometry, the *y* coordinate of a point; that is, the vertical distance of the point from the horizontal or *x*-axis. For example, a point with the coordinates (3,4) has an ordinate of 4. See abscissa.

Ordovician period

period of geological time 510-439 million years ago; the second period of the Palaeozoic era. Animal life was confined to the sea: reef-building algae and the first jawless fish are characteristic.

The period is named after the Ordovices, an ancient Welsh people, because the system of rocks formed in the Ordovician period was first studied in Wales.

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ore

body of rock, a vein within it, or a deposit of sediment, worth mining for the economically valuable mineral it contains. The term is usually applied to sources of metals. Occasionally metals are found uncombined (native metals), but more often they occur as compounds such as carbonates, sulphides, or oxides. The ores often contain unwanted impurities that must be removed when the metal is extracted.

Commercially valuable ores include bauxite (aluminium oxide, Al_2O_3) haematite (iron(III) oxide, Fe_2O_3), zinc blende (zinc sulphide, ZnS), and rutile (titanium dioxide, TiO_2).

Hydrothermal ore deposits are formed from fluids such as saline water passing through fissures in the host rock at an elevated temperature. Examples are the 'porphyry copper' deposits of Chile and Bolivia, the submarine copper-zinc-iron sulphide deposits recently discovered on the East Pacific Rise, and the limestone lead-zinc deposits that occur in the southern USA and in the Pennines of Britain.

Other ores are concentrated by igneous processes, causing the ore metals to become segregated from a magma - for example, the chromite- and platinum-rich bands within the bushveld, South Africa. Erosion and transportation in rivers of material from an existing rock source can lead to further concentration of heavy minerals in a deposit - for example, Malaysian tin deposits.

Weathering of rocks in situ can result in residual metal-rich soils, such as the nickel-bearing laterites of New Caledonia.

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oregano

any of several perennial herbs belonging to the mint family, especially the aromatic *O. vulgare*, also known as wild marjoram. It is native to Mediterranean countries and western Asia and naturalized in the Americas. Oregano is extensively used to season Mediterranean cooking. (Genus *Origanum*, family Labiatae.)

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orfe

freshwater fish belonging to the carp family. It grows up to 50 cm/1.7 ft in length, and feeds on small aquatic animals. The species is generally greyish-black, but an ornamental variety is orange. It lives in rivers and lakes of Europe and northwestern Asia. (Species *Leuciscus idus*, family Cyprinidae.)

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organ

in biology, a part of a living body that has a distinctive function or set of functions. Examples include the oesophagus, liver, or brain in animals, or a leaf in plants. An organ is composed of a group of coordinated tissues. A group of organs working together to perform a function is called an organ system, for example, the digestive system comprises a number of organs including the oesophagus, stomach, the small intestine, the pancreas, and the liver. The tissues of a leaf include the epidermis, palisade mesophyll, and spongy mesophyll. The tissues of the oesophagus include muscle, and epithelium.

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organelle

discrete and specialized structure in a living cell; organelles include mitochondria, chloroplasts, lysosomes, ribosomes, and the nucleus.

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organic chemistry

branch of chemistry that deals with carbon compounds. Organic compounds form the chemical basis of life and are more abundant than inorganic compounds. In a typical organic compound, each carbon atom forms bonds covalently with each of its neighbouring carbon atoms in a chain or ring, and additionally with other atoms, commonly hydrogen, oxygen, nitrogen, or sulphur.

The basis of organic chemistry is the ability of carbon to form long chains of atoms, branching chains, rings, and other complex structures. Compounds containing only carbon and hydrogen are known as **hydrocarbons**.

organic chemistry

To remember the prefixes for naming carbon chains:

Met **E**thel **p**roperly **b**ut **m**y **p**ants **h**ad **h**oles

Meth, **e**th, **p**rop, **b**ut, **p**ent, **h**ex, **h**ept
(methane can also be remembered by Me - one person)

Introduction to Organic Chemistry: Frequently Asked Questions

Go to site

Simple answers to 'Frequently Asked Questions' relating to organic chemistry. The page is part of a larger Web site called 'General Chemistry Online!'

Kilcoyne's Glossary

Go to site

Comprehensive glossary of chemical terms, from a site organized by the University of Sunderland, UK. Enter a chemistry-related word or phrase, and click for a definition.

Organic Chemistry: Introduction

Go to site

Interesting essay on organic chemistry that includes explanatory diagrams.

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organic compound

in chemistry, a class of compounds that contain carbon (carbonates, carbon monoxide, and carbon dioxide are excluded). The original distinction between organic and inorganic compounds was based on the belief that the molecules of living systems were unique, and could not be synthesized in the laboratory. Today it is routine to manufacture thousands of organic chemicals both in research and in the drug industry. Certain simple compounds of carbon, such as carbonates, oxides of carbon, carbon disulphide, and carbides are usually treated in inorganic chemistry.

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organic farming

farming without the use of synthetic fertilizers (such as nitrates and phosphates) or pesticides (herbicides, insecticides, and fungicides) or other agrochemicals (such as hormones, growth stimulants, or fruit regulators). Food produced by genetic engineering cannot be described as organic.

In place of artificial fertilizers, compost, manure, seaweed, or other substances derived from living things are used (hence the name 'organic'). Growing a crop of a nitrogen-fixing plant such as lucerne, then ploughing it back into the soil, also fertilizes the ground. Some organic farmers use naturally-occurring chemicals such as nicotine or pyrethrum to kill pests, but control by non-chemical methods is preferred. Those methods include removal by hand, intercropping (planting with companion plants which deter pests), mechanical barriers to infestation, crop rotation, better cultivation methods, and biological control. Weeds can be controlled by hoeing, mulching (covering with manure, straw, or black plastic), or burning off. Organic farming methods produce food with minimal pesticide residues and greatly reduce pollution of the environment. They are more labour-intensive, and therefore more expensive, but use less fossil fuel. Soil structure is greatly improved by organic methods, and recent studies show that a conventional farm can lose four times as much soil through erosion as an organic farm, although the loss may not be immediately obvious.

Organic Farming

introduction

Organic farming in Britain has grown since World War II from the activities of a few enthusiasts such as Lady Eve Balfour to the major movement of today with, in 2002, over 4,000 organic farmers cultivating almost 700,000 hectares. There was steady growth during the 1970s and 1980s and a sharp upturn towards the end of the 1990s, largely as a reaction to the BSE (bovine spongiform encephalopathy, or 'mad cow disease') epidemic and because of a decline in the fortunes of conventional farming. Public opposition to the introduction of genetically modified (GM) crops and the availability of financial assistance via the Ministry of Agriculture, Fisheries, and Food (MAFF) Organic Aid Scheme and, latterly, the Organic Farming Scheme have also been influential. In fact the Organic Farming Scheme became oversubscribed and additional funding was introduced to cope with the large numbers of farmers wishing to convert. Organic farming has ceased to be a fringe activity and has become very much a part of mainstream UK agriculture. The market for organic produce in the UK appears insatiable and a high percentage of produce sold is still imported. This means that there are continuing opportunities for farmers and horticulturists to develop indigenous organic enterprises.

perceived benefits and philosophy of organic farming

Of the many benefits claimed for organic farming, one of the main ones has been that the food so produced is somehow 'healthier' since it contains lower levels of pesticide, fertilizer, and antibiotic residues. For many consumers this provides the main incentive to shop for organic food. However, there is little, if any, hard evidence to support this claim, and healthiness, together with taste, must probably remain within the category of perceived rather than real benefits. Similarly, it is often pointed out that the health of the nation was much better in the 1940s than it is now, with lower incidences of heart disease and cancer, for example. It is difficult to track down the reasons for the current increase in these problems, which may be due to food produced with the use of pesticides and fertilizers, or the marked increase in our preference for fatty foods, for example. There is a great deal more to organic farming than operating without the use of artificial fertilizers, pesticides, and antibiotics. In fact some use of antibiotics as well as anthelmintics (used to kill certain parasites) is permitted on welfare grounds for the treatment of sick animals. Detailed attention to the management of soils, crop rotations involving legumes, the judicious use of composted organic wastes, mixed arable and livestock enterprises, and the replacement of routine antibiotic use with homeopathic veterinary remedies are all central to the success of many organic farms. But more than these there is, particularly among those who have been in the movement for some time, a philosophy of being at one with the environment and of farming with the principles of ecology to the fore. It is to be hoped that the newer entrants to this branch of agriculture will continue to adopt this holistic approach to their farming and that the 'commoditization' of organic produce, which is starting to happen, will not bring with it the familiar cycle of overproduction for maximum profit and subsequent decline. Many people want to buy organic produce and when they do they too buy into the idea of holistic, environmentally sustainable, non-intensive production.

good soil management

Of all the tenets of organic farming, that of good soil management would appear to be foremost. In fact one of the main guardians of organic standards in the UK has adopted the title The Soil Association just to emphasize the point. Damage to soil structure, increases in soil erosion, and the depletion of nutrients and soil organisms are all accusations laid at the door of conventional agriculture by organic farmers. Such criticism may not always be justified but does in fact establish some of the principles of organic practice. Cultivation on organic farms is always aimed at the minimization of soil erosion and the conservation of energy. It may also, by its timing, enable the control of some pest and weed problems and the conservation of nutrients. Cultivations are the main way in which organic farmers can control weeds. Various techniques exist, such as the 'stale seedbed' and the use of implements like the 'harrow comb', which can be used instead of herbicides. Less cultivation is normally required to produce a seedbed when the soil has been well supplied with organic matter. Organic material is decomposed in the soil by micro-organisms to produce humus, a sort of organic 'glue' that binds together individual particles to form larger aggregates and so increases the porosity of the soil. Organic matter is supplied from the addition of composted farmyard manure and other organic waste material to the soil at regular intervals, and also from the rotation of crops. In particular, the sowing of temporary grass/legume mixtures known as 'leys' will enhance the soil organic matter status. On an organic farm a field may very well spend 50% or more of its time under temporary leys, for periods of between one and four years. The other purpose for which the grass/legume leys are included in organic rotations is, of course, to provide nitrogen. The symbiotic association between various species of *Rhizobium* bacteria and members of the legume family is well known. A vigorous stand of red or white clover, lucerne (also known as alfalfa in other parts of the world), sainfoin, or trefoil can 'fix' in one year up to 250 kg/ha (220 lb/acre) of nitrogen in the form of microbial protein. These reservoirs of fertility are found in nodules that occur on the roots of leguminous plants. As the plants decay after cultivation, a proportion of the nitrogen so assimilated is mineralized by other soil bacteria, and eventually taken up by crop plants, such as the wheat normally sown into the high fertility situation that occurs after a ley is ploughed. Other leguminous plants frequently included in organic (and conventional) crop rotations are peas and beans and annual forage legumes such as vetches. Some idea of the financial value of the contribution of legume nitrogen may be gathered from investigating the current price of artificial nitrogen fertilizer. A tonne of 34.5% nitrogen ammonium nitrate fertilizer normally sells for about £100, which values a kilogram (2.2 lb) of non-organic nitrogen at about 29 pence. Conventional farmers are also reappraising their attitudes to clovers and lucerne in particular as a way of enhancing animal performance and saving costs.

nitrogen and other soil nutrients

Nitrogen is a particularly important nutrient for all crops and is the main constituent of plant proteins. Conventional farmers frequently apply 200-300 kg/ha (180-270 lb/acre) of nitrogen to achieve high-yielding crops but some of this leaches into rivers and groundwater and causes pollution. This is not the only source of nitrate pollution however. Organic farms too can pollute, particularly when nitrogen-rich ley pastures are ploughed in the autumn for arable cropping. There is concern about the level of nitrates in drinking water, and the European Union has decided that the level should not be more than 50 mg/litre (0.03 oz/pt) (although there is little hard evidence of health problems that can be linked to nitrate pollution). All farmers, both organic and conventional, can reduce nitrate leaching from their soils by complying with the MAFF Code of Practice for the Protection of Water. Organic crops can only obtain nitrogen from soil sources and so receive much reduced levels compared with conventional crops. Consequently they make much less vigorous foliage growth. This in turn usually means that there is far less disease apparent on the leaves. So in spite of the fact that organic farmers are precluded from applying the fungicides that conventional farmers do - anything up to three or four times in a season - the virtual absence of disease means that there is little need to do so in the first place! Apart from nitrogen, the other main nutrients required by crops are phosphorus and potassium. A certain amount of these is obtained from the natural weathering (breaking down) of minerals within the soil. Particularly in the case of phosphorus, this process is assisted by the presence of mycorrhizal fungi, which form associations with the roots of crop plants in much the same way that the nitrogen-fixing bacteria do with the roots of legumes. This enables the plants to access nutrients that would normally not be available because of the large amounts of fertilizers (especially phosphorus) applied to the soil each year by conventional farmers. In situations where nutrient levels have become very depleted, organic farmers are permitted to apply small amounts of low-solubility fertilizer minerals to replenish them.

organic livestock farming

Livestock enterprises on organic farms may not be sustained by intensive methods. This means that cattle and sheep are normally farmed at a lower stocking rate per hectare than on conventional farms. It also means that the enterprise may not be reliant on the use of such substances as anthelmintic drugs applied routinely. Measures have to be taken (for example alternate year-on-year grazing by cattle and sheep) to preclude infections. Similarly with pig and poultry enterprises, free-range and high-welfare systems are promoted to preclude the need for the routine use of the antibiotics and growth promoters that sustain their intensively reared cousins. Many organic producers use homeopathic veterinary remedies, but this is a very specialized area and expert advice should always be obtained. Animal feed must be obtained from mainly organic sources and in no circumstances may GM ingredients be used – this incurs substantial extra costs for organic livestock producers, particularly since so much of the world supply of soya is now obtained from GM varieties.

converting to organic farming

The yields obtained from organic enterprises, both crop and livestock, are normally lower than from comparable conventional farms. Organic crops in particular normally yield about 60% of the same crop grown conventionally. However, current undersupply means that substantial premiums are available and this has created a great deal of interest among conventional farmers wishing to convert. A two-year conversion period is stipulated prior to a farm achieving full organic status, and slightly longer may be needed to fully satisfy the requirements for some livestock enterprises. The conversion period presents a financial challenge and the farmer does not have the advantage of the price premiums enjoyed by fully organic producers. The purpose of the Organic Farming Scheme, introduced in 1999, was to offer aid for a five-year period from the start of conversion. It has been heavily oversubscribed and additional funding has been sought. Organic farmers are, in the main, relatively small producers but they have become extremely adept at marketing – some extremely innovative schemes have been evolved, including local farmers' markets and vegetable box delivery schemes. Also, many organic farmers run farm shops. Producer cooperatives have been formed and have taken up the box scheme idea. As more and more cultivators achieve full organic status it is going to be difficult to maintain the levels of premium currently being enjoyed. All of the main supermarkets have moved into organic produce in a big way, and have seen their sales rocket. But their track record in maintaining producer prices has not been good and the more astute organic producers sell to specialist outlets.

Organic farming: key dates

1888	Biological pest control, later to become an important aspect of organic agriculture, is first used in California to control scale insects on citrus plants.
1924	Austrian philosopher and educationalist Rudolf Steiner gives a series of lectures on agriculture. These describe methods for achieving harmony with natural forces, derived from his theories of anthroposophy. The lectures inspire the development of what becomes known as biodynamic agriculture.
1930	Biodynamic pioneers form the Demeter Trading Association to market their produce in Germany. The Association is banned by the Nazis in 1941.
1940	The English agronomist Sir Albert Howard publishes *An Agricultural Testament*. This influential book describes a theory of farming based on the maintenance of soil fertility through composting, and avoidance of mineral or chemical fertilizers.
1942	Inspired by the work of Howard, J I Rodale launches *Organic Gardening and Farming* magazine in the USA. Rodale does much to popularize the term 'organic' in an agricultural context.
1943	*The Living Soil* by Lady Eve Balfour, one of the most important figures in the development of organic farming in the UK, is published. She begins the 'Haughley Experiment' – a long-term (30 years) trial comparing the new intensive farming regime, reliant on chemicals, with the alternative organic methods championed by her and Albert Howard.
1946	The Soil Association is launched in England, catalysed by the work of Balfour, Howard, and others. It supports extensive research into the 'vital relationships between soil, plant, animal, and man'. The Association is based on Balfour's experimental farm in Suffolk. It will later become one of the most important organizations promoting organic farming and food.
1954	The Demeter Association is re-established in Germany to promote and regulate biodynamic produce.
1962	US biologist Rachel Carson's book *Silent Spring* describes the environmental damage done by heavy pesticide use, fuelling widespread public concern. There is a general increase in interest in 'natural' farming methods throughout the1960s and 1970s.
1975	British organic producers establish Organic Farmers and Growers, a cereal grain marketing cooperative.
1980	A new UK producers' self-help organization, the Organic Growers Association, is formed. It is followed in 1983 by a similar body, British Organic Farmers.
1986	The Organic Advisory Service is founded to assist British organic farmers. It is based at the Elm Farm Research Centre in Berkshire.
1987	The UK Register of Organic Food Standards (UKROFS) is established to oversee the certification of organic produce. At this time less than 0.1% of UK farmland is managed organically.
1989	Certification of organic producers in the UK is becoming more widespread, with 450 registered with the Soil Association, and 200 with Organic Farmers and Growers.
1991	European standards for organic production are agreed by liaison between the relevant national bodies of EC member states (for example, UKROFS in the UK), via the EC (as it then was). EEC Regulation No. 2092/91 defines the basic standards for farming and food processing and the requirements for policing. It is implemented in the UK by UKROFS.

1995	The UK government introduces the Organic Aid Scheme, offering payments to conventional farmers wishing to convert to organic methods. The Organic Conversion Information Service is launched the following year to advise farmers wishing to convert. The UK organic food market is growing at a very rapid rate, and is worth £140 million, yet only comprising 0.4% of the total food market; organic fruit and vegetables are the most popular organic product. 70% of the produce supplying the organic market is imported.
1996	The USA has over 70,000 government-certified organic farms; about 10% of Japan's farming villages have converted to organic production.
1997	The UK retail organic market is worth £273 million, having almost doubled in two years. Despite this, only 0.3% of British farmland is under organic methods, compared to 1.2% of the EU as a whole. Meanwhile, a poll indicates that over half of US consumers want organic methods to become the dominant form of agriculture in the USA.
1998	Controversy over the potential risks of genetic modification provides another boost for organic agriculture, which prohibits the use of GM crops. Sales of organic food are valued at £400 million in the UK, but 70% remains imported.
April 1999	The government opens its Organic Farming Scheme in England and Northern Ireland, which replaces the Organic Aid Scheme and raises payments to farmers wishing to convert to organic methods. The demand for the new scheme is so high that its entire 1999-2000 budget (£6.2 million) is allocated by August of the same year; a further £10 million is allocated in October 1999. Almost 1.5% of UK agricultural land is now organic, compared to 3% in Germany, 5% in Italy, 6% in Denmark, and 10% in Austria and Sweden. The EU average is 2.2%.
July 1999	Common standards for organic livestock and livestock products marketed in the EU are agreed by the Council of Ministers.
October 1999	The Organic Targets Bill is launched in Parliament, setting goals of 30% of UK farmland and 20% of UK food to be organic by 2010.
March 2000	The rapid growth of organic agriculture continues, with 2.7% of British agricultural land managed organically or under conversion to organic methods.
September 2001	The purple-skinned Sarpo potato, an obscure variety bred in Poland, provides an important breakthrough in organic farming. The tuber is found to have a natural resistance to potato blight, and can be grown commercially without pesticides.
May 2002	A European Union (EU) report warns that the introduction of genetically modified (GM) crops could destroy organic farming, because cross-contamination is virtually impossible to prevent.
July 2002	The UK government produces a 21-point action plan to triple organic food production, and reduce imports of organic products from 75% to 30%.
September 2003	Austria's attempt to turn itself into a GM-free zone, to protect wildlife, and conventional and organic crops, is blocked by the EU commission.
2004	A Defra commissioned survey finds that organic farmers are more likely to stay in farming than non-organic farmers, but that to maintain income levels, organic farmers needed to diversify more from their main farm activity.
2005	A report, The Impact of Organic Farming on the Rural Economy in England, is published by Exeter University.

International Federation of Organic Farming Movements

Go to site

Site of an international organization working to promote sustainable organic agriculture. There are a clear summary of the organization's goals, reports of international campaigns on food and farming issues, press releases, contacts for the hundreds of affiliated organizations, and details of related publications.

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organizer

in embryology, a part of the embryo that causes changes to occur in another part, through induction, thus 'organizing' development and differentiation.

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organophosphate insecticide

insecticidal compounds that cause the irreversible inhibition of the cholinesterase enzymes that break down acetylcholine. As this mechanism of action is very toxic to humans, the compounds should be used with great care. Malathion and permethrin may be used to control lice in humans and have many applications in veterinary medicine and agriculture. In 1998 organophosphates were the most widely used insecticides, with 40% of the global market.

According to the results of a survey by a UK team of psychiatrists, announced in 1998, one in ten farmers regularly exposed to organophosphates will suffer irreversible physical and mental damage. Sheep dipping is the most common source of exposure. Reported symptoms include tiredness and speech problems.
Organophosphate-induced delayed neuropathy is a condition of nerve and muscle damage through prolonged contact with organophosphates, which can lead to paralysis.

OR gate

in electronics, a type of logic gate.

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orimulsion

fuel made by mixing bitumen and water which can be burnt in the same way as heavy oil. It is cheap to make but the smoke produced has a high sulphur content.

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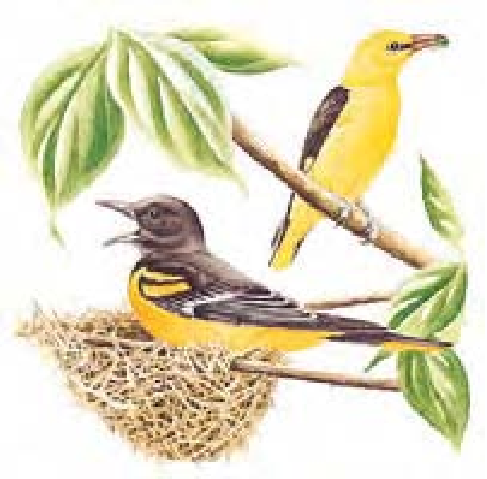
oriole

any of several brightly coloured songbirds belonging to two families: New World orioles belong to the family Icteridae, and Old World orioles are members of the family Oriolidae. They eat insects, seeds, and fruit.

oriole



(Image © Research Machines plc)

Most dictionaries suggest that the name 'oriole' comes from the Latin word *aureolus* meaning 'golden'. Indeed, many of the 28 species in the oriole family are combinations of golden yellow and black. Orioles are related to starlings and drongos and are found in Eurasia and a limited area of Africa. The golden oriole is found in Europe.

Orion

very prominent constellation in the equatorial region of the sky (see celestial sphere), identified with the hunter of Greek mythology.

The bright stars Alpha (Betelgeuse), Gamma (Bellatrix), Beta (Rigel), and Kappa Orionis mark the shoulders and legs of Orion. Between them the belt is formed by Delta, Epsilon, and Zeta, three second-magnitude stars equally spaced in a straight line. Beneath the belt is a line of fainter stars marking Orion's sword. One of these, Theta, is not really a star but the brightest part of the Orion nebula. Nearby is one of the most distinctive dark nebulae, the Horsehead.

Orion nebula

luminous cloud of gas and dust 1,500 light years away, in the constellation Orion, from which stars are forming. It is about 15 light years in diameter, and contains enough gas to make a cluster of thousands of stars.

At the nebula's centre is a group of hot young stars, called the **Trapezium**, which make the surrounding gas glow. The nebula is visible to the naked eye as a misty patch below the belt of Orion.

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ormolu

(French or moulu 'ground gold')

alloy of copper, zinc, and sometimes tin, used for furniture decoration.

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ornithology

study of birds. It covers scientific aspects relating to their structure and classification, and their habits, song, flight, and value to agriculture as destroyers of insect pests. Worldwide scientific banding (or the fitting of coded rings to captured specimens) has resulted in accurate information on bird movements and distribution. There is an International Council for Bird Preservation with its headquarters at the Natural History Museum, London.

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ornithophily

strategy evolved by flowers to ensure their pollination by birds. Ornithophilous flowers are typically brightly coloured, often red or orange. They produce large quantities of thin, watery nectar, and are scentless because most birds do not respond well to smell. They are found mostly in tropical areas, with hummingbirds being important pollinators in North and South America, and the sunbirds in Africa and Asia.

---

orogenesis

in its original, literal sense, orogenesis means 'mountain building', but today it more specifically refers to the tectonics of mountain building (as opposed to mountain building by erosion).

Orogenesis is brought about by the movements of the rigid plates making up the Earth's crust and uppermost mantle (described by plate tectonics). Where two plates collide at a destructive margin rocks become folded and lifted to form chains of mountains (such as the Himalayas). Processes associated with orogeny are faulting and thrusting (see fault), folding, metamorphism, and plutonism (see plutonic rock). However, many topographical features of mountains - cirques, U-shaped valleys - are the result of *non-orogenic* processes, such as weathering, erosion, and glaciation. Isostasy (uplift due to the buoyancy of the Earth's crust) can also influence mountain physiography.

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orrery

mechanical device for demonstrating the motions of the heavenly bodies. Invented about 1710 by George Graham, it was named after his patron, the 4th Earl of Orrery. It is the forerunner of the planetarium.

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orris root

underground stem of a species of iris grown in southern Europe. It is violet-scented and is used in perfumery and herbal medicine.

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orthochromatic

photographic film or paper of decreased sensitivity, which can be processed with a red safelight. Using it, blue objects appear lighter and red ones darker because of increased blue sensitivity.

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orthodontics

branch of dentistry concerned with dentition, and with treatment of any irregularities, such as correction of malocclusion (faulty position of teeth).

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orthopaedics

(Greek orthos 'straight'; pais 'child')

medical speciality concerned with the correction of disease or damage in bones and joints.

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ortolan

songbird belonging to the bunting family, common in Europe and West Asia, migrating to Africa in the winter. It is about 15 cm/6 in long and reddish-brown with black streaks on top, pinkish-buff below, and has an olive-green head and chest and a yellow throat; the female is paler with small dark streaks on the chest. The nest is built in the undergrowth, on the ground, or on banks. Long considered a delicacy among gourmets, it has become rare and is now a protected species. (Species *Emberiza hortulana*, family Emberizidae, order Passeriformes.)

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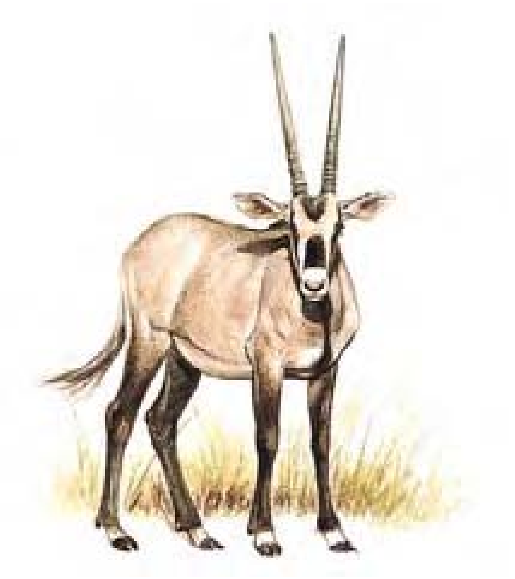
oryx

any of a group of large antelopes native to Africa and Asia. The **Arabian oryx** (*O. leucoryx*), at one time extinct in the wild, was successfully reintroduced into its natural habitat using stocks bred in captivity in 1982. By 1998 the oryx reintroduction project was seriously reduced through poaching. The population fell to 138, and 40 animals were returned to captivity as the population was believed to be no longer viable. By January 1999 there were fewer than 100 oryx remaining in the wild and only 11 of these were female. (Genus *Oryx*, family Bovidae.)

The **scimitar-horned oryx** (*O. tao*) of the Sahara is also rare. The **Beisa oryx** (*O. beisa*) in East Africa and **gemsbok** (*O. gazella*) in the Kalahari are more common. In profile the two long horns appear as one, which may have given rise to the legend of the unicorn.

oryx



(Image © Research Machines plc)

Once prized for its horns, this splendid antelope, the Arabian oryx, has been hunted almost to extinction although captive breeding and reintroduction programs seem to have saved it for the moment. It inhabits the dry, stony deserts of Arabia where it is well adapted to survive in the extremely arid conditions.

oryx

(Image © Corel)

An oryx roaming the Namib desert, Namibia, southwest Africa. Seen here in profile, only one of its two horns is visible and it is easy to see how the legend of the unicorn may have arisen.

OS/2

single-user computer operating system produced jointly by Microsoft Corporation and IBM for use on personal computers, particularly when attached to large IBM computers. Its main features are reliability – useful for running file servers – and a powerful object-oriented graphical user interface, Workplace Shell.

OS/2 was announced in 1987 but sales were poor. Microsoft abandoned it in 1992 to concentrate on Windows. IBM abandoned attempts to sell it on the mass market in 1997, but supports its use as a corporate and network computer operating system.

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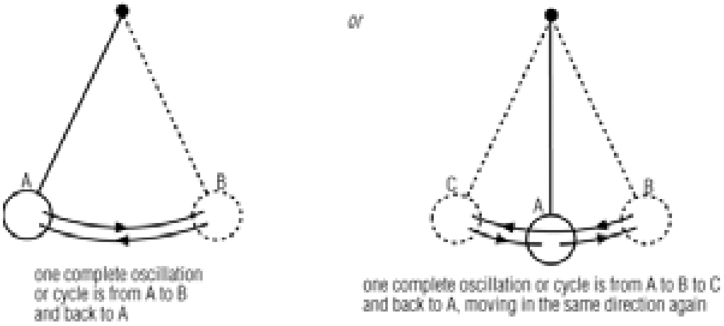
oscillating universe

in astronomy, theory stating that the gravitational attraction of the mass within the universe will eventually slow down and stop the expansion of the universe. The outward motions of the galaxies will then be reversed, eventually resulting in a 'Big Crunch' where all the matter in the universe will be contracted into a small volume of high density. This could undergo a further Big Bang, thereby creating another expansion phase. The theory suggests that the universe would alternately expand and collapse through alternate Big Bangs and Big Crunches. After a period when the idea of an oscillating universe fell out of favour, a version of it has been revived under the name of the cyclic model.

oscillation

one complete to-and-fro movement of a vibrating object or system. For any particular vibration, the time for one oscillation is called its period and the number of oscillations in one second is called its frequency. The maximum displacement of the vibrating object from its rest position is called the amplitude of the oscillation.

oscillation


A
B
one complete oscillation
or cycle is from A to B
and back to A
or
C
A
B
one complete oscillation or cycle is from A to B to C
and back to A, moving in the same direction again

(Image © Research Machines plc)

Alternate ways of defining the oscillation (one complete swing) of a pendulum.

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oscillator

any device producing a desired oscillation (vibration). There are many types of oscillator for different purposes. These involve various arrangements of thermionic valves or components such as transistors, inductors, capacitors, and resistors.

An oscillator is an essential part of a radio transmitter, generating the high-frequency carrier signal necessary for radio communication. The frequency is often controlled by the vibrations set up in a crystal (such as quartz).

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oscillograph

instrument for displaying or recording rapidly changing oscillations, electrical or mechanical.

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oscilloscope

another name for cathode-ray oscilloscope.

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osier

any of several willow trees and shrubs, cultivated for their supple branches which are used in basket making; in particular, *S. viminalis*. (Genus *Salix*.)

---

osmium

chemical symbol Os

(Greek osme 'odour')

hard, heavy, bluish-white, metallic element, atomic number 76, relative atomic mass 190.2. Together with the elements ruthenium, rhodium, palladium, iridium, and platinum, it forms the group of platinum metals, which have similar physical and chemical properties. It is resistant to tarnish and corrosion. It occurs in platinum ores and as a free metal (see native metal) with iridium in a natural alloy called osmiridium, containing traces of the other platinum group metals. Its uses include pen points and light-bulb filaments; like platinum, it is a useful catalyst.

It was discovered in 1803 and named in 1804 by English chemist Smithson Tennant (1761-1815) after the irritating smell of one of its oxides.

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osmoregulation

process whereby the water content of living organisms is maintained at a constant level. If the water balance is disrupted, the concentration of salts will be too high or too low, and vital functions, such as nerve conduction, will be adversely affected.

In mammals, loss of water by evaporation is counteracted by increased intake and by mechanisms in the kidneys that enhance the rate at which water is reabsorbed into the blood before urine production. Both these responses are mediated by hormones, primarily those of the adrenal cortex (see adrenal gland).

---

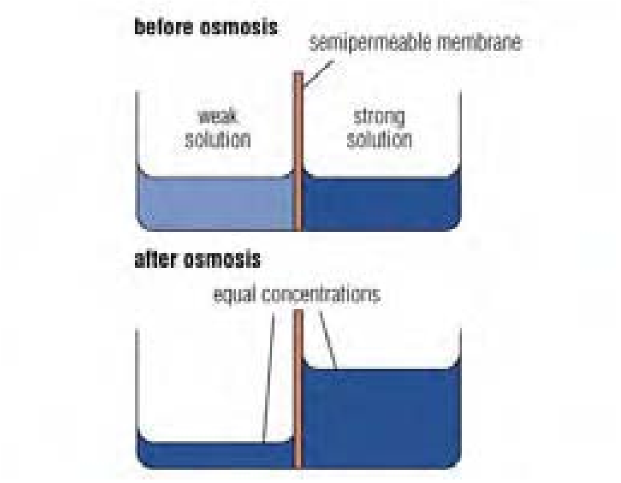
osmosis

movement of water through a partially (selectively) permeable membrane separating solutions of different concentrations. Water passes by diffusion from a **weak solution** (high water concentration) to a **strong solution** (low water concentration) until the two concentrations are equal. A membrane is partially permeable if it lets water through but not the molecules or ions dissolved in the water (the solute; for example, sugar molecules). Many cell membranes behave in this way, and osmosis is a vital mechanism in the transport of fluids in living organisms. One example is in the transport of water from soil (weak solution) into the roots of plants (stronger solution of cell sap) via the root hair cells. Another is the uptake of water by the epithelium lining the gut in animals. There are also membranes that humans can manufacture that are partially permeable.

If solutions have different concentrations of dissolved substance, there will be a difference in the concentration of water as well. Where there is a lot of dissolved substance there is less water. Where there is less dissolved substance there is more water. Water behaves like any other substance in diffusion. It diffuses from an area where there is a high concentration of it to an area where there is a lower concentration of it. Water diffuses down the concentration gradient for water and across the membrane. This means that it will diffuse from the dilute solution into the concentrated solution.

Excessive flow of water into a cell by osmosis can burst the cell. Cells protect against this using processes of osmoregulation. If external pressure is applied to the stronger solution, osmosis is arrested. By this mechanism plant cells can osmoregulate, since the cell wall of a fully turgid cell exerts pressure on the solution within the cell. Animal cells such as the red blood cell cannot osmoregulate in this way since they have no cell wall. Instead, the correct concentration of plasma is maintained by the kidney. This is important because if the concentration changes significantly, osmosis will take place and a lot of water will either diffuse out of cells into the blood or into cells from the blood, thereby damaging them.

osmosis



(Image © Research Machines plc)

Apparatus for demostrating osmosis. In 1877 German physicist Wilhelm Pfeffer used a similar apparatus to make the first ever measurement of osmotic pressure and show that osmotic pressure varies according to temperature and the strength of the solute (dissolved substance).

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osprey

bird of prey, sometimes called 'fish hawk' because it plunges feet first into the water to catch fish. It is dark brown above and a striking white below, and measures 60 cm/2 ft with a 2 m/6 ft wingspan. The nest is often built in trees near the seashore or lakeside, and two or three white eggs, blotched with crimson, are laid. Ospreys occur on all continents except Antarctica and have faced extinction in several areas. (Species *Pandion haliaetus*, family Pandionidae, order Falconiformes.)

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ossification

or osteogenesis

process whereby bone is formed in vertebrate animals by special cells (**osteoblasts**) that secrete layers of extracellular matrix on the surface of the existing cartilage. Conversion to bone occurs through the deposition of calcium phosphate crystals within the matrix.

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osteology

part of the science of anatomy, dealing with the structure, function, and development of bones.

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osteomyelitis

infection of bone, with spread of pus along the marrow cavity.

Now quite rare, it may follow from a compound fracture (where broken bone protrudes through the skin), or from infectious disease elsewhere in the body. It is more common in children whose bones are not yet fully grown.

The symptoms are high fever, severe illness, and pain over the limb. If the infection is at the surface of the bone it may quickly form an abscess; if it is deep in the bone marrow it may spread into the circulation and lead to blood poisoning. Most cases can be treated with immobilization, antibiotics, and surgical drainage.

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osteopathy

system of alternative medical practice that relies on physical manipulation to treat mechanical stress. It was developed over a century ago by US physician Andrew Taylor Still, who maintained that most ailments can be prevented or cured by techniques of spinal manipulation.

Osteopaths are generally consulted to treat problems of the musculo-skeletal structure such as back pain, and many doctors refer patients to them for such treatments. Although in the UK the wider applicability of their skills is not generally recognized, osteopathic doctors in the USA are also fully licensed to practice conventional medicine.

British Osteopathic Association

Go to site

Well-organized site that explains the basics behind the medical practice of osteopathy and gives details of related sites of interest and registered colleges and practitioners in the UK.

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osteoporosis

disease in which the bone substance becomes porous and brittle. It is common in older people, affecting more women than men. It may be treated with calcium supplements and etidronate. Approximately 1.7 million people worldwide, mostly women, suffer hip fractures, mainly due to osteoporosis. A single gene was discovered in 1993 to have a major influence on bone thinning.

Osteoporosis may occur in women whose ovaries have been removed, unless hormone-replacement therapy (HRT) is instituted; it may also occur in Cushing's syndrome and as a side effect of long-term treatment with corticosteroids. Early menopause in women, childlessness, small body build, lack of exercise, heavy drinking, smoking, and hereditary factors may be contributory factors.

MEdiC - Heath Explorer - Osteoporosis

Go to site

Fact sheet with basic information on osteoporosis. It includes risk factors and a catalogue of calcium food sources with exact nutritional information.

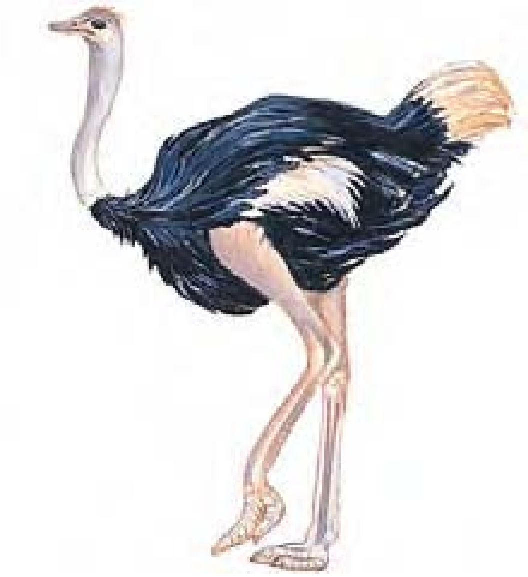
---

ostrich

large flightless bird. There is only one species, found in Africa. The male may be about 2.5 m/8 ft tall and weigh 135 kg/300 lb, and is the largest living bird. It has exceptionally strong legs and feet (two-toed) that enable it to run at high speed, and are also used in defence. It lives in family groups of one cock with several hens, each of which lays about 14 eggs. (Species *Struthio camelus*, order Struthioniformes.)

The adult male's body is covered with black feathers, the plumes of the wings and tail being white; females and young males have grey feathers. The bill is wide and flat, the small head has large eyes, and the long neck has a sparse covering of downy feathers. The male incubates the eggs at night, but the female may sit on them during the day. Their eggs are the smallest in relation to the adult's body size of any bird. Ostriches eat mainly plant material and they can survive for a long time without water.

ostrich



(Image © Research Machines plc)

The ostrich cannot fly but it is the fastest animal on two legs. It can run at speeds of up to 70 kph/44 mph. The ostrich lays the largest eggs of any bird, each egg being up to 20 cm/8 in long, weighing 1.3 kg/3 lb, and having the volume of 40 chicken eggs.

Ostwald, (Friedrich) Wilhelm (1853-1932)

Latvian-born German chemist who devised the Ostwald process (the oxidation of ammonia over a platinum catalyst to give nitric acid). His work on catalysts laid the foundations of the petrochemical industry. He was awarded the Nobel Prize for Chemistry in 1909 for his work in catalysis, and the principles of equilibria and rates of reaction.

Otis, Elisha Graves (1811-1861)

US engineer who developed an elevator that incorporated a safety device, making it acceptable for passenger use in the first skyscrapers. The device, invented in 1852, consisted of vertical ratchets on the sides of the elevator shaft into which spring-loaded catches would engage and 'lock' the elevator into position in the event of cable failure.

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otitis

inflammation of the ear. *Otitis externa*, occurring in the outer ear canal, is easily treated with antibiotics. Inflamed conditions of the middle ear (*otitis media*) or inner ear (*otitis interna*) are more serious, carrying the risk of deafness and infection of the brain. Treatment is with antibiotics or, more rarely, surgery. A 1999 US survey of children's middle-ear problems indicated that the risk is, to a large extent, hereditary.

Childhood Infections - Acute Otitis Media

Go to site

Useful information about acute otitis media, or earache. There is a detailed, illustrated description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

Childhood Infections - External Otitis (Swimmer's Ear)

Go to site

Useful information about *Otitis externa*. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection, how it can be treated both at home and professionally, and what to do should the symptoms occur.

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otosclerosis

overgrowth of bone in the middle ear causing progressive deafness. This inherited condition is gradual in onset, developing usually before middle age. It is twice as common in women as in men.

The middle ear cavity houses the sound-conduction mechanism called the ossicular chain, consisting of three tiny bones (ossicles) that magnify vibrations received at the eardrum for onward transmission to the inner ear. In otosclerosis, extraneous growth of spongy bone immobilizes the chain, preventing the conduction of sound. Surgery is necessary to remove the diseased bone and reconstruct the ossicular chain.

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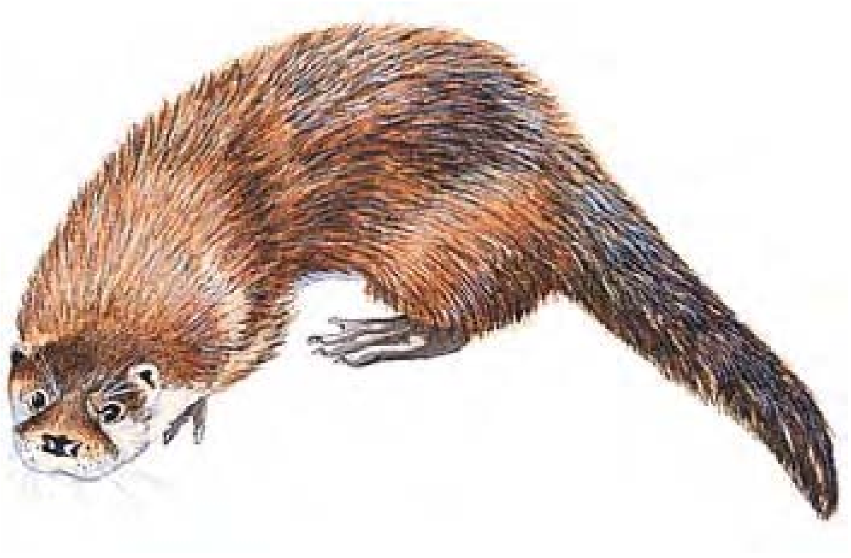
otter

any of various aquatic carnivores belonging to the weasel family, found on all continents except Australia. Otters have thick brown fur, short limbs, webbed toes, and long, compressed tails. They are social, playful, and agile.

otter



(Image © Research Machines plc)

Eurasian otters are among the fastest aquatic mammals, swimming at speeds of up to 10 kph/6 mph. They propel themselves by strong undulations of the body and tail and strokes of the hind feet. They can stay submerged for four minutes without coming up for air.

Sea Otter

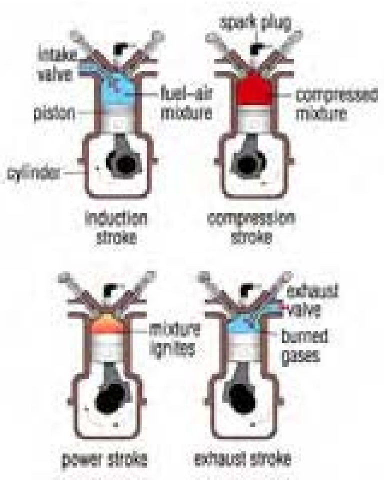
Go to site

Illustrated guide to the sea otter including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

Otto cycle

alternative name for the four-stroke cycle, introduced by the German engineer Nikolaus Otto (1832-1891) in 1876.

Otto cycle


spark plug
intake valve
fuel-air mixture
compressed mixture
piston
cylinder
induction stroke
compression stroke
exhaust valve
mixture ignites
burned gases
power stroke
exhaust stroke

(Image © Research Machines plc)

The four-stroke cycle of a modern petrol engine. The cycle is called the Otto cycle after German engineer Nikolaus Otto, who introduced it in 1876. It improved on earlier engine cycles by compressing the fuel mixture before it was ignited.

Oughtred, William (1575-1660)

English mathematician, credited as the inventor of the slide rule in 1622. His major work *Clavis mathematicae/The Key to Mathematics* (1631) was a survey of the entire body of mathematical knowledge of his day. It introduced the '×' symbol for multiplication, as well as the abbreviations 'sin' for sine and 'cos' for cosine.

Oughtred, William

Go to site

Biography of the English mathematician. The site contains a description of his works, and includes a page from *Clavis mathematicae* (1652) showing + and - and the notation for decimal fractions, all of which Oughtred is credited with inventing. Several literature references for further reading on the life and works of Oughtred are listed, and his portrait is also shown.

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ounce

another name for the snow leopard.

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ounce

unit of mass, one-sixteenth of a pound avoirdupois, equal to 437.5 grains (28.35 g); also one-twelfth of a pound troy, equal to 480 grains.

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outback

the inland region of Australia. Its main inhabitants are Aborigines, miners (including opal miners), and cattle ranchers. Its harsh beauty has been recorded by such artists as Sidney Nolan.

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output device

any device for displaying, in a form intelligible to the user, the results of processing carried out by a computer.

Electronic output devices can be mechanical, audio, or visual. Mechanical outputs include motors, solenoids, and other electromagnetic devices. Audio outputs include buzzers, loudspeakers, piezo transducers, and ultrasonic transmitters. Mechanical and audio outputs tend to have a higher power demand than other output devices. Visual outputs include lamps, LEDs (light-emitting diodes), and infrared transmitters.

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ouzel

or ousel

ancient name for the blackbird. The **ring ouzel** (*Turdus torquatus*) is similar to a blackbird, but has a white band across the breast. It is found in Europe in mountainous and rocky country.
Water ouzel is another name for the dipper.

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ovary

in female animals, the organ that generates the ovum. In humans, the ovaries are two whitish rounded bodies about 25 mm/1 in by 35 mm/1.5 in, located in the lower abdomen on either side of the uterus. Every month, from puberty to the onset of the menopause, an ovum is released from the ovary. This is called ovulation, and forms part of the menstrual cycle. In botany, an ovary is the expanded basal portion of the carpel of flowering plants, containing one or more ovules. It is hollow with a thick wall to protect the ovules. Following fertilization of the ovum, it develops into the fruit wall or pericarp.

The ovaries of female animals secrete the hormones responsible for the secondary sexual characteristics of the female, such as smooth, hairless facial skin and enlarged breasts. An ovary in a half-grown human fetus contains 5 million eggs, and so the unborn baby already possesses the female genetic information for the next generation.

In botany, the relative position of the ovary to the other floral parts is often a distinguishing character in classification; it may be either inferior or superior, depending on whether the petals and sepals are inserted above or below.

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overfishing

fishing at rates that exceed the sustained-yield cropping of fish species, resulting in a net population decline. For example, in the North Atlantic, herring has been fished to the verge of extinction, and the cod and haddock populations are severely depleted. In the developing world, use of huge factory ships, often by fisheries from industrialized countries, has depleted stocks for local people who cannot obtain protein in any other way. In their 2003 Global Environment Outlook Year Book, the United Nations Environment Program (UNEP) estimated that close to 75% of the world's fish stocks were already overexploited. See also fishing and fisheries.

Environmentalists have long been concerned at the wider implications of overfishing, in particular the devastation wrought on oceanic food chains. The United Nations Food and Agriculture Organization estimates that worldwide overfishing has damaged oceanic ecosystems to such an extent that their ability to support increased fish numbers is significantly reduced. With better management of fishing programmes the fishing catch could in principle be increased; however, it is estimated that, annually, tens of millions of tonnes of fish are discarded from fishing vessels at sea, because they are not the species sought.

overtone

note that has a frequency or pitch that is a multiple of the fundamental frequency, the sounding body's natural frequency. Each sound source produces a unique set of overtones, which gives the source its quality or timbre.

oviparous

method of animal reproduction in which eggs are laid by the female and develop outside the body, in contrast to ovoviviparous and viviparous. It is the most common form of reproduction.

ovoviviparous

method of animal reproduction in which fertilized eggs develop within the female (unlike oviparous), and the embryo gains no nutritional substances from the female (unlike viviparous). It occurs in some invertebrates, fishes, and reptiles.

ovulation

in female animals, the process of releasing egg cells (ova) from the ovary. In mammals it occurs as part of the menstrual cycle.

ovule

structure found in seed plants that develops into a seed after fertilization. It consists of an embryo sac containing the female gamete (ovum or egg cell), surrounded by nutritive tissue, the nucellus. Outside this there are one or two coverings that provide protection, developing into the testa, or seed coat, following fertilization.

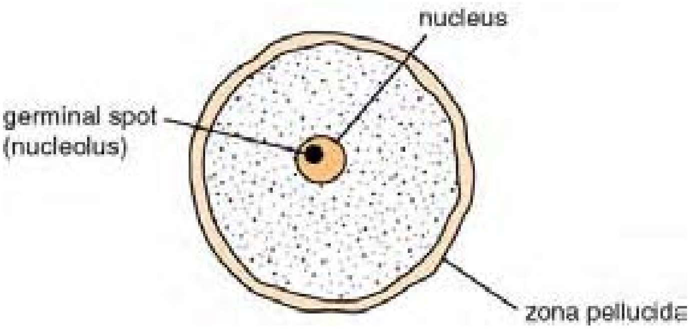
In angiosperms (flowering plants) the ovule is within an ovary, but in gymnosperms (conifers and their allies) the ovules are borne on the surface of an ovuliferous (ovule-bearing) scale, usually within a cone, and are not enclosed by an ovary.

ovum

plural ova

female gamete (sex cell) before fertilization. In mammals it is called an egg, and is produced by a special cell division called meiosis in the ovaries during the menstrual cycle. In plants, where it is also known as an egg cell or oosphere, the ovum is produced in an ovule. The ovum does not move by itself. It must be fertilized by a male gamete before it can develop further, except in cases of parthenogenesis.

ovum



(Image © Research Machines plc)

The structure of the female gamete, the ovum. The germinal spot is the nucleolus of the ovum.

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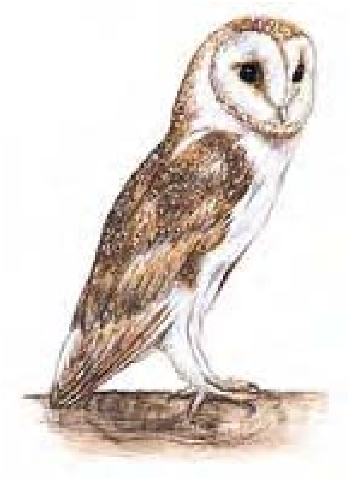
owl

any of a group of mainly nocturnal birds of prey found worldwide. They have hooked beaks, heads that can turn quickly and far round on their very short necks, and forward-facing immobile eyes, surrounded by 'facial discs' of rayed feathers; they fly silently and have an acute sense of hearing. Owls comprise two families: typical owls (family Strigidae), of which there are about 120 species, and barn owls (family Tytonidae), of which there are 10 species. (Order Strigiformes.)

They feed mainly on rodents, but sometimes also eat reptiles, fish, and insects, and some species have been seen feeding on carrion. All species lay white eggs, and begin incubation as soon as the first egg is laid. They regurgitate indigestible remains of their prey in pellets (castings).

owl



(Image © Research Machines plc)

The barn-owl family can be distinguished from other owl groups by its heart-shaped face, relatively small eyes, and long slender legs. The long, hooked beak is usually concealed by feathers. All barn-owls are hunters by night.

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ox

castrated male of domestic cattle, used in developing countries for ploughing and other agricultural work. Also the extinct wild ox or aurochs of Europe, and surviving wild species such as buffaloes and yaks.

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oxalic acid

or ethanedioic acid; $(COOH)_2.2H_2O$

white, poisonous solid, soluble in water, alcohol, and ether. Oxalic acid is found in rhubarb leaves, and its salts (oxalates) occur in wood sorrel (genus *Oxalis*, family Oxalidaceae) and other plants. It also occurs naturally in human body cells. It is used in the leather and textile industries, in dyeing and bleaching, ink manufacture, metal polishes, and for removing rust and ink stains.

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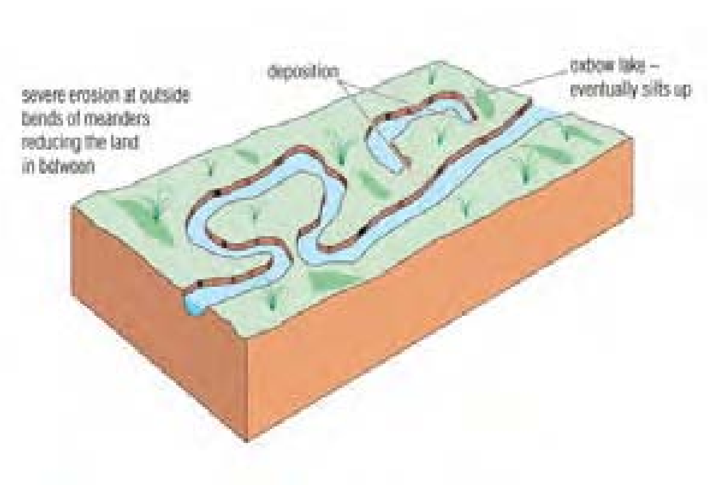
oxbow lake

curved lake found on the flood plain of a river. Oxbows are caused by the loops of meanders that are cut off at times of flood and the river subsequently adopts a shorter course. In the USA, the term bayou is often used.

oxbow lake



(Image © Research Machines plc)

The formation of an oxbow lake. As a river meanders across a flood plain, the outer bends are gradually eroded and the water channel deepens; as the loops widen, the neck of the loop narrows and finally gives way, allowing the water to flow in a more direct route, isolating the old water channel and forming an oxbow lake.

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oxidation

in chemistry, the loss of electrons, gain of oxygen, or loss of hydrogen by an atom, ion, or molecule during a chemical reaction.

At a simple level, oxidation may be regarded as the reaction of a substance with oxygen. For example, rusting, respiration, and combustion (burning) are all oxidation reactions. When carbon is burned in air it is oxidized to carbon dioxide:

$C + O_2 \rightarrow CO_2$

Oxidation may be brought about by reaction with another compound (oxidizing agent), which simultaneously undergoes reduction, or electrically at the anode (positive electrode) of an electrolytic cell.

oxidation and reduction: electrons

To remember the difference between oxidation and reduction with relation to electrons:

OILRIG

Oxidation **i**s **l**oss; **r**eduction **i**s **g**ain

oxidation and reduction: principles

To remember the principles of oxidation and reduction:

Remember that **Leo** the lion goes '**ger**'

Lose **e**lectrons - **o**xidation, **g**ain **e**lectrons - **r**eduction

---

oxidation

in earth science, a form of chemical weathering caused by the chemical reaction that takes place between certain iron-rich minerals in rock and the oxygen in water. It tends to result in the formation of a red-coloured soil or deposit. The inside walls of canal tunnels and bridges often have deposits formed in this way.

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oxidation number

Roman numeral often seen in a chemical name, indicating the valency of the element immediately before the number. Examples are lead(II) nitrate, manganese(IV) oxide (manganese dioxide), and potassium manganate(VII) (potassium permanganate).

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oxide

compound of oxygen and another element, frequently produced by burning the element or a compound of it in air or oxygen.

Oxides of metals are normally bases and will react with an acid to produce a salt in which the metal forms the cation (positive ion). Some of them will also react with a strong alkali to produce a salt in which the metal is part of a complex anion (negative ion; see amphoteric). Most oxides of non-metals are acidic (dissolve in water to form an acid). Some oxides display no pronounced acidic or basic properties. Some elements can form different oxides, for example burning carbon can result in carbon monoxide (CO) or carbon dioxide (CO_2).

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oxlip

plant closely related to the cowslip.

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oxpecker

or tick-bird

either of two species of African birds belonging to the starling family. They were thought to climb around on the bodies of large mammals, feeding on ticks and other parasites and on cattle earwax, but in a British study, published in April 2000, of red-billed oxpeckers on oxen in Zimbabwe, researchers found that the oxpeckers were not eating the oxen ticks, but were feeding on blood by pecking at existing wounds. Oxpeckers are usually seen in groups of seven or eight, attending a herd of buffaloes or antelopes, and may help to warn the host of approaching dangers.

Oxpeckers belong to the species *Buphagus africana*, family Sturnidae, order Passeriformes. Both species have dingy brown plumage, a tawny undersurface and tail, and large laterally flattened colourful bills - one species has a red bill, the other a red and yellow bill.

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oxyacetylene torch

gas torch that burns ethyne (acetylene) in pure oxygen, producing a high-temperature flame (3,000°C/5,400°F). It is widely used in welding to fuse metals. In the cutting torch, a jet of oxygen burns through metal already melted by the flame.

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oxygen

chemical symbol O

(Greek oxys 'acid'; genes 'forming')

colourless, odourless, tasteless, non-metallic, gaseous element, atomic number 8, relative atomic mass 15.9994. It is the most abundant element in the Earth's crust (almost 50% by mass), forms about 21% by volume of the atmosphere, and is present in combined form in water and many other substances. Oxygen is a by-product of photosynthesis and the basis for respiration in plants and animals.

Oxygen is very reactive and combines with all other elements except the noble gases (rare gases) and fluorine. Combustion (burning) and rusting are two examples of reactions involving oxygen. It is present in carbon dioxide, silicon dioxide (quartz), iron ore, calcium carbonate (limestone). In nature it exists as a molecule composed of two atoms (O_2); single atoms of oxygen are very short-lived owing to their reactivity. They can be produced in electric sparks and by the Sun's ultraviolet radiation in the upper atmosphere, where they rapidly combine with molecular oxygen to form ozone (O_3), an allotrope of oxygen.

Oxygen is obtained for industrial use by the fractional distillation of liquid air, by the electrolysis of water, or by heating manganese(IV) oxide with potassium chlorate. In the laboratory it is prepared by the action of the catalyst manganese(IV) oxide on hydrogen peroxide. The simple laboratory test for oxygen is that it relights a glowing spill. Oxygen is essential for combustion, and is used with ethyne (acetylene) in high-temperature oxyacetylene welding and cutting torches.

The element was first identified by English chemist Joseph Priestley in 1774 and independently in the same year by Swedish chemist Karl Scheele. It was named by French chemist Antoine Lavoisier in 1777.

Oxygen: Discovery

the French revolution

Not many scientists are credited with founding a major branch of science, but Antoine Lavoisier, the French aristocrat (1743-1794), is universally regarded as the founder of modern chemistry.

Before Lavoisier, chemistry had been dominated for 100 years by an influential theory of matter proposed by the German chemist Georg Stahl (1660-1743). This theory held that a combustible material burned because it contained a substance called **phlogiston**. Charcoal was a prime example of a phlogiston-rich material. The fact that metallurgists obtained some metals from their ores by heating them with charcoal seemed to lend support to the phlogiston theory of combustion. With hindsight, the reasons why such a theory persisted are obvious enough. Chemists had no clear idea of what a chemical element was, nor any understanding of the nature of gases.

Lavoisier's contribution

Lavoisier restructured chemistry and gave it its modern form. He provided a firm foundation for the atomic theory proposed by British chemist and physicist John Dalton (1766-1844), and his chemical elements were later classified in the Periodic Table.

fixed air?

The key experiments Lavoisier did seem simple enough. He burned phosphorus, lead and other solid elements in a sealed container. He noted that although the weight of the container and its contents did not increase, the weights of the solids in it did. He showed that the increase in weight of the solid was exactly compensated by the diminished weight of air present.

In 1772, he recorded the observation that when phosphorus and sulphur burn, their weight increases. He deduced that they combine with air. It followed that there should be a way of releasing this 'fixed' air. It should be explained that in the 18th century, because of the imperfect understanding scientists had of the nature of gases, they generally and confusingly referred to them as different sorts of 'air'.

the oxygen theory of combustion

Then in 1774, using a very large burning glass that belonged to the French Academy of Sciences, Lavoisier showed that when litharge (lead oxide, a compound of lead containing oxygen) is roasted with charcoal, an enormous volume of 'air' was indeed liberated. Although other scientists had already made similar experiments, it was Lavoisier who finally drew all the evidence together, and discovered the oxygen theory of combustion. He did not come to his conclusions immediately, but as the result of several related steps.

In 1774, Lavoisier was visited in Paris by the English chemist, Joseph Priestley (1773-1804). Priestley had heated a calx (he used the oxide of mercury) in a closed apparatus, and collected the gas that was liberated in the process. Priestley had found that this gas supported combustion better than air: a candle flame burned with a marvellous brilliance when placed in a container full of it.

the acid former

Lavoisier repeated Priestley's experiments, and convinced himself of the presence in air of a gas which combined with substances when they burn, and that it was the same gas given off when the oxide of mercury was heated. He named this gas 'oxygine', or 'acid former' (from the Greek), because he believed all acids contained oxygen.

Lavoisier had in the meantime identified the other main component of air, nitrogen, which he named 'azote', from the Greek for 'no life'. He also demonstrated that when hydrogen, which chemists of the day called 'inflammable air', was burned with oxygen, water was formed.

Lavoisier could now put the final nail in the coffin of the phlogiston theory because he could now explain that when metals dissolved in an acid, the hydrogen evolved came from the water, and not from the metal, as the phlogistonists asserted.

from combustion to respiration

The oxygen theory of combustion was now complete: when a substance burned, it combined with the oxygen in the air. To publish these results, Lavoisier and his colleagues started the journal *Annales de Chimie* in 1778. His textbook *An Elementary Treatise of Chemistry* was published the following year, and remained a model for modern chemical instruction for several decades.

Lavoisier also realized that respiration was like a slow form of combustion, in which the oxygen breathed in 'burned' the carbon in foodstuffs, which was then exhaled. As with the experiments on combustion, Lavoisier and his colleagues carried out exact measurements, using a guinea-pig. This is how the phrase 'to be a guinea-pig' originated.

Lavoisier was guillotined on 8 May 1794, executed on trumped-up charges during the Age of Terror. The mathematician Joseph Lagrange (1736-1813) said: 'It required only a moment to sever his head, and probably one hundred years will not suffice to produce another like it.'

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oxygen debt

physiological state produced by vigorous exercise, in which the lungs cannot supply all the oxygen that the muscles need. In other words, the lungs and bloodstream, pumped by the heart, cannot supply sufficient oxygen for aerobic respiration in the muscles. In such a situation the muscles can continue to break down glucose to liberate energy for a short time using anaerobic respiration. This partial breakdown produces lactic acid, which results in a sensation of fatigue when it reaches certain levels in the muscles and the blood. This explains why it is possible to run faster in a sprint than over longer distances. During the sprint, the muscles can respire anaerobically. Once the vigorous muscle movements cease, the body breaks down the accumulated lactic acid on top of the 'normal' breakdown of glucose in aerobic respiration, using up extra oxygen to do so. Panting after exercise is an automatic mechanism to 'pay off' the oxygen debt.

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oxytocin

hormone that stimulates the uterus in late pregnancy to initiate and sustain labour. It is secreted by the pituitary gland. After birth, it stimulates the uterine muscles to contract, reducing bleeding at the site where the placenta was attached.

Intravenous injections of oxytocin may be given to induce labour, strenghtn contractions, or control haemorrhage after birth. It is also secreted during lactation. Oxytocin sprayed in the nose a few minutes before nursing improves milk production.

oyster

edible shellfish with a rough, irregular hinged shell, found on the sea bottom in coastal areas. Oysters are bivalve molluscs; the upper valve (shell) is flat, the lower hollow, like a bowl, and the two are hinged by an elastic ligament. The mantle, a protective layer of skin, lies against the shell, shielding the inner body, which includes the organs for breathing, digesting food, and reproduction. Oysters commonly change their sex once a year, sometimes more often; females can release up to one million eggs during a spawning period. (Family Ostreidae.)

Oysters have been considered a delicacy since ancient times. Among the species commercially exploited for food today are the North American eastern oyster (*Crassostrea virginica*) of the Atlantic coast and the European oyster (*Ostrea edulis*). The former is oviparous (eggs are discharged straight into the water) and the latter is larviparous (eggs and larvae remain in the mantle cavity for a period before release). Oyster farming is increasingly practised, the beds being specially cleansed for the easy setting of the free-swimming larvae (known as 'spats'), and the oysters later properly spaced for growth and fattened.

Valuable pearls are not obtained from members of the true oyster family; they occur in pearl oysters (family Pteriidae). There are also tree oysters (family Isognomonidae) and thorny oysters (family Spondylidae).

oyster catcher

any of several quite large, chunky shorebirds, with a long, heavy bill which is flattened at the sides and used to prise open the shells of oysters, mussels, and other shellfish. (Family Haematopodidae, order Charadriiformes.)

oz

abbreviation for ounce.

Ozalid process

trademarked copying process used to produce positive prints from drawn or printed materials or film, such as printing proofs from film images. The film is placed on top of chemically treated paper and then exposed to ultraviolet light. The image is developed dry using ammonia vapour.

ozone

gas consisting of three atoms of oxygen (O_3), which is therefore an allotrope of oxygen. It is formed when the molecule of the stable form of oxygen (O_2) is split by ultraviolet radiation or electrical discharge. It forms the ozone layer in the upper atmosphere, which protects life on Earth from ultraviolet rays, a cause of skin cancer.

Ozone is a highly reactive pale-blue gas with a penetrating odour.

ozone depleter

any chemical that destroys the ozone in the stratosphere. Most ozone depleters are chemically stable compounds containing chlorine or bromine, which remain unchanged for long enough to drift up to the upper atmosphere. The best known are chlorofluorocarbons (CFCs).

Other ozone depleters include halons, used in some fire extinguishers; methyl chloroform and carbon tetrachloride, both solvents; some CFC substitutes; and the pesticide methyl bromide.

CFCs accounted for approximately 75% of ozone depletion in 1995, whereas methyl chloroform (atmospheric concentrations of which had markedly decreased during 1990-94) accounted for an estimated 12.5%. The ozone depletion rate overall is now decreasing as international agreements to curb the use of ozone-depleting chemicals begin to take effect. In 1996 there was a decrease in ozone depleters in the lower atmosphere. This trend is expected to continue into the stratosphere over the next few years.

ozone layer

thin layer of the gas ozone in the upper atmosphere which shields the Earth from harmful ultraviolet rays. A continent-sized hole has formed over Antarctica as a result of damage to the ozone layer. This has been caused in part by chlorofluorocarbons (CFCs), but many reactions destroy ozone in the stratosphere: nitric oxide, chlorine, and bromine atoms are implicated.

It is believed that the ozone layer is depleting at a rate of about 5% every ten years over northern Europe, with depletion extending south to the Mediterranean and southern USA. However, ozone depletion over the polar regions is the most dramatic manifestation of a general global effect. Ozone levels over the Arctic in spring 1997 fell over 10% since 1987, despite the reduction in the concentration of CFCs and other industrial compounds which destroy the ozone when exposed to sunlight. It is thought that this may be because of an expanding vortex of cold air forming in the lower stratosphere above the Arctic, leading to increased ozone loss. It is expected that an Arctic hole as large as that over Antarctica could remain a threat to the northern hemisphere for several decades.

The size of the hole in the ozone layer in October 1998 was three times the size of the USA, larger than it had ever been before. In autumn 2000, the hole in the ozone layer was at its largest ever. Observers had hoped that its 1998 level was due to El Niño and would not be exceeded.

Ozone: Thinning of the Ozone Layer

the ozone layer

The atmosphere consists of a number of gases, the most important of which from the point of view of life on Earth is oxygen. It is a by-product of plant metabolism, it is essential to the metabolism of animals, and it also takes part in an important reaction in the stratosphere.

what is ozone?

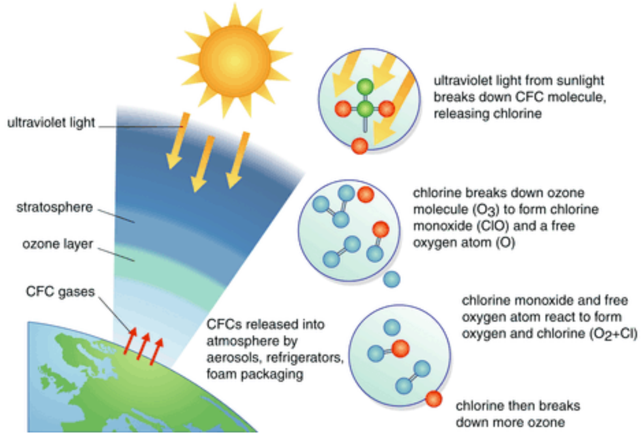
The oxygen molecule consists of two atoms of oxygen – written as O_2. In the stratosphere the ultraviolet rays of the Sun can break the molecule down into individual atoms – O and O. These atoms are unstable and can attach themselves to other oxygen molecules to form molecules of ozone – oxygen with three atoms of oxygen – O_3. Under the influence of radiation from another part of the ultraviolet spectrum the molecules of ozone can break down and unite with more free oxygen atoms to form oxygen molecules again – O_3 unites with O to produce O_2 and O_2.

As a result there is a layer in the atmosphere where ozone is continually produced and destroyed. This ozone layer lies between 15 and 50 km above the ground – with the greatest concentration at about 23 km – and is estimated to contain about 5 billion tonnes of ozone at one time. All this activity absorbs the energy of the ultraviolet light and prevents it from reaching the ground, which is a good thing as certain wavebands of ultraviolet light can cause cancers, cataracts, and decreases in crop yields.

thinning of the ozone layer

The presence of certain other molecules, particularly of chlorine, influences the speed of these reactions – usually increasing the speed of the breakdown of the ozone. This is very noticeable in springtime in the Antarctic when chlorine from pollutants is released from the icy winter clouds. The ozone concentration is reduced here, and the still conditions cannot bring it in from elsewhere, resulting in the so-called ozone hole. It is believed that much of the chlorine responsible comes from industrial gases such as CFCs, as well as from natural sources such as volcanoes. This became a worldwide problem as a thinning of the ozone layer over Europe was detected early in 1993.

ozone layer


ultraviolet light
stratosphere
ozone layer
CFC gases
CFCs released into atmosphere by aerosols, refrigerators, foam packaging
ultraviolet light from sunlight breaks down CFC molecule, releasing chlorine
chlorine breaks down ozone molecule (O_3) to form chlorine monoxide (ClO) and a free oxygen atom (O)
chlorine monoxide and free oxygen atom react to form oxygen and chlorine (O_2+Cl)
chlorine then breaks down more ozone

(Image © Research Machines plc)

The destruction of the ozone layer by chlorofluorocarbons (CFCs). CFCs discharged into the atmosphere break down in sunlight releasing chlorine, which breaks down the ozone to form chlorine monoxide and a free oxygen atom. These products react together to form oxygen and chlorine, leaving the chlorine to break down another ozone molecule, and so on.

Pa

in physics, symbol for pascal, the SI unit of pressure, equal to a pressure of one newton per square metre.

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paca

large, tailless, nocturnal, burrowing rodent, related to the agoutis. The paca, about 60 cm/2 ft long, is native to Central and South America. (Genus *Cuniculus*, family Dasyproctidae.)

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pacemaker

or sinoatrial node (SA node)

in vertebrates, a group of muscle cells in the wall of the heart that contracts spontaneously and rhythmically, setting the pace for the contractions of the rest of the heart. The pacemaker's intrinsic rate of contraction is increased or decreased, according to the needs of the body, by stimulation from the autonomic nervous system. The term also refers to a medical device implanted under the skin of a patient whose heart beats inefficiently. It delivers minute electric shocks to stimulate the heart muscles at regular intervals and restores normal heartbeat.

The latest pacemakers are powered by radioactive isotopes for long life and weigh no more than 15 g/0.5 oz.

Pacific Ocean

world's largest ocean, extending from Antarctica to the Bering Strait; area 166,242,500 sq km/64,186,500 sq mi; greatest breadth 16,000 km/9,942 mi; length 11,000 km/6,835 mi; average depth 4,188 m/13,749 ft; greatest depth of any ocean is the found in the Mariana Trench, in the northwest Pacific, with a depth of 11,034 m/36,201 ft.

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packet switching

method of transmitting data between computers connected in a network. Packet switched networks do not provide a dedicated connection between two locations, as with a circuit switched network. Packet switched networks make more effective use of bandwidth than circuit switched networks, and are more resilient to breaks in network links because there are always multiple routes from source to destination.

It is possible that a large message be broken down into many small packets, each equipped with a sequence number to ensure it can be reassembled properly if some packets take a different route through the network of switches and arrive out of order.

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paediatrics

medical speciality concerned with the care of children. Paediatricians treat childhood diseases such as measles, chicken pox, and mumps, and immunize children against more serious infections such as diphtheria. Their role also includes treating and identifying disorders caused by lack of proper nutrition or child abuse.

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page printer

computer printer that prints a complete page of text and graphics at a time. Page printers use electrostatic techniques, very similar to those used by photocopiers, to form images of pages, and range in size from small laser printers designed to work with microcomputers to very large machines designed for high-volume commercial printing.

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paging

method of increasing a computer's apparent memory capacity. See virtual memory.

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pain

sense that gives an awareness of harmful effects on or in the body. It may be triggered by stimuli such as trauma, inflammation, and heat. Pain is transmitted by specialized nerves and also has psychological components controlled by higher centres in the brain. Drugs that control pain are known as painkillers or analgesics.

A pain message to the brain travels along the sensory nerves as electrical impulses. When these reach the gap between one nerve and another, biochemistry governs whether this gap is bridged and may also either increase or decrease the attention the message receives or modify its intensity in either direction. The main type of pain transmitter is known simply as 'substance P', a neuropeptide concentrated in a certain area of the spinal cord. Substance P has been found in fish, and there is also evidence that the same substances that cause pain in humans (for example, bee venom) cause a similar reaction in insects and arachnids (for instance, spiders).

Since the sensation of pain is transmitted by separate nerves from that of fine touch, it is possible in diseases such as syringomyelia to have no sense of pain in a limb, yet maintain a normal sense of touch. Such a desensitized limb is at great risk of infection from unnoticed cuts and abrasions.

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painkiller

agent for relieving pain. Types of painkiller include analgesics such as aspirin and aspirin substitutes, morphine, codeine, paracetamol, and synthetic versions of the natural inhibitors, the encephalins and endorphins, which avoid the side effects of the others.

Topical nerve irritants are also used in salves, such as camphor and eucalyptus; they cause the nerve endings to react to them, bringing increased blood flow to the areas and alleviating localized and joint pain.

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paint

any of various materials used to give a protective and decorative finish to surfaces or for making pictures. A paint consists of a pigment suspended in a vehicle, or binder, usually with added solvents. It is the vehicle that dries and hardens to form an adhesive film of paint. Among the most common kinds are cellulose paints (or lacquers), oil-based paints, emulsion (water-based) paints, and special types such as enamels and primers.

types of paint

Lacquers consist of a synthetic resin (such as an acrylic resin or cellulose acetate) dissolved in a volatile organic solvent, which evaporates rapidly to give a very quick-drying paint. A typical **oil-based paint** has a vehicle of a natural drying oil (such as linseed oil), containing a prime pigment of iron, lead, titanium, or zinc oxide, to which coloured pigments may be added. The finish – gloss, semimatt, or matt – depends on the amount of inert pigment (such as clay or silicates). Oil-based paints can be thinned with, and brushes cleaned in, a solvent such as turpentine or white spirit (a petroleum product).
Emulsion paints, sometimes called latex paints, consist of pigments dispersed in a water-based emulsion of a polymer (such as polyvinyl chloride [PVC] or acrylic resin). They can be thinned with water, which can also be used to wash the paint out of brushes and rollers.
Enamels have little pigment, and they dry to an extremely hard, high-gloss film.
Primers for the first coat on wood or metal, on the other hand, have a high pigment content (as do undercoat paints). Aluminium or bronze powder may be used for priming or finishing objects made of metal.

Palaeocene epoch

(Greek 'old' + 'recent')

first epoch of the Tertiary period of geological time, 65–56.5 million years ago. Many types of mammals spread rapidly after the disappearance of the great reptiles of the Mesozoic. Flying mammals replaced the flying reptiles, swimming mammals replaced the swimming reptiles, and all the ecological niches vacated by the reptiles were adopted by mammals.

At the end of the Palaeocene there was a mass extinction that caused more than half of all bottom-dwelling organisms to disappear worldwide, over a period of around 1,000 years. Surface-dwelling organisms remained unaffected, as did those on land. The cause of this extinction remains unknown, though US palaeontologists have found evidence (released in 1998) that it may have been caused by the Earth releasing tonnes of methane into the oceans causing increased water temperatures.

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palaeomagnetism

study of the magnetic properties of rocks in order to reconstruct the Earth's ancient magnetic field and the former positions of the continents, using traces left by the Earth's magenetic field in igneous rocks before they cool. Palaeomagnetism shows that the Earth's magnetic field has reversed itself – the magnetic north pole becoming the magnetic south pole, and vice versa – at approximate half-million-year intervals, with shorter reversal periods in between the major spans.

Starting in the 1960s, this known pattern of magnetic reversals was used to demonstrate seafloor spreading or the formation of new ocean crust on either side of mid-oceanic ridges. As new material hardened on either side of a ridge, it would retain the imprint of the magnetic field, furnishing datable proof that material was spreading steadily outward. Palaeomagnetism is also used to demonstrate continental drift by determining the direction of the magnetic field of dated rocks from different continents.

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palaeontology

the study of ancient life, encompassing the structure of ancient organisms and their environment, evolution, and ecology, as revealed by their fossils and the rocks in which those fossils are found. The practical aspects of palaeontology are based on using the presence of different fossils to date particular rock strata and to identify rocks that were laid down under particular conditions; for instance, giving rise to the formation of oil.

The use of fossils to trace the age of rocks was pioneered in Germany by Johann Friedrich Blumenbach

(1752–1830) at Göttingen, followed by Georges Cuvier and Alexandre Brongniart in France in 1811.

Early Dinosaur Discoveries in North America

Go to site

Interesting history of early dinosaur discoveries in North America. Includes a section on the Feuding Paleontologists, Edward Drinker Cope and rival Othniel Marsh, and provides information on the world's first nearly complete dinosaur skeleton excavated near Haddonfield, New Jersey, in 1858. There are photos and hypertext links to additional information.

Museum of Palaeontology

Go to site

Large amount of detailed information on the subject in a carefully structured and carefully cross-referenced site. You can explore palaeontology through the three areas of phylogeny, geology, and evolution.

Strange Science

Go to site

Subtitled 'The Rocky Road to Modern Palaeontology and Biology', this site examines some of the medieval discoveries that led to the growth of interest in modern-day science. The site is illustrated with images that clearly show how people's perception of the world differed, and how people made up for gaps in their knowledge with a little imagination!

Palaeozoic era

era of geological time 570–245 million years ago. It comprises the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian periods. The Cambrian, Ordovician, and Silurian constitute the Lower or Early Palaeozoic; the Devonian, Carboniferous, and Permian make up the Upper or Late Palaeozoic. The era includes the evolution of hard-shelled multicellular life forms in the sea; the invasion of land by plants and animals; and the evolution of fish, amphibians, and early reptiles.

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palate

in mammals, the roof of the mouth. The bony front part is the hard palate, the muscular rear part the soft palate. Incomplete fusion of the two lateral halves of the palate (cleft palate) causes interference with speech.

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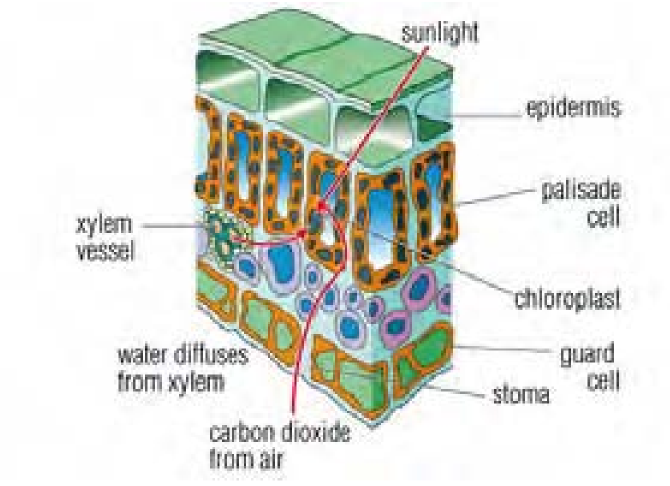
palisade cell

cylindrical cell lying immediately beneath the upper epidermis of a leaf. Palisade cells normally exist as one closely packed row and contain many chloroplasts. During the hours of daylight palisade cells are photosynthetic, using the energy of the sun to create carbohydrates from water and carbon dioxide.

palisade cell



(Image © Research Machines plc)

Palisade cells are closely packed, columnar cells, lying in the upper surfaces of leaves. They contain many chloroplasts (where photosynthesis takes place) and are well adapted to receive and process the components necessary for photosynthesis – carbon dioxide, water, and sunlight. For instance, their vertical arrangement means that there are few cross-walls to interfere with the passage of sunlight.

---

palladium

chemical symbol Pd

lightweight, ductile and malleable, silver-white, metallic element, atomic number 46, relative atomic mass 106.4. Together with the elements ruthenium, rhodium, osmium, iridium, and platinum, it forms the group of platinum metals, which have similar physical and chemical properties. Like the other platinum metals it is resistant to tarnish and corrosion. It often occurs in nature as a free metal (see native metal) in a natural alloy with platinum. Palladium is used as a catalyst, in alloys of gold (to make white gold) and silver, in electroplating, and in dentistry.

It was discovered in 1803 by English physicist William Wollaston, and named after the asteroid Pallas (found in 1802).

---

palliative

in medicine, any treatment given to relieve symptoms rather than to cure the underlying cause. In conditions that will resolve of their own accord (for instance, the common cold) or that are incurable, the entire treatment may be palliative.

---

palm

any of a group of large treelike plants with a single tall stem that has a thick cluster of large palmate (five-lobed) leaves or pinnate leaves (leaflets either side of the stem) at the top. Most of the numerous species are tropical or subtropical. Some, such as the coconut, date, sago, and oil palms, are important economically. (Family Palmae.)

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palsy

in medicine, another term for paralysis.

---

pampas grass

any of a group of large grasses native to South America, especially *C. argentea*, which is grown in gardens and has tall leaves and large clusters of feathery white flowers growing around the tips of the flower-bearing stems. (Genus *Cortaderia*.)

---

panchromatic

in photography, a term describing highly sensitive black-and-white film made to render all visible spectral colours in correct grey tones. Panchromatic film is always developed in total darkness.

---

pancreas

in vertebrates, a gland of the digestive system located close to the duodenum. When stimulated by the hormone secretin, it releases enzymes into the duodenum that digest starches, proteins, and fats. In humans, it is about 18 cm/7 in long, and lies behind and below the stomach. It contains groups of cells called the **islets of Langerhans**, which secrete the hormones insulin and glucagon that regulate the blood sugar level.

---

panda

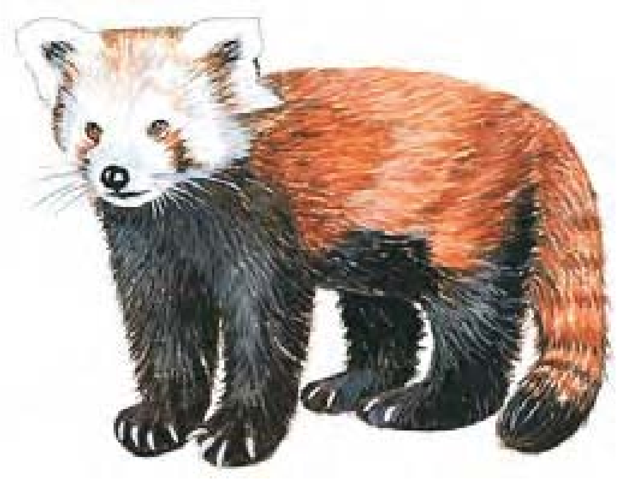
one of two carnivores of different families, native to northwestern China and Tibet. The **giant panda** *Ailuropoda melanoleuca* has black-and-white fur with black eye patches and feeds mainly on bamboo shoots, consuming about 8 kg/17.5 lb of bamboo per day. It can grow up to 1.5 m/4.5 ft long, and weigh up to 140 kg/300 lb. It is an endangered species. In 2000 there were only 1,000 remaining in the wild, and a further 120 in zoos.

The **lesser**, or **red**, **panda** *Ailurus fulgens*, of the raccoon family, is about 50 cm/1.5 ft long, and is black and chestnut, with a long tail.

Pandas' bamboo diet is of low nutritional value, being about 90% water. This makes it impossible for them to hibernate, since although they spend about 12 hours of every day eating, they cannot accumulate the necessary reserves of fat. There is some dispute about whether they should be included in the bear family or the raccoon family, or classified as a family of their own.

Destruction of the giant pandas' natural habitats threatens to make them extinct in the wild, and they are the focus of conservation efforts. In July 1998 China's national Academy of Sciences announced a project to clone the panda by 2003. They plan to transfer the nucleus of a panda cell into that of another bear species, with the same species being used as a surrogate mother. In 1999 Chinese scientists succeeded in cloning hybrid embryos using the nucleus from a panda cell transferred into a rabbit ovum. The scientists will now attempt to implant an embryo into another bear species, probably a black bear.

panda



(Image © Research Machines plc)

The lesser, or red, panda lives in the bamboo forests of Nepal, West Myanmar, and South West China. A quiet creature, it spends the day asleep, curled up on a branch with its head tucked into its chest and its tail over its head. It feeds on bamboo shoots, grass, roots, fruit, acorns, and the occasional bird's egg.

Giant Panda Facts

Go to site

Information about the giant panda from the International World Wildlife Fund, Canada. Descriptions of the behaviour of the animals, as well as details of the threats to the existence of the species, are included, as well as a bibliography.

Pangaea

or Pangea

(Greek 'all-land')

single land mass, made up of all the present continents, believed to have existed between 300 and 200 million years ago; the rest of the Earth was covered by the Panthalassa ocean. Pangaea split into two land masses – Laurasia in the north and Gondwanaland in the south – which subsequently broke up into several continents. These then moved slowly to their present positions (see plate tectonics).

The former existence of a single 'supercontinent' was proposed by German meteorologist Alfred Wegener in 1912.

---

pangolin

or scaly anteater

toothless mammal of tropical Africa and Southeast Asia. They are long-tailed and covered with large, overlapping scales, except on the muzzle, sides of the head, throat, chest, and belly. They have an elongated skull and a long, extensible tongue. Pangolins measure 30-100 cm/12-39 in long, exclusive of the prehensile tail, which is about twice as long as the body.

Some are arboreal and others are terrestrial. All live on ants and termites. Pangolins comprise the order Pholidota. There is only one genus (*Manis*) and family Manidae, with seven species.

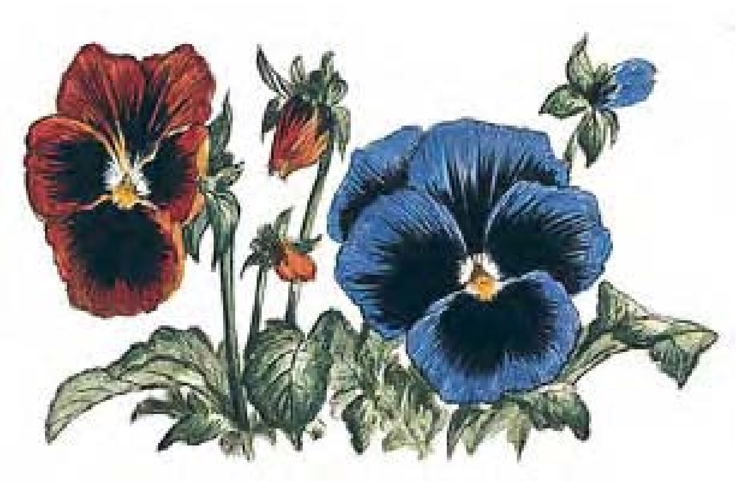
The lower gums of the mouth form two thickened horny ridges separated by a groove along which the cylindrical wormlike tongue slips in and out. The feet are strongly clawed, especially on the third toe of the forefoot, which is used in burrowing and in climbing. The extreme tip of the tail is free from scales and padded with thick skin. To deter predators, a powerful stench is emitted by the entire surface of the skin, and its bony overlapping scales protect it when it rolls up into a ball.

---

pansy

cultivated plant derived from the European wild pansy (*Viola tricolor*) and including many different varieties and strains. The flowers are usually purple, yellow, or cream, or a mixture of these colours, and there are many highly developed varieties bred for size, colour, or special markings. Several of the 400 different species are scented. (Family Violaceae.)

pansy



(Image © Research Machines plc)

There are over 400 species of pansy, or violet, widely distributed in temperate regions. The flowers have five unequally shaped petals.

Panthalassa

ocean that covered the surface of the Earth not occupied by the world continent Pangaea between 300 and 200 million years ago.

panther

another name for the leopard.

pantothenic acid

water-soluble vitamin ($C_9H_{17}NO_5$) of the B complex, found in a wide variety of foods. Its absence from the diet can lead to dermatitis, and it is known to be involved in the breakdown of fats and carbohydrates.

Papanicolaou test

in medicine, another name for cervical smear.

papaya

tropical evergreen tree, native from Florida to South America. Varieties are grown throughout the tropics. The edible fruits are like melons, with orange-coloured flesh and large numbers of blackish seeds in the centre; they can weigh up to 9 kg/20 lb. (*Carica papaya*, family Caricaceae.)

The fruit juice and the tree sap contain papain, an enzyme used to tenderize meat and help digestion.

papaya

(Image © Corel)

Papayas ripening on the tree in Negril, Jamaica. The papaya is a soft, sweet fruit with a high vitamin C content.

---

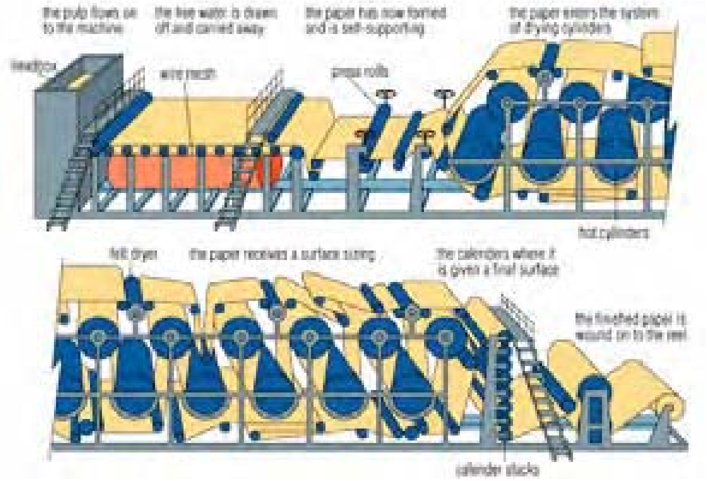
paper

thin, flexible material made in sheets from vegetable fibres (such as wood pulp) or rags and used for writing, drawing, printing, packaging, and various household needs. The name comes from papyrus, a form of writing material made from water reed, used in ancient Egypt. The invention of true paper, originally made of pulped fishing nets and rags, is credited to Tsai Lun, Chinese minister of agriculture, in AD 105.

Paper came to the West with Arabs who had learned the secret from Chinese prisoners of war in Samarkand in 768. It spread from Morocco to Moorish Spain and to Byzantium in the 11th century, then to the rest of Europe. All early paper was handmade within frames.

With the spread of literacy there was a great increase in the demand for paper. Production by hand of single sheets could not keep pace with this demand, which led to the invention, by Louis Robert (1761–1828) in 1799, of a machine to produce a continuous reel of paper. The process was developed and patented in 1801 by François Didot, Robert's employer. Today most paper is made from wood pulp on a Fourdrinier machine, then cut to size; some high-grade paper is still made from esparto or rag. Paper products absorb 35% of the world's annual commercial wood harvest; recycling avoids some of the enormous waste of trees, and most papermakers plant and replant their own forests of fast-growing stock.

paper


the pulp flows on to the machine
the free water is drawn off and carried away
the paper has now formed and is self-supporting
the paper enters the system of drying cylinders
headbox
wire mesh
press rolls
hot cylinders
felt dryer
the paper receives a surface sizing
the calenders where it is given a final surface
the finished paper is wound on to the reel
calender stacks

(Image © Research Machines plc)

Today's fully automatic papermaking machines can be 200 m/640 ft long and produce over 1,000 m/3,200 ft of paper in a minute. The most common type of papermaking machine is the Fourdrinier, named after two British stationer brothers who invented it in 1803. Their original machine deposited the paper on pieces of felt, after which it was finished by hand.

International paper sizes

Name	**Dimensions**	
Classic series		
large post	419 × 533 millimetres	161/2 × 21 inches
demy	444 × 572 millimetres	171/2 × 221/2 inches
medium	457 × 584 millimetres	18 × 23 inches
royal	508 × 635 millimetres	20 × 25 inches

double crown	508 × 762 millimetres	20 × 30 inches
A series (books, magazines, stationery)		
A0	841 × 1,189 millimetres	331/8 × 463/4 inches
A1	594 × 841 millimetres	233/8 × 331/8 inches
A2	420 × 594 millimetres	161/2 × 233/8 inches
A3	297 × 420 millimetres	113/4 × 161/2 inches
A4	210 × 297 millimetres	81/4 × 113/4 inches
A5	148 × 210 millimetres	57/8 × 81/4 inches
B series (posters, etc.)		
B0	1,414 × 1,000 millimetres	555/8 × 393/8 inches
B1	1,000 × 707 millimetres	393/8 × 277/8 inches
B2	707 × 500 millimetres	277/8 ×195/8 inches
B3	500 × 353 millimetres	195/8 × 137/8 inches
B4	353 × 250 millimetres	137/8 × 97/8 inches
B5	250 × 176 millimetres	97/8 × 7 inches
C series (envelopes)		
C4	324 × 229 millimetres	123/4 × 9 inches
C5	229 × 162 millimetres	9 × 63/8 inches
C6	162 × 114 millimetres	63/8 × 41/2 inches
DL	220 × 110 millimetres	85/8 × 43/8 inches

You Can Make Paper

Go to site

Fun and environmentally conscious project aiming to teach children about paper and how to make their own home-made paper. Friendly chat follows the step-by-step instructions. The site also offers interactive demonstrations on cellular phones, gravity, smoking and our lungs, relativity, magnets, and more. Children (and adults) can post their questions to a query box.

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paper nautilus

another name for the argonaut.

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papovavirus

in medicine, group of viruses that include the causative agents of papilloma (warts and verrucas) in humans.

---

pappus

plural pappi

in botany, a modified calyx comprising a ring of fine, silky hairs, or sometimes scales or small teeth, that persists after fertilization. Pappi are found in members of the daisy family (Compositae) such as the dandelions *Taraxacum*, where they form a parachutelike structure that aids dispersal of the fruit.

Pap test

or Pap smear

common name for cervical smear.

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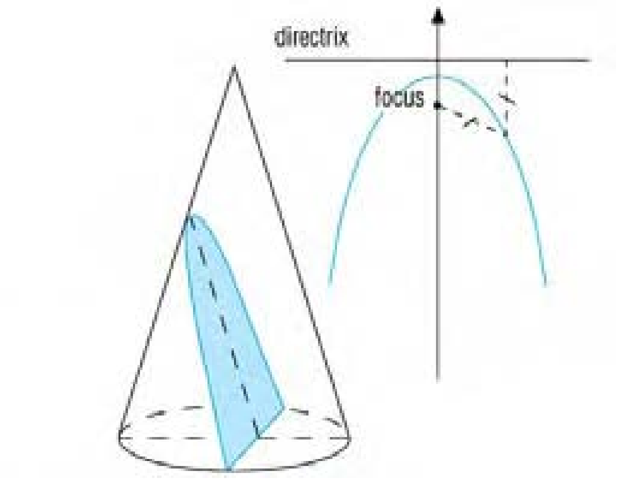
parabola

in mathematics, a curve formed by cutting a right circular cone with a plane parallel to the sloping side of the cone. A parabola is one of the family of curves known as conic sections. The graph of $y = x^2$ is a parabola.

It can also be defined as a path traced out by a point that moves in such a way that the distance from a fixed point (focus) is equal to its distance from a fixed straight line (directrix); it thus has an eccentricity of 1.

The trajectories of missiles within the Earth's gravitational field approximate closely to parabolas (ignoring the effect of air resistance). The corresponding solid figure, the paraboloid, is formed by rotating a parabola about its axis. It is a common shape for headlight reflectors, dish-shaped microwave and radar aerials, and radiotelescopes, since a source of radiation placed at the focus of a paraboloidal reflector is propagated as a parallel beam.

parabola



(Image © Research Machines plc)

A parabola is a curve produced when a cone is cut by a plane. It is one of the family of curves called conic sections that also includes the circle, ellipse, and hyperbola. These curves are produced when the plane cuts the cone at different angles and positions.

Parabola

Go to site

Introduction to parabolas and links to associated curves. If you have a Java-enabled browser you can experiment interactively with this curve and its associates. There are also links to mathematicians who have studied the parabola, to the parabola's particular attributes, and to related Web sites.

Paracelsus, Philippus Aureolus (1493-1541)

adopted name of Theophrastus Bombastus von Hohenheim

Swiss physician, alchemist, and scientist who developed the idea that minerals and chemicals might have medical uses (iatrochemistry). He introduced the use of laudanum (which he named) for pain-killing purposes.

Overturning the contemporary view of illness as an imbalance of the four humours (see humours, theory of), Paracelsus sought an external agency as the source of disease. This encouraged new modes of treatment, supplanting, for example, bloodletting, and opened the way for new ideas on the source of infection.

Paracelsus was extremely successful as a doctor. His descriptions of miners' diseases first identified silicosis and tuberculosis as occupational hazards. He recognized goitre as endemic and related to minerals in drinking water, and originated a medical account of chorea, rather than believing this nervous disease to be caused by possession by spirits. Paracelsus was the first to distinguish the congenital from the infectious form of syphilis, and showed that it could be treated with carefully controlled doses of a mercury compound.

---

paracetamol

analgesic, particularly effective for musculoskeletal pain. It is as effective as aspirin in reducing fever, and less irritating to the stomach, but has little anti-inflammatory action. An overdose can cause severe, often irreversible or even fatal, liver and kidney damage.

---

parachute

any canopied fabric device strapped to a person or a package, used to slow down descent from a high altitude, or returning spent missiles or parts to a safe speed for landing, or sometimes to aid (through braking) the landing of a plane or missile. Modern designs enable the parachutist to exercise considerable control of direction, as in skydiving.

Leonardo da Vinci sketched a parachute design, but the first descent, from a balloon at a height of 670 m/2,200 ft over Paris, was not made until 1797 by André-Jacques Garnerin (1769-1823). The first descent from an aircraft was made by Capt Albert Berry in 1912 from a height of 457 m/1,500 ft over Missouri.

A parachute is typically folded into a pack from which it is released by a rip cord or other device. It originally consisted of some two dozen panels of silk, Garnerin's parachute was canvas, (later nylon) in a circular canopy with shroud lines to a harness. Modern parachutes are variously shaped, often small and rectangular.

In **parascending** the parachuting procedure is reversed, the canopy (parafoil) to which the person is attached being towed behind a vehicle to achieve an ascent.

paradigm

all those factors, both scientific and sociological, that influence the research of the scientist. The term, first used by the US historian of science Thomas Kuhn, has subsequently spread to social studies and politics.

---

paraffin

common name for alkane, any member of the series of hydrocarbons with the general formula C_nH_{2n+2}.

The lower members are gases, such as methane (marsh or natural gas). The middle ones (mainly liquid) form the basis of petrol, kerosene, and lubricating oils, while the higher ones (paraffin waxes) are used in ointment and cosmetic bases.

---

parakeet

any of various small long-tailed parrots, order Psittaciformes, with a moderate beak. They include the **ring-necked parakeets**, genus *Psittacula*, which are very common in India and Africa, and cockatiels, and budgerigars, natives of Australia. The **king parakeet** is about the size of a magpie and has a red head and breast and green wings.

---

paraldehyde

common name for ethanal trimer.

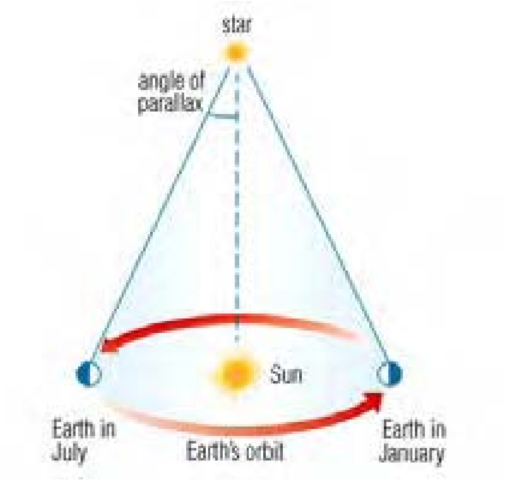
---

parallax

change in the apparent position of an object against its background when viewed from two different positions. In astronomy, nearby stars show a shift owing to parallax when viewed from different positions on the Earth's orbit around the Sun. A star's parallax is used to deduce its distance from the Earth.

Nearer bodies such as the Moon, Sun, and planets also show a parallax caused by the motion of the Earth.

parallax



(Image © Research Machines plc)

The parallax of a star, the apparent change of its position during the year, can be used to find the star's distance from the Earth. The star appears to change its position because it is viewed at a different angle in July and January. By measuring the angle of parallax, and knowing the diameter of the Earth's orbit, simple geometry can be used to calculate the distance to the star.

---

parallel device

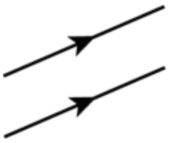
in computing, a device that communicates binary data by sending the bits that represent each character simultaneously along a set of separate data lines, unlike a serial device.

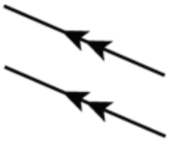
---

parallel lines and parallel planes

straight lines or planes that always remain a constant distance from one another no matter how far they are extended.

Examples of parallel lines found in everyday life include railway lines, the verticals of goal posts, and shelves in a book-case. Parallel lines are shown in diagrams by using single or double arrows:





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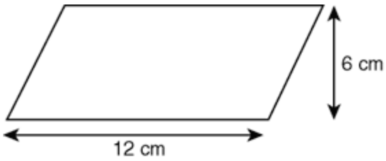
parallelogram

a quadrilateral (a shape with four sides) with opposite pairs of sides equal in length and parallel, and opposite angles equal. The diagonals of a parallelogram bisect each other. Its area is the product of the length (l) of one side and the perpendicular distance (height h) between this and the opposite side; the formula is $A = l \times h$. In the special case when all four sides are equal in length, the parallelogram is known as a rhombus, and when the internal angles are right angles, it is a rectangle or square.

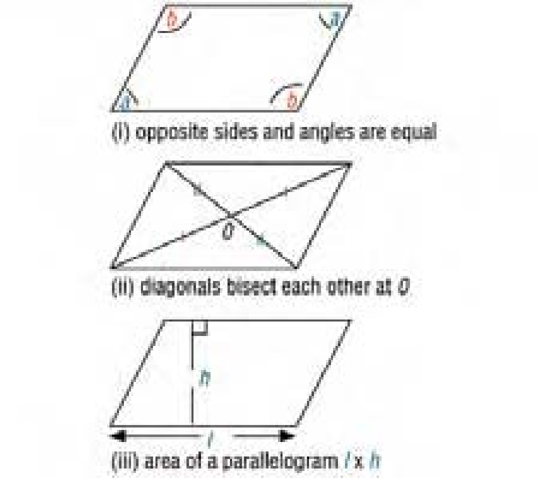
For example, to find the area of a parallelogram 12 cm long and 6 cm high:



$A = l \times h$, so

$A = 12 \times 6 = 72\ \text{cm}^2$

parallelogram


b
a
a
b
(i) opposite sides and angles are equal
O
(ii) diagonals bisect each other at O
h
l
(iii) area of a parallelogram l x h

(Image © Research Machines plc)

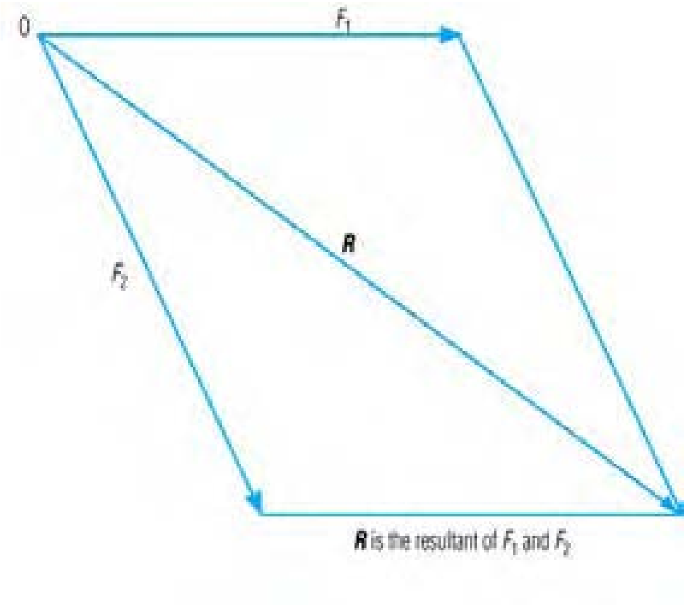
Some properties of a parallelogram.

---

parallelogram of forces

in physics and applied mathematics, a method of calculating the resultant (combined effect) of two different forces acting together on an object. Because a force has both magnitude and direction it is a vector quantity and can be represented by a straight line. A second force acting at the same point in a different direction can be represented by another line drawn at an angle to the first. By completing the parallelogram (of which the two lines are sides) a diagonal may be drawn from the original angle to the opposite corner to represent the resultant force vector.

parallelogram of forces



(Image © Research Machines plc)

The diagram shows how the parallelogram of forces can be used to calculate the resultant (combined effect) of two different forces acting together on an object. The two forces are represented by two lines drawn at an angle to each other. By completing the parallelogram (of which the two lines are sides), a diagonal may be drawn from the original angle to the opposite corner to represent the resultant force vector.

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parallel processing

emerging computer technology that allows more than one computation at the same time. Although in the 1990s this technology enabled only a small number of computer processor units to work in parallel, in theory thousands or millions of processors could be used at the same time.

Parallel processing, which involves breaking down computations into small parts and performing thousands of them simultaneously, rather than in a linear sequence, offers the prospect of a vast improvement in working speed for certain repetitive applications.

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paralysis

loss of voluntary movement due to failure of nerve impulses to reach the muscles involved. It may result from almost any disorder of the nervous system, including brain or spinal cord injury, poliomyelitis, stroke, and progressive conditions such as a tumour or multiple sclerosis. Paralysis may also involve loss of sensation due to sensory nerve disturbance.

---

parameter

variable factor or characteristic. For example, length is one parameter of a rectangle; its height is another. In computing, it is frequently useful to describe a program or object with a set of variable parameters rather than fixed values.

For example, if a programmer writes a routine for drawing a rectangle using general parameters for the length, height, line thickness, and so on, any rectangle can be drawn by this routine by giving different values to the parameters.

Similarly, in a word-processing application that stores parameters for font, page layout, type of justification, and so on, these can be changed by the user.

---

paranoia

mental disorder marked by delusions of grandeur or persecution. In popular usage, paranoia means baseless or exaggerated fear and suspicion.

In **chronic paranoia**, patients exhibit a rigid system of false beliefs and opinions, believing themselves, for example, to be followed by the secret police, to be loved by someone at a distance, or to be of great importance or in special relation to God. There are no hallucinations and patients are in other respects normal.

In **paranoid states**, the delusions of persecution or grandeur are present but not systematized.

In **paranoid schizophrenia**, the patient suffers from many unsystematized and incoherent delusions, is extremely suspicious, and experiences hallucinations and the feeling that external reality has altered.

---

paranormal

not within the range of, or explicable by, established science. Paranormal phenomena include **extrasensory perception** (ESP) which takes in clairvoyance, precognition, and telepathy; **telekinesis**, the movement of objects from one position to another by human mental concentration; and **mediumship**, supposed contact with the spirits of the dead, usually via an intermediate 'guide' in the other world. Parapsychology is the study of such phenomena.

Paranormal phenomena are usually attributed to the action of an unknown factor, psi.

There have been many reports of sporadic paranormal phenomena, the most remarkable being reports by one person, or occasionally more, of apparitions or hallucinatory experiences associated with another person's death.

Anomalist Site

Go to site

Internet edition of a twice-yearly magazine exploring the mysteries of science, history, and nature. Created by writers, scientists, and investigators intrigued by 'that which departs from the common', the online presentation includes contributions on every neglected, unexplained, unexpected, and extraordinary aspect of the world, and invites contributions from visitors.

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paraplegia

paralysis of the lower limbs, involving loss of both movement and sensation; it is usually due to spinal injury.

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parapsychology

(Greek para 'beyond')

study of paranormal phenomena, which are generally subdivided into two types: extrasensory perception (ESP), or the paracognitive; and psychokinesis (PK), telekinesis, or the paraphysical – movement of an object without the use of physical force or energy.

Most research into parapsychology has been experimental. The first Society for Psychical Research was established in London in 1882 by scientists, philosophers, classical scholars, and spiritualists. Despite continued scepticism within the scientific establishment, a chair of parapsychology was established in in 1984 at Edinburgh University, endowed by the Hungarian author Arthur Koestler.

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paraquat

technical name 1,1-dimethyl-4,4-dipyridylium; $CH_3(C_5H_4N)_2CH_3.2CH_3SO_4$

nonselective herbicide (weedkiller). Although quickly degraded by soil micro-organisms, it is deadly to human beings if ingested.

---

parasite

organism that lives on or in another organism (called the host) and depends on it for nutrition, often at the expense of the host's welfare. Parasites that live inside the host, such as liver flukes and tapeworms, are called **endoparasites**; those that live on the exterior, such as fleas and lice, are called **ectoparasites**.

Parasitic wasps, such as ichneumons, are more correctly **parisitoids**, as they ultimately kill their hosts.

parasite

Birds support a vast variety of parasites. A curlew may carry over 1,000 feather lice, and a single grouse can harbour 10,000 nematode worms within its intestines.

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parasympathetic nervous system

in medicine, a division of the autonomic nervous system.

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parathyroid

one of a pair of small endocrine glands. Most tetrapod vertebrates, including humans, possess two such pairs, located behind the thyroid gland. They secrete parathyroid hormone, which regulates the amount of calcium in the blood.

---

paratyphoid fever

infectious disease of the intestinal tract, similar to typhoid fever but milder and less dangerous. It is caused by bacteria of the genus *Salmonella* and is treated with antibiotics.

Paré, Ambroise (c. 1509-1590)

French surgeon who introduced modern principles to the treatment of wounds. As a military surgeon, Paré developed new ways of treating wounds and amputations, which greatly reduced the death rate among the wounded. He abandoned the practice of cauterization (sealing with heat), using balms and soothing lotions instead, and used ligatures to tie off blood vessels.

Paré eventually became chief surgeon to Charles IX. He also made important contributions to dentistry and childbirth, and invented an artificial hand.

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parenchyma

plant tissue composed of loosely packed, more or less spherical cells, with thin cellulose walls. Although parenchyma often has no specialized function, it is usually present in large amounts, forming a packing or ground tissue. It usually has many intercellular spaces.

---

parental care

in biology, the time and energy spent by a parent in order to rear its offspring to maturity. Among animals, it ranges from the simple provision of a food supply for the hatching young at the time the eggs are laid (for example, many wasps) to feeding and protection of the young after hatching or birth, as in birds and mammals. In the more social species, parental care may include the teaching of skills – for example, female cats teach their kittens to hunt.

Babyworld

Go to site

Help for all first-time parents that includes medical information - an extensive database of possible ailments, for example, but also covers such topics as pregnancy, daily care, development, and news. There is also a regularly updated gallery of images and the opportunity to chat and share advice with other (prospective) parents online.

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parity

of a number, the state of being either even or odd. In computing, the term refers to the number of 1s in the binary codes used to represent data. A binary representation has **even parity** if it contains an even number of 1s and **odd parity** if it contains an odd number of 1s.

For example, the binary code 1000001, commonly used to represent the character 'A', has even parity because it contains two 1s, and the binary code 1000011, commonly used to represent the character 'C', has odd parity because it contains three 1s. A **parity bit** (0 or 1) is sometimes added to each binary representation to give all the same parity so that a validation check can be carried out each time data are transferred from one part of the computer to another. So, for example, the codes 1000001 and 1000011 could have parity bits added and become **0**1000001 and **1**1000011, both with even parity. If any bit in these codes should be altered in the course of processing the parity would change and the error would be quickly detected.

Parkes Observatory

observatory in New South Wales, Australia, operated by the Australian National Radio Facility and run by the Commonwealth Scientific and Industrial Research Organization (CSIRO). It has a radio telescope with a 64-m/210-ft aperture. Much of its research concentrates on pulsars.

Parkes Observatory Home Page

Go to site

Guide to the work of Australia's main radio telescope. In addition to scientific details for radio astronomers, there is information of general interest and education projects for school students and visitors. Astronomical images can be accessed (including an interactive map of the radio sky) and there is daily updated information on what the radio astronomers are doing.

Parkinson, Norman (1913-1990)

adopted name of Ronald William Smith

English fashion and portrait photographer. He caught the essential glamour of each decade from the 1930s to the 1980s. Long associated with the magazines *Vogue* and *Queen*, he was best known for his colour work, and from the late 1960s took many official portraits of the royal family.

Parkinson's disease

or parkinsonism or paralysis agitans

degenerative disease of the brain characterized by a progressive loss of mobility, muscular rigidity, tremor, and speech difficulties. The condition is mainly seen in people over the age of 50.

Parkinson's disease destroys a group of cells called the *substantia nigra* ('black substance') in the upper part of the brainstem. These cells are concerned with the production of a neurotransmitter known as dopamine, which is essential to the control of voluntary movement. The almost total loss of these cells, and of their chemical product, produces the disabling effects. A defective gene responsible for 1 in 20 cases was identified in 1992.

The disease occurs in two forms: **multiple system atrophy (MSA)**, which is a failure of the central nervous system and accounts for 1 in 5 cases; and **pure autonomic failure (PAF)**, a deficit in the peripheral nerves. Symptoms, particularly in the early stages, can be identical. In 1997, an estimated 1.5 million Americans and over 120,000 Britons were suffering with Parkinson's.

The introduction of the drug L-dopa in the 1960s seemed at first the answer to Parkinson's disease. However, it became evident that long-term use brings considerable problems. At best, it postpones the terminal phase of the disease. Brain grafts with dopamine-producing cells were pioneered in the early 1980s, and attempts to graft Parkinson's patients with fetal brain tissue have been made. This experimental surgery brought considerable improvement to some PAF patients, but is ineffective in the MSA form. In 1989 a large US study showed that the drug deprenyl may slow the rate at which disability progresses in patients with early Parkinson's disease.

In 1997, the National Human Genome Research Institute at the National Institutes of Health in the USA announced that its scientists discovered a gene that causes Parkinson's disease. The gene produces a protein called alpha synuclein. When the instructions of the gene go wrong, the protein's structure is affected and this causes a buildup of deposits on brain cells that are usually seen in Parkinson's sufferers. According to 1999 research, however, there is strong evidence that environmental factors may also cause the disease in people aged 50 or over.

Parkinson's Disease: Hope through Research

Go to site

Extensive background information on Parkinson's disease. Amongst other issues, it discusses the causes and symptoms of the disorder, the diagnostic methods used and the treatments and medications that are available, the role of surgery in the treatment of the disease, and diet and exercise as ways of alleviating its symptoms.

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parrot

tropical bird found mainly in Australia and South America. These colourful birds have been valued as pets in the Western world for many centuries. Parrots have the ability to imitate human speech. They are mainly vegetarian, and range in size from the 8.5 cm/3.5 in pygmy parrot to the 100 cm/40 in Macaw. The smaller species are commonly referred to as parakeets. The plumage is often very colourful, and the call is usually a harsh screech. In most species the sexes are indistinguishable. Several species are endangered. Parrots are members of the family Psittacidae, of the order Psittaciformes.

Parrots all have powerful hooked bills and feet adapted for tree climbing. The bill, with its elongated tip, is well adapted in most parrots for tearing up fruit and cracking nuts, and in a number of species the tongue is highly specialized for extracting honey by means of a brushlike tip.

The talent for imitating human speech is marked in the grey parrot *Psittacus erithacus* of Africa. Alex, a 20-year-old African grey taking part in a long-term language project at the University of Arizona during 1996, can count up to six, name 100 objects and describe their colour, texture, and shape. Parrots were among the first items to be traded between natives and European settlers and merchants.

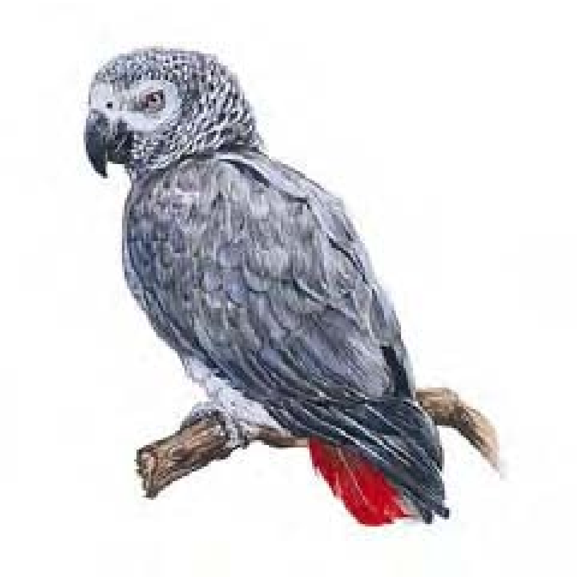
under threat

Many parrot species are threatened: of the 350 species, more than 90 were under threat of extinction and a further 40 species were vulnerable in 1998. The most serious threat is caused by destruction of the rainforest, although trapping for the pet trade is also a major threat to many species.

unusual parrots

The kakapo of New Zealand is flightless and usually lives on the ground, though it can still climb trees. The kea, another New Zealand parrot, differs from the rest of the group in having developed carnivorous habits.

parrot



(Image © Research Machines plc)

The grey parrot of the lowland forest and savannah of Kenya and Tanzania. Large flocks roost together in the trees at the forest edge, or on small river or lake islands. At sunrise, the birds fly off in pairs to search for food. They eat seeds, nuts, berries, and fruit, particularly the fruit of the oil palm.

Communication with Parrots: The Pepperburg Home Page

Go to site

Page devoted to US ethologist Irene Pepperburg's work on communication between humans and parrots - notably Alex, an African Grey Parrot that can count and identify objects, shapes, colours, and materials.

Parrot

Go to site

Illustrated guide to the parrot including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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parrot fish

or parrot wrasse

member of a family of marine bony fish. The teeth of this group have fused to form extremely hard beaks that are able to bite off pieces of coral; these, with seaweed and molluscs, form the principal food. The fish are all brilliantly coloured, and some may grow up to 1 m/3.3 ft in length.

classification

Parrot fish comprise the family Scaridae, order Perciformes, class Osteichthyes.

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parsec

symbol pc

unit used for distances to stars and galaxies. One parsec is equal to 3.2616 light years, 2.063 × 10^5 astronomical units, and 3.857 × 10^{13} km.

A parsec is the distance at which a star would have a parallax (apparent shift in position) of one second of arc when viewed from two points the same distance apart as the Earth's distance from the Sun; or the distance at which one astronomical unit subtends an angle of one second of arc.

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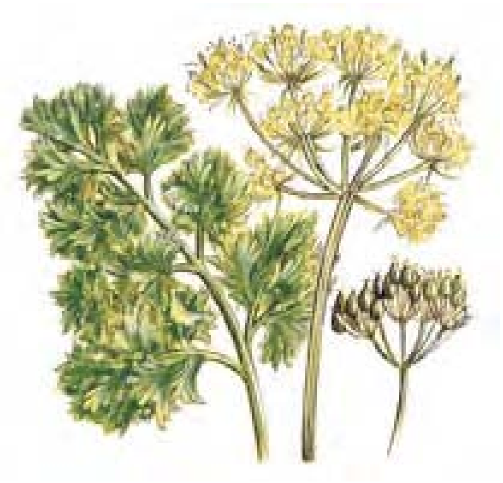
parsley

herb belonging to the carrot family, cultivated for flavouring and garnishing in cookery and for its nutrient value, being rich in vitamin C and minerals. It can grow up to 45 cm/1.5 ft high and has aromatic, curled or flat pinnate leaves (leaflets either side of the stem) and delicate open clusters of yellow flowers. It is a biennial plant. (*Petroselinum crispum*, family Umbelliferae.)

parsley



(Image © Research Machines plc)

The hardy biennial parsley has been cultivated for so long that its origin is uncertain. It may have originated in southeast Europe. The mild-flavoured leaves and seeds are widely used as a herb in cooking.

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parsnip

temperate biennial plant belonging to the carrot family, found in Europe and Asia, and cultivated for its tapering, creamy-white, aromatic root, which is much used as a winter vegetable. (*Pastinaca sativa*, family Umbelliferae.)

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parthenocarpy

in botany, the formation of fruits without seeds. This phenomenon, of no obvious benefit to the plant, occurs naturally in some plants, such as bananas. It can also be induced in some fruit crops, either by breeding or by applying certain plant hormones.

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parthenogenesis

development of an ovum (egg) without any genetic contribution from a male. Parthenogenesis is the normal means of reproduction in a few plants (for example, dandelions) and animals (for example, certain fish). Some sexually reproducing species, such as aphids, show parthenogenesis at some stage in their life cycle to accelerate reproduction to take advantage of good conditions.

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particle detector

one of a number of instruments designed to detect subatomic particles and track their paths; they include the cloud chamber, bubble chamber, spark chamber, and multiwire chamber.

The earliest particle detector to reveal the paths of particles was the cloud chamber, which contains a super-saturated vapour in which particles leave a trail of droplets, in much the same way that a jet aircraft leaves a trail of vapour in the sky. A bubble chamber contains a superheated liquid, such as liquid hydrogen, in which a particle leaves a trail of bubbles. A spark chamber contains a series of closely-packed parallel metal plates, each at a high voltage. As particles pass through the chamber, they leave a visible spark between the plates. A modern multiwire chamber consists of an array of fine, closely-packed wires, each at a high voltage. As a particle passes through the chamber, it produces an electrical signal in the wires. A computer analyses the signal and reconstructs the path of the particles. Multiwire detectors can be used to detect X-rays and gamma rays, and are used as detectors in positron emission tomography (PET).

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particle physics

the study of the properties of elementary particles and of fundamental interactions (see forces, fundamental).

Pioneering research took place at the Cavendish laboratory, Cambridge, England. In 1895 Joseph Thomson discovered that all atoms contain identical, negatively charged particles called electrons that could easily be freed. By 1913 Ernest Rutherford had shown that electrons surround a very small, positively-charged nucleus (which in the case of a hydrogen atom consists of a single positively charged particle, a proton, identified by James Chadwick in 1932). The nuclei of all the other elements are made up of protons and uncharged particles called neutrons. 1932 also saw the discovery of a particle (predicted in 1928 by Paul Dirac) with the mass of an electron, but an equal and opposite charge, called the positron. This was the first example of an antiparticle; it is now known that almost all particles have corresponding antiparticles. In 1933 Wolfgang Pauli argued that a hitherto unsuspected particle must accompany electrons in beta-ray emission - the so-called electron-neutrino.

particles and fundamental forces

By the mid-1930s, four fundamental kinds of force had been identified: (1) The electromagnetic force acts between all particles with electric charge, and was thought to be related to the exchange between the particles of photons, packets of electromagnetic radiation. (2) In 1935 the Japanese physicist Hideki Yukawa suggested that the strong force (holding protons and neutrons together in the nucleus) was caused by the exchange of particles with a mass of about a tenth that of a proton; these particles, called pions (originally pi-mesons), were found by the British physicist Cecil Powell in 1946. (3) Theoretical work on the weak nuclear force began with Enrico Fermi in the 1930s. The existence of the particles that carry the weak force, the W and Z particles (weakons), was confirmed in 1983 at CERN. (4) The fourth fundamental force, gravitation, is experienced by all matter, the postulated carrier of this force being the graviton.

leptons, hadrons, and quarks

The electron, three types of neutrinos, and the positive and negative muons are the leptons - particles with half-integral spin that 'feel' the weak, but not the strong, force. The muon (found by US physicist Carl Anderson in cosmic radiation in 1937) produces the muon neutrino when it decays. The tauon, a surprise discovery of the 1970s, produces the tauon neutrino when it decays. Hadrons (particles that 'feel' the strong force) started to turn up in bewildering profusion in experiments in the 1950s and 1960s. They are classified into mesons, with whole-number or zero spins, and baryons (which include protons and neutrons), with half-integral spins. It was shown in the early 1960s that if hadrons of the same spin are represented as points on suitable charts, simple patterns are formed. This symmetry enabled a hitherto unknown particle, the omega-minus, to be predicted from a gap in one of the patterns; it then turned up in experiments. In 1964, Murray Gell-Mann suggested that all hadrons were composed of just three types or 'flavours' of a new particle with half-integral spin and a charge of magnitude either 1/3 or 2/3 that of an electron; Gell-Mann christened the particle 'quark'. Mesons are quark-antiquark pairs (spins either add to one or cancel to zero), and baryons are quark triplets. To account for new mesons, such as the psi, the number of quark flavours was conjectured to be six (up, down, top, bottom, strange, and charm), and this had been confirmed by 1985.

Particle physics: key dates

1897	English physicist John Joseph Thomson demonstrates the existence of the electron, the first known subatomic particle. It revolutionizes knowledge of atomic structure by indicating that the atom can be subdivided.
1920	New Zealand-born British physicist Ernest Rutherford recognizes the hydrogen nucleus as a fundamental particle and names it the 'proton'.
1932	British physicist James Chadwick discovers the neutron, an important discovery in the development of nuclear reactors.
1932	US scientist Carl David Anderson, while analysing cosmic rays, discovers positive electrons ('positrons'), the first form of antimatter to be discovered.
1935	Japanese physicist Hideki Yukawa proposes the existence of a new particle, an exchange particle, to explain the strong nuclear force.
1936	Austrian physicist Victor Hess shares the Nobel Prize for Physics with US physicist Carl Anderson; Hess for discovering cosmic radiation and Anderson for discovering the positron.
1947	The British physicists Cecil Frank Powell and G P S Occhialini discover the pion (or pi-meson) subatomic particle.
1953	US physicist Murray Gell-Mann introduces the concept of 'strangeness', a property of subatomic particles, to explain their behaviour.
1956	US physicists Clyde Cowan and Fred Reines detect the existence of the neutrino, a particle with no electric charge and no mass, at the Los Alamos Laboratory.
16 November 1974	US physicists Burton Richter and Samuel Chao Chung Ting announce that they have separately discovered the J/ψ particle, which consists of a charm quark combined with its antiparticle. It confirms the existence of the charm quark.
August 1975	US physicist Martin Perl discovers the tau lepton (or tauon), a fundamental particle.
1977	German-born US physicist Leon Lederman discovers the fifth ('beauty' or 'bottom') quark, in proton-neucleon collisions, combined with its antiquark in a particle called the upsilon meson.
1979	The first direct evidence of the gluon is seen at the DESY laboratory in Hamburg, produced by the Petra accelerator.
1983	W and Z gauge bosons are observed at CERN by the UA1 and UA2 collaborations.
1994	US scientists at Fermilab, near Chicago, Illinois, announce the discovery of the sixth and final 'top' quark.
1995	Physicists at CERN, in Switzerland, detect 'glueballs', gluons that stick together and behave as single particles.
1997	Israeli physicist Rafi de-Picciotto demonstrates the formation within semiconductors of 'quasiparticles', which have a charge one-third that of an electron.
1998	Scientists at the Fermi National Accelerator laboratory in Batvia, Illinois, announce the discovery of the tau neutrino, the least stable elementary particle of the lepton class.
2001	A team of US, Canadian, and British physicists woring on the SNO experiment discover that the Sun emits electron neutrinos that transform into tau and muon neutrinos, solving the 30-year-old mystery of the shortage of solar neutrinos, and demonstrating that neutrinos have mass.
2006	First results are published by the Minos collaboration, aiming to measure the parameters controlling neutrino oscillations.

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particle, subatomic

see subatomic particle.

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partridge

any of various medium-sized ground-dwelling fowl of the family Phasianidae, order Galliformes, that also includes pheasants, quail, and chickens. Partridges are Old World birds, some of which have become naturalized in North America.

Partridges pair very early in the year, the males, like the males of most gallinaceous species, being very pugnacious. The nest is made with a minimum of trouble on the ground in fields or hedgerows, and contains 10-20 olive brown eggs. The hen hatches them, but the male is attentive to her during incubation. The young are fed chiefly on ant pupae, and other insects when these are not available; these and snails and slugs form a considerable proportion of the food of older birds, but in addition grain and other seeds are consumed in great quantity when obtainable. The young remain with their parents for some months, forming coveys of about 20 birds. In the morning and evening they search the stubble and pastures for food, but during the day they hide wherever safe cover may be found.

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parturition

in medicine, another term for labour.

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parvovirus

in medicine, one of a group of viruses responsible for epidemic nausea and vomiting. Outbreaks can affect whole communities and are more common in the winter. Symptoms include nausea, vomiting, diarrhoea, and giddiness but the disease is not serious and usually lasts for less than three days.

Pascal

acronym for Program Appliqué à la Selection et la Compilation Automatique de la Littérature

high-level computer-programming language. Designed by Niklaus Wirth in the 1960s as an aid to teaching programming, it is still widely used as such in universities, and as a good general-purpose programming language. Most professional programmers, however, now use C or C++. Pascal was named after the 17th-century French mathematician Blaise Pascal.

Pascal declarations

To remember the order of declarations in Pascal:

Let's **c**ook **t**extured **v**egetable **p**rotein

Labels, **c**onstants, **t**ypes, **v**ariables, **p**rocedures

Pascal Central

Go to site

Provides an important gateway to Pascal on the Internet. The easily navigable pages contain articles, news and announcements, and links to dozens of Web sites with Pascal code and tools for programmers.

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pascal

symbol Pa

SI unit of pressure, equal to one newton per square metre. It replaces bars and millibars (10^5 Pa equals one bar). It is named after the French mathematician Blaise Pascal.

Pascal, Blaise (1623-1662)

French philosopher and mathematician. He contributed to the development of hydraulics, calculus, and the mathematical theory of probability.

mathematics

Pascal's work in mathematics widened general understanding of conic sections, introduced an algebraic notational system that rivalled that of Descartes and made use of the arithmetical triangle (called Pascal's triangle) in the study of probabilities.

Together with Fermat, Pascal studied two specific problems of probability: the first concerned the probability that a player will obtain a certain face of a dice in a given number of throws; and the second was to determine the portion of the stakes returnable to each player of several if a game is interrupted. Pascal used the arithmetical triangle to derive combinational analysis.
Pascal's triangle is a triangular array of numbers in which each number is the sum of the pair of numbers

above it. In general the *n*th ($n = 0, 1, 2, \ldots$) row of the triangle gives the binomial coefficients $^{n}C_{r}$, with $r = 0, 1, \ldots, n$.

In 1657–59, Pascal also perfected his 'theory of indivisibles' – the forerunner of integral calculus – which enabled him to study problems involving infinitesimals, such as the calculations of areas and volumes.

hydrostatics, Pascal's principle and hydraulics

Pascal's work in hydrostatics involved repeating the experiment by Italian physicist Evangelista Torricelli to prove that air pressure supports a column of mercury. He confirmed that a vacuum must exist in the space at the top of the tube, and set out to prove that the column of mercury is held up by the weight of air exerted on the container of liquid at the base of the tube. Pascal suggested that at high altitudes there would be less air above the tube and that the column would be lower. Poor health prevented him from undertaking the experiment himself, so he entrusted it to his brother-in-law who obtained the expected results using a mercury column in the mountains of the Puy de Dôme in 1648. This led rapidly to investigations of the use of the mercury barometer in weather forecasting.

Pascal then turned to a study of pressure in liquids and gases, and found that pressure is transmitted equally in all directions throughout a fluid and is always exerted perpendicular to any surface in or containing the fluid. Propounded in a treatise on hydrostatics in 1654, **Pascal's principle** is fundamental to applications of hydrostatics and governs the operation of hydraulic machines, such as the hydraulic press and jack.

calculating machine

Between 1642 and 1645, Pascal constructed a machine to carry out the processes of addition and subtraction, and then organized the manufacture and sale of these first calculating machines. At least seven of these 'computers' still exist. One was presented to Queen Christina of Sweden in 1652.

Pensées

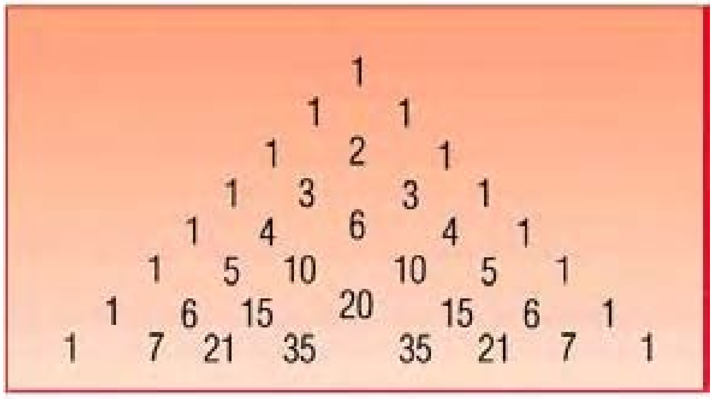
Go to site

Text of Pascal's famous work.

Pascal's triangle

triangular array of numbers (with 1 at the apex), in which each number is the sum of the pair of numbers above it. It is named after French mathematician Blaise Pascal, who used it in his study of probability. When plotted at equal distances along a horizontal axis, the numbers in the rows give the binomial probability distribution (with equal probability of success and failure) of an event, such as the result of tossing a coin.

Pascal's triangle


1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1
1 6 15 20 15 6 1
1 7 21 35 35 21 7 1

(Image © Research Machines plc)

In Pascal's triangle, each number is the sum of the two numbers immediately above it, left and right – for example, 2 is the sum of 1 and 1, and 4 is the sum of 3 and 1. Furthermore, the sum of each row equals a power of 2 – for example, the sum of the 3rd row is $4 = 2^2$; the sum of the 4th row is $8 = 2^3$.

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pasqueflower

plant *Anemone patens* of the buttercup family, native to the central USA. It has a hairy stalk and hairy leaves near the base. The showy lavender-blue flowers are 2 in/5 cm across.

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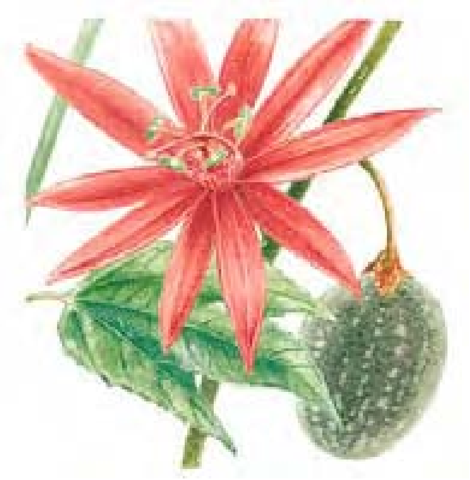
passion flower

any of a group of tropical American climbing plants. They have distinctive flowers consisting of a saucer-shaped petal base, a fringelike corona or circle of leafy outgrowths inside the ring of petals, and a central stalk bearing five pollen-producing stamens and three pollen-receiving stigmas. The flowers can be yellow, greenish, purple, or red. Some species produce edible fruit. (Genus *Passiflora*, family Passifloraceae.)

Parts of the flower were said by Jesuit missionaries to South America to resemble symbols of Christ's crucifixion, for example the crown of thorns, the five wounds, and the three nails; hence the name, referring to the suffering, or passion, of Christ on the cross.

passion flower



(Image © Research Machines plc)

These climbing, vinelike plants derive their name from the 'passion' or sufferings of Jesus at the crucifixion. Spanish missionaries to South America, where many species grow, thought the flowers resembled the crown of thorns and the wounds on Jesus' body. Some species are cultivated for their edible fruits or decorative flowers.

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passive margin

in plate tectonics, a boundary between oceanic and continental crust that is within a single tectonic plate rather than at the boundary between two plates. Very little tectonic activity occurs at passive margins. Examples include the east coast of North America and the entire coast of Australia.

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passive smoking

inhalation of tobacco smoke from other people's cigarettes; see smoking.

Pasteur, Louis (1822-1895)

French chemist and microbiologist who discovered that fermentation is caused by micro-organisms and developed the germ theory of disease. He also created a vaccine for rabies, which led to the foundation of the Pasteur Institute in Paris in 1888.

stereoisomers

Pasteur first gained recognition through his early work on the optical activity of stereo isomers. In 1848 he presented a paper to the Paris Academy of Sciences in which he reported that there are two molecular forms of tartaric acid, one that rotates plane polarized light to the right and another (a mirror image of the first) that rotates it to the left. In addition, he showed that one form can be assimilated by living micro-organisms whereas its optical antipode cannot.

fermentation

A query from an industrialist about wine- and beer-making prompted Pasteur's research into fermentation. Using a microscope he found that properly aged wine contains small spherical globules of yeast cells whereas sour wine contains elongated yeast cells. He proved that fermentation does not require oxygen, yet it involves living micro-organisms, and that, to produce the correct type of fermentation (alcohol-producing rather than lactic acid-producing), it is necessary to use the correct type of yeast. Pasteur also realized that, after wine has formed, it must be gently heated to about 50°C/122°F - pasteurized - to kill the yeast and thereby prevent souring during the ageing process.

spontaneous generation and the germ theory of disease

Pasteur then turned his attention to spontaneous generation, a problem that had once again become a matter of controversy. Pasteur showed that dust in the air contains spores of living organisms that reproduce when introduced into a nutrient broth. Then he boiled the broth in a container with a U-shaped tube that allowed air to reach the broth but trapped dust in the U-bend. He found that the broth remained free of living organisms, disproving the theory of spontaneous generation.

In the mid-1860s, the French silk industry was seriously threatened by a disease that killed silkworms and Pasteur was commissioned by the government to investigate the disease. He announced in 1868 that he had found a minute parasite that infects the silkworms, and recommended that all infected silkworms be destroyed. His advice was followed and the disease eliminated. This stimulated his interest in infectious diseases and, from the results of his previous work on fermentation, spontaneous generation, and the silkworm disease, Pasteur developed the **germ theory of disease**. This theory was probably the most important single medical discovery of all time, because it provided both a practical method of combating disease by disinfection and a theoretical foundation for further research.

the prevention of disease

Continuing his research into disease, in 1881 Pasteur developed a method for reducing the virulence of certain pathogenic micro-organisms. By heating a preparation of anthrax bacilli he attenuated their virulence but found that they still brought about the full immune response when injected into sheep. Using a similar method, Pasteur then inoculated fowl against chicken cholera, following the work of Edward Jenner (who first vaccinated against cowpox in 1796).

In 1882 Pasteur began what proved to be his most spectacular research: the prevention of rabies. He demonstrated that the causative micro-organism (actually a virus, although the existence of viruses was not known at that time) infects the nervous system and then, using the dried tissues of infected animals, he succeeded in obtaining an attenuated form of the virus suitable for the inoculation of human beings. The culmination of this work came on 6 July 1885, when Pasteur used his vaccine to save the life of a young boy who had been bitten by a rabid dog. The success of this experiment brought Pasteur even greater acclaim and led to the establishment of the Pasteur Institute in 1888.

Pasteur, Louis

More germs are transmitted when shaking hands than when kissing. Louis Pasteur, the pioneer of hygienic methods, refused to shake hands with acquaintances for fear of infection.

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pasteurization

treatment of food to reduce the number of micro-organisms it contains and so protect consumers from disease. Harmful bacteria are killed and the development of others is delayed. For milk, the method involves heating it to 72°C/161°F for 15 seconds followed by rapid cooling to 10°C/50°F or lower. The process also kills beneficial bacteria and reduces the nutritive property of milk.

The experiments of Louis Pasteur on wine and beer in the 1850s and 1860s showed how heat treatment slowed the multiplication of bacteria and thereby the process of souring. Pasteurization of milk made headway in the dairy industries of Scandinavia and the USA before 1900 because of the realization that it also killed off bacteria associated with the diseases of tuberculosis, typhoid, diphtheria, and dysentery.

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pastoral farming

the rearing or keeping of animals in order to obtain meat or other products, such as milk, skins, and hair. Animals can be kept in one place or periodically moved (nomadic pastoralism).

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patchouli

soft-wooded eastern Indian shrub belonging to the mint family; the leaves are the source of the perfume patchouli. (*Pogostemon heyneanus*, family Labiateae.)

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patch test

in medicine, the placing of small amounts of possible allergens on to the skin, usually on the arm or back, to identify the cause of an allergic reaction. A red flare and swelling will appear in the area of application if the individual is allergic to that substance. Patch tests can achieve very quick results, but in some cases the patch must remain in place for several days.

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patella

or kneecap

flat bone embedded in the knee tendon of birds and mammals, which protects the joint from injury.

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pathogen

(Greek 'disease producing')

any micro-organism that causes disease. Most pathogens are parasites, and the diseases they cause are incidental to their search for food or shelter inside the host. Nonparasitic organisms, such as soil bacteria or those living in the human gut and feeding on waste foodstuffs, can also become pathogenic to a person whose immune system or liver is damaged. The larger parasites that can cause disease, such as nematode worms, are not usually described as pathogens.

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pathology

medical speciality concerned with the study of disease processes and how these provoke structural and functional changes in the body.

Pauling, Linus Carl (1901-1994)

US theoretical chemist and biologist. He was awarded the Nobel Prize for Chemistry in 1954 for his study of the nature of chemical bonds, especially in complex substances. His ideas are fundamental to modern theories of molecular structure. He also investigated the properties and uses of vitamin C as related to human health. He was awarded the Nobel Prize for Peace in 1962 for having campaigned for the control of nuclear weapons and nuclear testing.

work

Pauling's work on the nature of the chemical bond included much new information about interatomic distances. Applying his knowledge of molecular structure to proteins in blood, he discovered that many proteins have structures held together with hydrogen bonds, giving them helical shapes.

He was a pioneer in the application of quantum-mechanical principles to the structures of molecules, relating them to interatomic distances and bond angles by X-ray and electron diffraction, magnetic effects, and thermochemical techniques. In 1928, Pauling introduced the concept of hybridization of bonds. This provided a clear, basic insight into the framework structure of all carbon compounds - in effect, of the whole of organic chemistry. He also studied electronegativity of atoms and polarization (location of electrons) in chemical bonds. Electronegativity values can be used to show why certain substances, such as hydrochloric acid, are acid, whereas others, such as sodium hydroxide, are alkaline. Much of this work was consolidated in his book *The Nature of the Chemical Bond* (1939).

Dr Linus Pauling Profile

Go to site

Description of the life and works of the double Nobel prizewinner Linus Pauling. Pauling is one of the very few people to have won more than one Nobel prize, having won the prize for chemistry in 1954, followed by the prize for peace in 1962. The Web site contains not only a profile and biographical information, but also holds a lengthy interview with Pauling from 1990 accompanied by a large number of photographs, video sequences, and audio clips.

Pavlov, Ivan Petrovich (1849-1936)

Russian physiologist who was awarded a Nobel Prize for Physiology or Medicine in 1904 for his discovery of the physiology of digestion. Pavlov studied conditioned reflexes in animals (see conditioning). His work had a great impact on behavioural theory (see behaviourism) and learning theory.

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pawpaw

or papaw

small tree belonging to the custard-apple family, native to the eastern USA. It produces oblong fruits 13 cm/5 in long with yellowish edible flesh. The name 'pawpaw' is also used for the papaya. (*Asimina triloba*, family Annonaceae.)

PCP

abbreviation for **phencyclidine hydrochloride**, a drug popularly known as angel dust.

---

pea

climbing leguminous plant (see legume) with pods of round green edible seeds, grown since prehistoric times for food. The pea is a popular vegetable and is eaten fresh, canned, frozen, or dried. The **sweet pea** (*Lathyrus odoratus*) of the same family is grown for its scented red, purple, pink, and white butterfly-shaped flowers; it is a popular cottage garden plant. (Edible pea *Pisum sativum*, family Leguminosae.)

Garden Peas

Go to site

Contains extensive information on the garden pea. There are notes on the different varieties, and there is also a guide to planting peas, taking account of soil, temperature, and sunlight.

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peach

yellow-reddish round edible fruit of the peach tree, which is cultivated for its fruit in temperate regions and has oval leaves and small, usually pink, flowers. The fruits have thick velvety skins; nectarines are a smooth-skinned variety. (*Prunus persica*, family Rosaceae.)

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peacock

technically, the male of any of various large pheasants, order Galliformes. The name is most often used for the common peacock *Pavo cristatus*, a bird of the pheasant family, native to South Asia. It is rather larger than a pheasant. The male has a large fan-shaped tail, brightly coloured with blue, green, and purple 'eyes' on a chestnut background, that is raised during courtship displays. The female (peahen) is brown with a small tail.

The hen lays 4-8 eggs in the spring, and incubation takes 30 days. She remains with her chicks eight months. The green peacock, *P. muticus*, native to Southeast Asia, breeds freely with the common peacock. A third species, *Afropavus congensis*, was discovered in the late 1930s in the forests of the Congo. These are much smaller than the common peacock and do not have erectile tail coverts.

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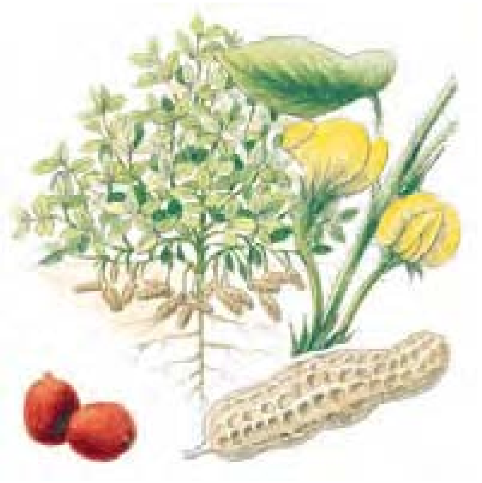
peanut

or groundnut or monkey nut

South American vinelike annual plant. After flowering, the flower stalks bend and force the pods into the earth to ripen underground. The nuts are a staple food in many tropical countries and are widely grown in the southern USA. They provide a valuable edible oil and are the basis for a large number of processed foods. (*Arachis hypogaea*, family Leguminosae.)

peanut



(Image © Research Machines plc)

The peanut, groundnut, or monkey nut is a leguminous perennial plant belonging to the pea family, native to South America. After flowering, its pods bury themselves in the ground where the fruits ripen. The plant is widely cultivated for the kernels which are rich in oil and protein.

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pear

succulent, gritty-textured edible fruit of the pear tree, native to temperate regions of Europe and Asia. White flowers precede the fruits, which have a greenish-yellow and brown skin and taper towards the stalk. Pear trees are cultivated for their fruit which are eaten fresh or canned; a wine known as perry is made from pear juice. (*Pyrus communis*, family Rosaceae.)

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pearl

shiny, hard, rounded abnormal growth composed of nacre (or mother-of-pearl), a chalky substance. Nacre is secreted by many molluscs, and deposited in thin layers on the inside of the shell around a parasite, a grain of sand, or some other irritant body. After several years of the mantle (the layer of tissue between the shell and the body mass) secreting this nacre, a pearl is formed.

Although commercially valuable pearls are obtained from freshwater mussels and oysters, most precious pearls come from the various species of the family Pteriidae (the pearl oysters) found in tropical waters off northern and western Australia, off the Californian coast, in the Gulf, and in the Indian Ocean. Because of their rarity, large mussel pearls of perfect shape are worth more than those from oysters.

Artificial pearls were first cultivated in Japan in 1893. A tiny bead of shell from a clam, plus a small piece of membrane from another pearl oyster's mantle (to stimulate the secretion of nacre) is inserted in oysters kept in cages in the sea for three years, and then the pearls are harvested.

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peat

organic matter found in bogs and formed by the incomplete decomposition of plants such as sphagnum moss. Northern Asia, Canada, Finland, Ireland, and other places have large deposits, which have been dried and used as fuel from ancient times. Peat can also be used as a soil additive.

Peat bogs began to be formed when glaciers retreated, about 9,000 years ago. They grow at the rate of only a millimetre a year, and large-scale digging can result in destruction both of the bog and of specialized plants growing there. The destruction of peat bogs is responsible for diminishing fish stocks in coastal waters; the run-off from the peatlands carries high concentrations of iron, which affects the growth of the plankton on which the fish feed.

Approximately 60% of the world's wetlands are peat. In May 1999 the Ramsar Convention on the Conservation of Wetlands approved a peatlands action plan that should have a major impact on the conservation of peat bogs.

peat

(Image © Research Machines plc)

Peat is cut in lines across the bog and left to dry. It is a slow-burning fuel that is still used in many Irish houses.

peat

(Image © Research Machines plc)

Cut turf lies drying above an Irish bog. The peat is produced over thousands of years, forming a fossil fuel that may, due to overuse, become exhausted.

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pecan

nut-producing hickory tree (*C. illinoensis* or *C. pecan*), native to the central USA and northern Mexico and now widely cultivated. The trees grow to over 45 m/150 ft, and the edible nuts are smooth-shelled, the kernel resembling a smooth, oval walnut. (Genus *Carya*, family Juglandaceae.)

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peccary

one of two species of the New World genus *Tayassu* of piglike hoofed mammals. A peccary has a gland in the middle of its back which secretes a strong-smelling substance. Peccaries are blackish in colour, covered with bristles, and have tusks that point downwards. Adults reach a height of 40 cm/16 in, and a weight of 25 kg/60 lb.

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pectoral

relating to the upper area of the thorax associated with the muscles and bones used in moving the arms or forelimbs, in vertebrates. In birds, the *pectoralis major* is the very large muscle used to produce a powerful downbeat of the wing during flight.

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pedicel

stalk of an individual flower, which attaches it to the main floral axis, often developing in the axil of a bract.

---

peepul

another name for the bo tree.

Pegasus

a constellation of the northern hemisphere, near Cygnus, represented as the winged horse of Greek mythology.

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pegmatite

extremely coarse-grained igneous rock of any composition found in veins; pegmatites are usually associated with large granite masses.

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pekan

or fisher marten

North American marten (carnivorous mammal) *Martes penanti* about 1.2 m/4 ft long, with a doglike face, and brown fur with white patches on the chest. It eats porcupines.

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pekingese

breed of small long-haired dog first bred at the Chinese court as the 'imperial lion dog'. It has a flat skull and flat face, is typically less than 25 cm/10 in tall, and weighs less than 5 kg/11 lb.

Pekingese Club of America

Go to site

Information about the history of the breed, the breed standard, shows, veterinary advice, and many tips for owners. There is also a comprehensive listing of other Pekingese sites across the world.

Peking man

Chinese representative of an early species of human, found as fossils, 500,000-750,000 years old, in the cave of Choukoutien in 1927 near Beijing (Peking). Peking man used chipped stone tools, hunted game, and used fire. Similar varieties of early human have been found in Java and East Africa.

Their classification is disputed: some anthropologists classify them as *Homo erectus*, others as *Homo sapiens pithecanthropus*.

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pelargonium

or geranium

any of a group of shrubby, tender flowering plants belonging to the geranium family, grown extensively for their colourful white, pink, scarlet, and black-purple flowers. They are the familiar summer bedding and pot 'geraniums'. Ancestors of the garden hybrids came from southern Africa. (Genus *Pelargonium*, family Geraniaceae.)

pelican

large water bird of family Pelecanidae, order Pelecaniformes, remarkable for the pouch beneath the bill, which is used as a fishing net and temporary store for catches of fish. Some species grow up to 1.8 m/6 ft and have wingspans of 3 m/10 ft.

The legs are short and the feet large, with four webbed toes; the tail is short and rounded, and the neck long. The wings are long and expansive, and the birds are capable of rapid flight. The species are widely distributed, frequenting the seashore and margins of lakes, and feeding almost exclusively on fish, which are deposited in the pouch for subsequent digestion.

pellagra

chronic disease mostly seen in subtropical countries in which the staple food is maize. It is caused by deficiency of nicotinic acid (one of the B vitamins), which is contained in protein foods, beans and peas, and yeast. Symptoms include diarrhoea, skin eruptions, and mental disturbances.

pellitory-of-the-wall

plant belonging to the nettle family, found growing in cracks in walls and rocks and also on banks in western and southern Europe; it is widely cultivated in gardens. The stems are up to 1 m/3 ft tall and reddish, the leaves are lance-shaped, and the greenish male and female flowers grow separately but on the same plant. (*Parietaria judaica*, family Urticaceae.)

Peltier effect

in physics, a change in temperature at the junction of two different metals produced when an electric current flows through them. The extent of the change depends on what the conducting metals are, and the nature of change (rise or fall in temperature) depends on the direction of current flow. It is the reverse of the Seebeck effect. It is named after the French physicist Jean Charles Peltier (1785–1845) who discovered it in 1834.

pelvis

in vertebrates, the lower area of the abdomen featuring the bones and muscles used to move the legs or hindlimbs. The **pelvic girdle** is a set of bones that allows movement of the legs in relation to the rest of the body and provides sites for the attachment of relevant muscles.

pendulum

weight (called a 'bob') swinging at the end of a rod or cord. The regularity of a pendulum's swing was used in making the first really accurate clocks in the 17th century. Pendulums can be used for measuring the acceleration due to gravity (an important constant in physics).

Specialized pendulums are used to measure velocities (ballistic pendulum) and to demonstrate the Earth's rotation (Foucault's pendulum).

Penfield, Wilder Graves (1891-1976)

Canadian neurosurgeon who, while developing surgical options for the treatment of epilepsy, located several functional areas of the cerebral cortex by stimulating the patient's brain electrically while he or she was conscious. He demonstrated that sensations and memories, including memories that could not be recalled except by electrical stimulation, had specific locations in the brain that remained constant. He devised the homunculus, a schematic representation showing the site and relative proportions of the cortical areas specialized for motor and sensory functions.

penguin

marine flightless bird, family Spheniscidae, order Sphenisciformes, mostly black and white, found in the southern hemisphere. They comprise 18 species in six genera. Males are usually larger than the females. Penguins range in size from 40 cm/1.6 ft to 1.2 m/4 ft tall, and have thick feathers to protect them from the intense cold. They are awkward on land (except on snow slopes down which they propel themselves at a rapid pace), but their wings have evolved into flippers, making them excellent swimmers. Penguins congregate to breed in 'rookeries', and often spend many months incubating their eggs while their mates are out at sea feeding. They feed on a mixture of fish, squid, and krill.

The wing is long and has no covert or quill feathers, and always remains open. The feathers are tiny, with very broad shafts and little vane or web. The legs of the birds are placed far back, and in the water the feet are stretched out straight behind and held motionless, the wings working rapidly as if being used in flight. Moult in penguins is general and areas of feathers are lost at once. It is usually a rapid process unlike the ordered progressive moult of flying birds. Penguins generally moult once a year, and have to stay out of the water during this time, without feeding.

The nest is often no more than a slight hollow in the ground, but some penguins, especially the Adelie penguins *Pygoscelis adeliae*, collect stones, with which they bank the nest round. One or two eggs are laid, and both birds, but chiefly the male, attend to their incubation. Both parents are very devoted to the young, one always staying to guard them, the other bringing them sea crustaceans and other small animals, which the young take by pushing their beaks far down the parent's throat.

They are very social birds, living together, and usually breed in vast colonies, always returning to the same rookery (breeding group). The young gather in groups while the parents are foraging for food. When the parents return, the chicks often have to chase for food, with the stronger chick being fed first. They spend much time preening themselves and each other (allopreening).

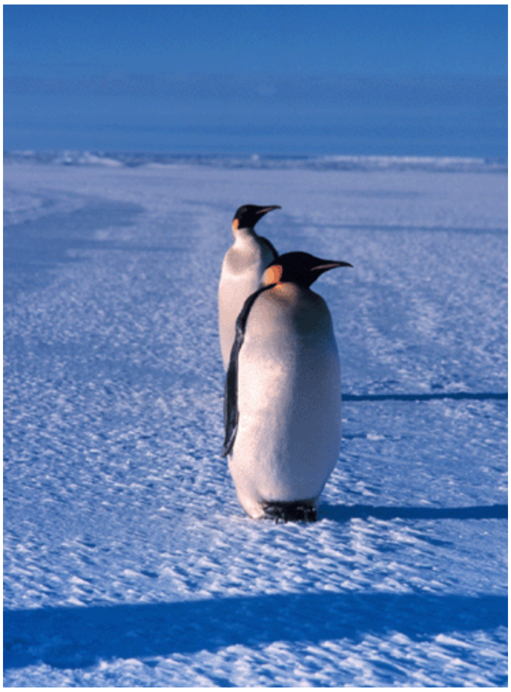
It was estimated in 1997 that the penguin population fell 20% in 10 years. Zoologists blame over-fishing, particularly by large trawling fleets.

Cape penguin

(Image © Corel)

A Cape penguin sunning itself on the Rocky Islands of Namibia, southwest Africa. Although flightless, the penguin is an excellent swimmer and is more agile in water than on land.

penguin



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

For a sociable bird, the emperor penguin spends a considerable time per year in a single-gender group. Males and females may trek together to the breeding ground, but having laid the eggs, the females depart en masse. Males incubate the eggs and then themselves depart, leaving the returned females to look after the hatchlings.

penguin

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Emperor penguins have evolved a means of conserving heat even through an Antarctic winter on shore. They have a double layer of long, densely-packed feathers and beneath the skin are large deposits of blubber-like fat. Both these factors provide excellent insulation, so that even the featherless area of the male's skin remains warm enough to incubate an egg.

Penguin Page

Go to site

Lots of information about penguins – the different species, their behaviour, reproduction, relatives and friends, predators, and fossils.

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penicillin

any of a group of antibiotic (bacteria killing) compounds obtained from filtrates of moulds of the genus *Penicillium* (especially *P. notatum*) or produced synthetically. Penicillin was the first antibiotic to be discovered (by Alexander Fleming); it kills a broad spectrum of bacteria, many of which cause disease in humans.

The use of the original type of penicillin is limited by the increasing resistance of pathogens and by allergic reactions in patients. Since 1941, numerous other antibiotics of the penicillin family have been discovered which are more selective against, or resistant to, specific micro-organisms.

Penicillin: Discovery

chance favours the prepared mind

'I think the discovery and development of penicillin may be looked on as quite one of the luckiest accidents that have occurred in medicine.' With these words, Professor Howard Florey (1898-1968), an Australian pathologist, concluded a lecture he gave in 1943 at the Royal Institution. The topic was penicillin: the first, and still perhaps overall the best of a range of natural chemotherapeutic agents called antibiotics.

Together with Ernst Chain (1906-1979), Howard Florey had made the practical exploitation of penicillin possible on a worldwide scale.

a chance discovery

The story of the discovery of penicillin started with a chance observation made by Scottish bacteriologist Alexander Fleming (1881-1955), while he was working in 1928 in his laboratory at St Mary's Hospital in London.

Fleming was doing research on staphylococcus, a species of bacterium that can cause disease in humans and animals. In the laboratory such bacteria are grown in dishes containing a culture medium - a jelly-like substance which contains their food. Fleming noticed that one of his dishes had been accidentally contaminated with a mould. The mould could have entered the laboratory through an open window. All around where the mould was growing, the staphylococci had disappeared.

Fleming investigates the mould

Intrigued, because he had correctly concluded that the mould must contain a substance that killed the bacterium, Fleming isolated the mould and grew more of it in a culture broth. He found that the broth acquired a high antibacterial activity. He tested the action of the broth with a wide variety of pathogenic bacteria, and found that many of them were quickly destroyed.

Fleming was also able to demonstrate that the white corpuscles in human blood were not sensitive to the broth. This suggested to him that other human cells in the body would not be affected by it.

penicillin is discovered

The mould that Fleming's acute powers of observation had noted in a single culture dish, was found to be *Penicillium notatum*. Fleming named the drug penicillin after this mould.

There the matter rested for 15 years. At the time that penicillin was discovered, it would have been extremely difficult to isolate and purify the drug using the chemical techniques then available. It would also have been quite easily destroyed by them. Without any of the pure substance, Fleming had no way of knowing its extraordinarily high antibacterial activity and its almost negligible toxicity. In fact, penicillin diluted 80,000,000 times will still inhibit the growth of staphylococcus. To translate this number of noughts into something tangible: if one drop of water is diluted 80,000,000 times it would fill over 6,000 whisky bottles.

the first practical application

Then in 1935, German-born British biochemist Ernst Chain joined Professor Florey at Oxford. There in 1939 he began a survey of antimicrobial substances. One of the first he looked at was Fleming's mould. It was chosen because it was already known to be active against staphylococcus, and because, since it was difficult to purify, it represented a biochemical challenge.

A method of purification using primitive apparatus was discovered, and an experiment using penicillin to treat infected mice was carried out with remarkable success. Eventually, enough penicillin was made to treat the first human patient in the terminal stage of a generalized infection. The patient showed an astonishing, although temporary, recovery. Five more seriously ill patients were successfully treated.

Because these patients had already failed to respond to sulphonamide drugs, the value of penicillin was now clearly apparent. For although suphonamides are much more toxic to bacteria than to leucocytes (white blood cells), they do have some poisonous action on the whole human organism.

the new lifesaver

England, then in the midst of World War II, had insufficient resources to manufacture the new wonder drug on a sufficiently large scale. Florey went to the USA to try to interest the large pharmaceutical companies in penicillin. As a result of an outstanding effort, enough penicillin was produced in time to treat all the battle casualties of the Normandy landings in 1944. The use of penicillin in wartime saved countless lives, as it has continued to do ever since.

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peninsula

land surrounded on three sides by water but still attached to a larger landmass. Florida, USA, is an example.

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penis

male reproductive organ containing the urethra, the channel through which urine and semen are voided. It transfers sperm to the female reproductive tract to fertilize the ovum. In mammals, the penis is made erect by vessels that fill with blood, and in most mammals (but not humans) is stiffened by a bone.

Snakes and lizards have a paired structure that serves as a penis; other reptiles have a single organ. A few birds, mainly ducks and geese, also have a type of penis, as do snails, barnacles, and some other invertebrates. Many insects have a rigid, nonerectile male organ, usually referred to as an intromittent organ.

Penn, Irving (1917-)

US fashion, advertising, portrait, editorial, and fine art photographer. In 1948 he made the first of many journeys to Africa and the Far East, resulting in a series of portrait photographs of local people, avoiding sophisticated technique. He was associated for many years with *Vogue* magazine in the USA. He has always been dedicated to the optimal presentation of his work and is a master printer of such processes as platinum-palladium and selenium-toned silver gelatin.

Pennsylvanian period

US term for the Upper or Late Carboniferous period of geological time, 323-290 million years ago; it is named after the US state, which contains vast coral deposits.

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pennyroyal

European perennial plant belonging to the mint family, with oblong leaves and clusters or whorls of purplish flowers growing around the stem at intervals. It is found in wet places on sandy soil. (*Mentha pulegium*, family Labiatae.)

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pentadactyl limb

typical limb of the mammals, birds, reptiles, and amphibians. These vertebrates (animals with backbone) are all descended from primitive amphibians whose immediate ancestors were fleshy-finned fish. The limb which evolved in those amphibians had three parts: a 'hand/foot' with five digits (fingers/toes), a lower limb containing two bones, and an upper limb containing one bone.

This basic pattern has persisted in all the terrestrial vertebrates, and those aquatic vertebrates (such as seals) that are descended from them. Natural selection has modified the pattern to fit different ways of life. In flying animals (birds and bats) it is greatly altered and in some vertebrates, such as whales and snakes, the limbs are greatly reduced or lost. Pentadactyl limbs of different species are an example of homologous organs.

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pentagon

five-sided plane figure. A regular pentagon has all five sides of equal length and all five angles of equal size, 108°. It has golden section proportions between its sides and diagonals. The five-pointed star formed by drawing all the diagonals of a regular pentagon is called a **pentagram**. This star has further golden sections.

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pentanol

common name amyl alcohol; $C_5H_{11}OH$

clear, colourless, oily liquid, usually with a characteristic choking odour. It is obtained by the fermentation of starches and from the distillation of petroleum. There are eight possible isomers.

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penumbra

region of partial shade between the totally dark part (umbra) of a shadow and the fully illuminated region outside. It occurs when a source of light is only partially obscured by a shadow-casting object. The darkness of a penumbra varies gradually from total darkness at one edge to full brightness at the other. In astronomy, a penumbra is a region of the Earth from which only a partial eclipse of the Sun can be seen.

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peony

any of a group of perennial plants native to Europe, Asia, and North America, remarkable for their large, round, brilliant white, pink, or red flowers. Most popular in gardens are the common peony (*P. officinalis*), the white peony (*P. lactiflora*), and the taller tree peony (*P. suffruticosa*). (Genus *Paeonia*, family Paeoniaceae.)

Peonies - Glorious in Bloom

Go to site

Image of a peony, as well as a detailed description of the plant. There are also notes on growing peonies, taking account of the acidity of the soil and the amount of sunlight and moisture that they require.

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pepper

climbing plant native to the East Indies. When gathered green, the berries are crushed to release the seeds for the spice called black pepper. When the berries are ripe, the seeds are removed and their outer skin is discarded, to produce white pepper. Chilli pepper, cayenne or red pepper, and the sweet peppers used as a vegetable come from capsicums native to the New World. (*Piper nigrum*, family Piperaceae.)

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peppermint

perennial herb of the mint family, native to Europe, with oval aromatic leaves and purple flowers. Oil of peppermint is used in medicine and confectionery. (*Mentha piperita*, family Labiatae.)

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pepsin

enzyme that breaks down proteins during digestion. It is produced by the walls of the stomach. It requires a strongly acidic environment such as that present in the stomach. It digests large protein molecules into smaller protein molecules (smaller polypeptides) and is therefore a protease - an enzyme that breaks down a protein.

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peptide

molecule comprising two or more amino acid molecules (not necessarily different) joined by **peptide bonds**, whereby the acid group of one acid is linked to the amino group of the other (—CO.NH—). The number of amino acid molecules in the peptide is indicated by referring to it as a di-, tri-, or polypeptide (two, three, or many amino acids).

Proteins are built up of interacting polypeptide chains with various types of bonds occurring between the chains. Incomplete hydrolysis (splitting up) of a protein yields a mixture of peptides, examination of which helps to determine the sequence in which the amino acids occur within the protein.

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percentage

way of representing a number as a fraction of 100. For example, 45 percent (45%) equals 45/100, and 45% of 20 is 45/100 × 20 = 9.

percentage increase/decrease

In general, if a quantity changes from one value to another then

percentage = 100 × (difference in the values)/old value

For example, in a sale the price of a bicycle is reduced from £120 to £90, that is there is a discount of £30. The percentage decrease is 100 × 30/120 = 25%.

fractions as percentages

To express a fraction as a percentage, its denominator must first be converted to 100. For example, value-added tax (VAT) as a fraction is 7/40:

7/40 = 17.5/100 = 17.5%

The use of percentages often makes it easier to compare fractions that do not have a common denominator (a number divisible by both the bottom numbers), for instance when comparing rates of inflation or rates of simple interest.

To convert a fraction to a percentage on a calculator, divide the numerator by the denominator and then multiply by 100. The percentage will correspond to the first two figures of the decimal; for example, 7/12 = 0.5833333 = 58.3% (correct to 1 decimal place), and 7/32 = 0.21875 = 21.9% (correct to 1 decimal place).

The percentage sign is thought to have been derived as an economy measure when recording in old counting houses; writing in the numeric symbol for 25/100 would take two lines of parchment, and hence the '100' denominator was put alongside the 25 and rearranged to '%'.

S-Cool! GCSE Maths Revision Guide

Go to site

Split into four stages, this page deals with two main areas: 'Fractions and decimals' and 'Using percentages'. Stage one lists the key topics for quick revision, and stage two is a guide through them. Stage three contains questions to test stage two, and stage four is a glossary with all the important key terms. This is a colourful and easy-to-use site, which also has further links to other maths topics.

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perch

any of the largest order of spiny-finned bony fishes, the Perciformes, with some 8,000 species. This order includes the sea basses, cichlids, damselfishes, mullets, barracudas, wrasses, and gobies. Perches of the freshwater genus *Perca* are found in Europe, Asia, and North America. They have varied shapes and are usually a greenish colour. They are very prolific, spawning when about three years old, and have voracious appetites.

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perennating organ

in plants, that part of a biennial plant or herbaceous perennial that allows it to survive the winter; usually a root, tuber, rhizome, bulb, or corm.

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perennial plant

plant that lives for more than two years. Herbaceous perennials have aerial stems and leaves that die each autumn. They survive the winter by means of an underground storage organ (perennating organ), such as a bulb or rhizome. Trees and shrubs or woody perennials have stems that persist above ground throughout the year, and may be either deciduous or evergreen. See also annual plant, biennial plant.

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perforation

in medicine, piercing of an organ through mechanical injury or disease.

Ulcers, large tumours, or penetrating injuries may result in the perforation of the abdominal organs. If the intestinal contents enter the abdominal cavity, the large numbers of bacteria that they contain can cause peritonitis and septicaemia (blood poisoning), which can be fatal. Surgery is required to wash away the contamination and repair the perforation. Perforation of major blood vessels results in haemorrhage and requires urgent surgical treatment.

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perfume

fragrant essence used to scent the body, cosmetics, and candles. More than 100 natural aromatic chemicals may be blended from a range of 60,000 flowers, leaves, fruits, seeds, woods, barks, resins, and roots, combined by natural animal fixatives and various synthetics. Favoured ingredients include balsam, civet (from the African civet cat) hyacinth, jasmine, lily of the valley, musk (from the musk deer), orange blossom, rose, and tuberose.

Culture of the cells of fragrant plants, on membranes that are constantly bathed in a solution to carry the essential oils away for separation, is now being adopted to reduce costs.

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perfusion

in biology, the passage of fluid through tissues. For example, oxygen contained in the moist air that enters the lungs perfuses into the blood through the pulmonary tissues.

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perianth

in botany, a collective term for the outer whorls of the flower, which protect the reproductive parts during development. In most dicotyledons the perianth is composed of two distinct whorls, the calyx of sepals and the corolla of petals, whereas in many monocotyledons the sepals and petals are indistinguishable and the segments of the perianth are then known individually as tepals.

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pericarp

wall of a fruit. It encloses the seeds and is derived from the ovary wall. In fruits such as the acorn, the pericarp becomes dry and hard, forming a shell around the seed. In fleshy fruits the pericarp is typically made up of three distinct layers. The **epicarp**, or **exocarp**, forms the tough outer skin of the fruit, while the **mesocarp** is often fleshy and forms the middle layers. The innermost layer or **endocarp**, which surrounds the seeds, may be membranous or thick and hard, as in the drupe (stone) of cherries, plums, and apricots.

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peridot

pale-green, transparent gem variety of the mineral olivine.

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peridotite

rock consisting largely of the mineral olivine; pyroxene and other minerals may also be present. Peridotite is an ultramafic rock containing less than 45% silica by weight. It is believed to be one of the rock types making up the Earth's upper mantle, and is sometimes brought from the depths to the surface by major movements, or as inclusions in lavas.

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perigee

in astronomy, the point at which an object, travelling in an elliptical orbit around the Earth, is at its closest to the Earth. The point at which it is furthest from the Earth is the apogee.

periglacial environment

bordering a glacial area but not actually covered by ice all year round, or having similar climatic and environmental characteristics, such as in mountainous areas. Periglacial areas today include parts of Siberia, Greenland, and North America. The rock and soil in these areas is frozen to a depth of several metres (permafrost) with only the top few centimetres thawing during the brief summer (the active layer). The vegetation is characteristic of tundra.

During the last ice age all of southern England was periglacial. Weathering by freeze-thaw (the alternate freezing and thawing of ice in rock cracks) would have been severe, and solifluction (movement of soil that is saturated by water) would have taken place on a large scale, causing wet topsoil to slip from valley sides.

periglacial

(Image © Garret Nagle)

The characteristic cold and rugged appearance of high mountain areas is produced by freeze-thaw weathering, and the development of snow and ice. Such areas, having the same conditions as those experienced on a glacier, but not frozen all year round, are known as periglacial.

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perihelion

in astronomy, the point at which an object, travelling in an elliptical orbit around the Sun, is at its closest to the Sun. The point at which it is furthest from the Sun is the aphelion.

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perimeter

or boundary

line drawn around the edge of an area or shape. For example, the perimeter of a rectangle is the sum of the lengths of its four sides; the perimeter of a circle is known as its circumference.

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period

another name for menstruation; see menstrual cycle.

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period

in physics, the time taken for one complete cycle of a repeated sequence of events. For example, the time taken for a pendulum to swing from side to side and back again is the period of the pendulum. The period is the reciprocal of the frequency.

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periodic table of the elements

a table in which the elements are arranged in order of their atomic number. There are eight groups of elements, plus a block of transition metals in the centre. Group 1 contains the alkali metals; Group 2 the alkaline-earth metals; Group 7 the halogens; and Group 0 the noble gases (rare gases). A zigzag line through the groups separates the metals on the left-hand side of the table from the non-metals on the right. The horizontal rows in the table are called **periods**. The table summarizes the major properties of the elements and enables predictions to be made about their behaviour.

There are striking similarities in the chemical properties of the elements in each of the groups (vertical columns), which are numbered 1-7 (I-VII) and 0 to reflect the number of electrons in the outermost unfilled shell and hence the maximum valency. Reactivity increases down a group. A gradation (trend) of properties may be traced along the periods. Metallic character increases across a period from right to left, and down a group. A large block of elements, between Groups 2 and 3, contains the transition elements, characterized by displaying more than one valence state.

The Periodic Table

introduction

Think how difficult it would be to assemble a jigsaw of which about 35 of the pieces were missing and roughly 20 of the 65 you had were too damaged to fit properly. Could you work out the shapes of some of the missing pieces? This is exactly what Mendeleyev in 1869 when he produced the first Periodic Table.

earlier attempts

Several 19th century scientists had sought earlier to identify patterns in the properties of chemical elements linked to the weights of the atoms. Dobereiner had noticed sets of three similar elements (triads) for which the average weight of the lightest and heaviest was close to the weight of the middle one (try chlorine 35.5, bromine 80 and iodine 127). British chemist Newlands wrote the elements in order of increasing weight, noting that an element resembled the eight following. His 'Law of Octaves' soon broke down because of missing elements from a fundamentally correct law. He was ridiculed (why not list the elements alphabetically!), flung out of 'The Royal Society', Britain's top scientific institution, only to be reinstated when it was realized that he had nearly beaten Mendeleyev.

who was Mendeleyev?

Dmitri Ivanovitch Mendeleyev was born in Tobolsk (Siberia) in 1834 and brought to St Petersburg, capital of Tzarist Russia, for his secondary education by his ambitious mother who had realized her youngest son's potential. After research throughout Europe he was appointed Chemistry Professor at St Petersburg in 1865. His first marriage foundered because of all the time he spent researching; later he married a young student. After discontent among the university students Mendeleyev took their petition to the education minister who sacked him from his professorial chair. Later both Oxford and Cambridge awarded him honorary doctorates. Aged 53 he made a solo balloon ascent to view a solar eclipse. A Periodic Table was carried aloft in his funeral procession in February 1907.

Mendeleyev's special contribution

Mendeleyev is said to have been playing patience when he suddenly visualized the arrangement of the elements in the patterns of the cards. It is certainly true that 20 years of previous education had equipped him to formulate the 'Periodic Law' which he developed for the remaining 40 years of his life. It stated that the elements display periodic (i.e. regularly repeating) properties when listed in order of increasing atomic weight.

Accurate atomic weights were needed for all 19th century element patterns. Mendeleyev correctly recalculated some values better to fit his table. However iodine and tellurium provided a problem since iodine was chemically similar to bromine yet the heavier element tellurium fitted below bromine according to the weight order. Mendeleyev's solution was to have his research assistants redetermine tellurium's atomic weight to be the smaller. Thus he correctly positioned the two elements but for the wrong reason. Today we know that the elements are listed in order of increasing atomic number which only differs from the atomic weight order in three instances.

A stroke of genius was to leave spaces for elements yet to be discovered and to boldly predict properties for five such elements. Good scientists explain known information, great ones correctly predict unknown facts. Fortunately three of these missing elements were found within 20 years and their properties matched predictions to a remarkable degree.

modern periodic tables

Note the plural. There are many different formats, some are three-dimensional but all show the elements in order of increasing atomic number. Most have vertical columns called groups and horizontal rows called periods. The underlying reason for the arrangement is the electron arrangement of the atoms of the elements. All elements in the same group have the same number of electrons in the outermost shell which governs the chemical nature of an element, hence their chemical similarity. Elements in the same period have the same number of electron shells, an extra electron being added for each increase in the atomic number.

metals and nonmetals

Crossing from left to right elements become more nonmetallic and descending they become more metallic. Thus moving diagonally down to the right, elements are comparable in their metallic/nonmetallic nature. This can be shown by a staircase, or better, as a diagonal line through the boxes of those elements which cannot be clearly classified either as a metal or a nonmetal. For example the use of silicon in computers stems from it being a semi-conductor. Metals are conductors, nonmetals are insulators so semi-conductors are both. Science is not black and white but shades of grey.

using the periodic table

The group number is given in Roman numerals above the main groups. For groups I-IV the group number is the sole valency. For groups V-VII, the main valency is (8-group number) with a less common valency of the group number from the third period onwards. Group 0 (there is no Roman numeral for zero) on the far right is called the noble gases. Their valency is regarded as 0. These elements were once called inert gases but to the astonishment of chemists Bartlett made compounds between fluorine, xenon and krypton.
The Periodic Table is less helpful with transition metals which have a valency of 2 and usually other(s).

One can copy Mendeleyev's work by making predictions about 'unknown' elements. Knowing that both sodium and potassium react with water producing hydrogen and an alkali, it is reasonable to predict the same behaviour for rubidium and caesium directly below them. Since potassium is more reactive than sodium, it is likely that caesium will be the most reactive of the four. It is! When added to a bowl of water it shatters the container! Incidentally caesium is one of three elements which have different spelling in North America and the UK. Which are the others?

are there more elements to discover?

By 1950 all the elements for which Mendeleyev had left gaps had been discovered. Some are extremely rare and were identified from the radioactive decay of other elements, sometimes in the debris of atomic bomb tests (1944-1950). However elements with atomic numbers above 92 have been created by bombarding atoms of uranium with neutrons, carbon nuclei, and other subatomic particles. These synthetic elements are all identified from their radioactivity. As the atomic number increases it becomes harder to make the elements, so less of the element exists... and it is decaying all the time. It is possible to identify 10-18 g but there is less than 1 g of the elements with atomic number greater than 100.

The discoverer of an element has the right to name it. Some chose their country (gallium, francium), or a property (chromium has compounds in many colours), or the place of discovery (such as strontium, named after the Scottish village of Strontian). Only three places in the world have the facilities to make the synthetic elements. Both the USSR and the USA claimed initial discovery of elements 104 and 105 but each country gave them different names (for example 104 to the Russians was Kurschatovium (Ku) but to the Americans was Rutherfordium (Rf). This scientific argument was initially solved by giving them artificial temporary names, unnilquadium (a hundredandfourium), and unnilpentium. A committee sat for years to decide officially who were the discoverers.

symbols and names

Element symbols are internationally agreed but the name differs with the language. This difference is only slight with elements discovered since 1850. Less reactive metals, isolated for hundreds of years may have very different names. Petrol is unleaded in the UK, bleifrei in Germany, sans plomb in France, senza piomba in Italy, sin plomo in Spain. Note how the last three names relate to the Latin plumbum from which the symbol Pb is derived, as are plumber and plumbline.

unusual formats

Hundreds of versions exist of the Periodic Table. For example: some show the physical state (solid, liquid or gas) of the element; in the UK only, the metal mercury and the nonmetal bromine are liquids; three-dimensional varieties divide up the Periodic Table into its four blocks labelled s, p, d and f according to the shape of the outer electron cloud round the nucleus.

The Periodic Table today is the most recognizable logo of chemistry. Despite the range of formats they are all related to Mendeleyev's original formulation. Element 101 is named after him but strangely he never won a Nobel prize.

periodic table: first three periods

To remember the elements in their correct order in the first three periods of the table (hydrogen being omitted and potassium included):

Here **li**es **Be**njamin **B**old **c**ry **n**ot **o**ld **f**riend **ne**edlessly **Na**ture **m**a**g**nifies **al**l **si**mple **p**eople **s**ometimes, **cl**ots **a**nd **k**ings

Helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminium, silicon, phosphorus, sulphur, chlorine, argon, potassium (**H, He, Li, Be, B, C, N, O, F, Ne, Na, Mg, Al, Si, P, S, Cl, Ar, K**)

periodic table: third period

To remember the third period elements:

Nagging **M**a**g**gie **al**ways **sips** **cla**ret

Na, Mg, Al, Si, P, S, Cl, Ar

pi

To remember the digits of pi, in these rhymes the number of letters in each word is equal to the corresponding digit of pi (pi - 3.14159265358979323846264338327 95...)

May I have a large container of coffee? or See I have a rhyme assisting, my feeble brain, its tasks oft-times resisting or I wish I could determine pi
Eureka! cried the great inventor
Christmas pudding, Christmas pie
Is the problem's very centre
(this one assumes you can remember the first digit) or Sir, I send a rhyme excelling
In sacred truth and rigid spelling
Numerical sprites elucidate
for me the lexicon's full weight.
If nature gain, who can complain
tho' Dr Johnson fulminate
or How I want a drink, alcoholic of course, after the heavy chapters involving quantum mechanics. One is, yes, adequate even enough to produce some fun and pleasure for an instant, miserably brief

Chemical Elements - Noble Gases

Go to site

All six noble gases are explained in detail. Each page contains basic information on the particular gas, such as atomic number and symbol, and explains the facts behind its discovery, as well as providing related links.

Modelling the Periodic Table: An Interactive Simulation

Go to site

Free software to assist students in studying elements and creating their own model of the periodic table of elements. You can create the simulation online (Shockwave plug-in required) or download it.

Periodic Table

Go to site

Virtual periodic table. Each element can be clicked on, which brings up a separate page that includes common reactions, common forms, and properties of the element.

Web Elements

Go to site

Periodic table on the Web, with 12 different categories of information available for each element – from its physical and chemical characteristics to its electronic configuration.

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periodontal disease

formerly pyorrhoea

disease of the gums and bone supporting the teeth, caused by the accumulation of plaque and micro-organisms; the gums recede, and the teeth eventually become loose and may drop out unless treatment is sought. Bacteria can eventually erode the bone that supports the teeth, so that surgery becomes necessary.

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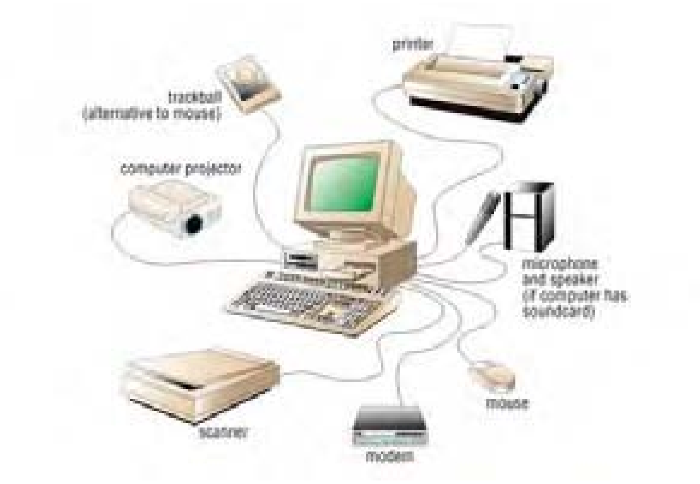
peripheral device

in computing, any item connected to a computer's central processing unit (CPU). Typical peripherals include keyboard, mouse, monitor, and printer. Users who enjoy playing games might add a joystick or a trackball; others might connect a modem, scanner, or integrated services digital network (ISDN) terminal to their machines.

peripheral device



(Image © Research Machines plc)

Some of the types of peripheral device that may be connected to a computer include printers, scanners, and modems.

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periscope

optical instrument designed for observation from a concealed position such as from a submerged submarine. In its basic form it consists of a tube with parallel mirrors at each end, inclined at 45° to its axis. The periscope attained prominence in naval and military operations of World War I.

Although most often thought of as a submarine observation device, periscopes were widely used in the trenches during World War I to allow observation without exposing the observer, and special versions were also developed to be attached to rifles.

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peristalsis

wavelike contractions, produced by the contraction of smooth muscle, that pass along tubular organs, such as the intestines. The same term describes the wavelike motion of earthworms and other invertebrates, in which part of the body contracts as another part elongates.

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peritoneum

membrane lining the abdominal cavity and digestive organs of vertebrates.
Peritonitis, inflammation within the peritoneum, can occur due to infection or other irritation. It is sometimes seen following a burst appendix and quickly proves fatal if not treated.

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periwinkle

in botany, any of several trailing blue-flowered evergreen plants of the dogbane family, native to Europe and Asia. They range in length from 20 cm/8 in to 1 m/3 ft. (Genus *Vinca*, family Apocynaceae.)

The related Madagascar periwinkle (*Catharanthus roseus*) produces chemicals that prevent the division of cells and are used to treat leukaemia.

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periwinkle

in zoology, any marine snail of the family Littorinidae, found on the shores of Europe and eastern North America. Periwinkles have a conical spiral shell, and feed on algae.

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permafrost

condition in which a deep layer of soil does not thaw out during the summer. Permafrost occurs under periglacial conditions. It is claimed that 26% of the world's land surface is permafrost.

Permafrost gives rise to a poorly drained form of grassland typical of northern Canada, Siberia, and Alaska known as tundra.

Permian

period of geological time 290–245 million years ago, the last period of the Palaeozoic era. Its end was marked by a dramatic change in marine life – the greatest mass extinction in geological history – including the extinction of many corals and trilobites. Deserts were widespread, terrestrial amphibians and mammal-like reptiles flourished, and cone-bearing plants (gymnosperms) came to prominence. In the oceans, 49% of families and 72% of genera vanished in the late Permian. On land, 78% of reptile families and 67% of amphibian families disappeared.

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permutation

in mathematics, a specified arrangement of a group of objects.

It is the arrangement of *a* distinct objects taken *b* at a time in all possible orders. It is given by $a!/(a-b)!$, where '!' stands for factorial. For example, the number of permutations of four letters taken from any group of six different letters is $6!/2! = (1 \times 2 \times 3 \times 4 \times 5 \times 6)/(1 \times 2) = 360$. The theoretical number of four-letter 'words' that can be made from an alphabet of 26 letters is $26!/22! = 358,800$.

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perovskite

yellow, brown, or greyish-black orthorhombic mineral, $CaTiO_3$, which sometimes contains cerium.
Other minerals that have a similar structure are said to have the **perovskite structure**. The term also refers to $MgSiO_3$ with the perovskite structure, the principal mineral that makes up the Earth's lower mantle.

$CaTiO_3$ perovskite occurs primarily as a minor constituent of some igneous rocks in the Earth's crust and mantle and in some meteorites. $MgSiO_3$ perovskite has the same chemical composition as pyroxene, a principal constituent of the upper mantle. But the extreme pressures in the lower mantle cause the oxygen atoms to be packed more tightly together than in pyroxene, giving rise to the perovskite form of $MgSiO_3$ in the lower mantle.

The perovskite structure of $MgSiO_3$ was discovered in diamond-anvil cell experiments in which upper mantle materials that are stable at the Earth's surface, such as the mineral pyroxene, are squeezed at high pressures to simulate the Earth's interior. Although this mineral does not occur naturally at the Earth's surface it is thought to be the most abundant mineral in the mantle, and therefore Earth's most abundant mineral.

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perpendicular

at a right angle; also, a line at right angles to another line or to a plane. Everyday examples include lamp posts, which are perpendicular to the road, and walls, which are perpendicular to the ground.

For a pair of skew lines (lines in three dimensions that do not meet), there is just one common perpendicular, which is at right angles to both lines; the nearest points on the two lines are the feet of this perpendicular.

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perpetual motion

idea that a machine can be designed and constructed in such a way that, once started, it will do work indefinitely without requiring any further input of energy (motive power). Such a device would contradict at least one of the two laws of thermodynamics that state that (1) energy can neither be created nor destroyed (the law of conservation of energy) and (2) heat cannot by itself flow from a cooler to a hotter object. As a result, all practical (real) machines require a continuous supply of energy, and no heat engine is able to convert all the heat into useful work.

Perseus

a bright constellation of the northern hemisphere, near Cassiopeia. It is represented as the mythological hero; the head of the decapitated Gorgon, Medusa, is marked by Algol (Beta Persei), the best known of the eclipsing binary stars. During the second half of July and the first half of August the **Perseid meteor shower** radiates from its northern part.

Perseus lies in the Milky Way and contains the Double Cluster, a twin cluster of stars called h and Chi Persei. They are just visible to the naked eye as two hazy patches of light close to one another.

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persicaria

any of a group of plants belonging to the dock family, found growing in waste places and arable land, often near water. Common persicaria (*P. persicaria*) is sprawling in shape and has lance-shaped, black-spotted leaves and spikes of pink flowers. Pale persicaria (*P. lapathifolium*) is slightly larger, with pale dots on the leaves, and heads of usually white flowers. Both are found throughout much of the northern hemisphere. (Genus *Polygonum*, family Polygonaceae.)

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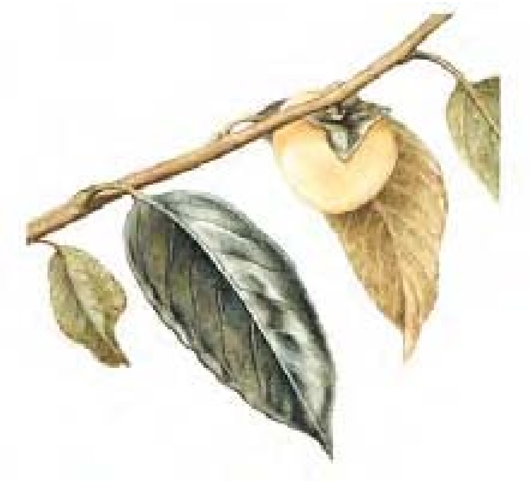
persimmon

any of a group of tropical trees belonging to the ebony family, especially the common persimmon (*D. virginiana*) of the southeastern USA. Growing up to 19 m/60 ft high, the persimmon has alternate oval leaves and yellow-green flowers. The small, sweet, orange fruits are edible. (Genus *Diospyros*, family Ebenaceae.)

The Japanese persimmon (*D. kaki*) has larger fruits and is widely cultivated.

persimmon



(Image © Research Machines plc)

Persimmon is the name given to the usually edible fruits of some species of the genus *Diospyros*. This genus includes various shrubs and trees native to the tropics and subtropical areas of the world. Persimmons are cultivated widely in Japan and China as ornamentals and for their fruits, some of which also produce a useful dye.

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personal computer

PC

another name for microcomputer. The term is also used, more specifically, to mean the IBM Personal Computer and computers compatible with it.

The first IBM PC was introduced in the USA in 1981; it had 64 kilobytes of random access memory (RAM) and one floppy-disk drive. It was followed in 1983 by the XT (with a hard-disk drive) and in 1984 by the AT (based on a more powerful microprocessor). Many manufacturers have copied the basic design, which is now regarded as a standard for business microcomputers.

PC Show and Tell

Go to site

Free, simple instruction on using a wide range of computer hardware and software, including Microsoft Outlook Express and Palm handheld computers. Requires registration and download of viewing software in order to watch tutorials about the products. Tutorials cover over 100 software products and can be personalized to your skill level and the products you use.

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personality

individual's characteristic way of behaving across a wide range of situations. Two broad dimensions of personality are extroversion and neuroticism. A number of more specific personal traits have also been described, including psychopathy (antisocial behaviour).

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perspective

realistic representation of a three-dimensional object in two dimensions.
One-point linear perspective is an effective way to give a picture depth and a sense of distance and space. It is based on three key principles: that the horizon line is always at eye-level; that the vanishing point is the point to which all lines parallel to the viewer recede; and that convergence lines meet at the vanishing point (all diagonal lines recede to the vanishing point). All horizontal and vertical lines remain parallel to one another to avoid objects becoming distorted.
Two-point linear perspective follows the same principles, but uses two sets of converging lines and no horizontal lines; as a result there are two vanishing points.

In perspective the horizon line refers to the line where the sky and earth seem to meet; it is on this line that the vanishing point is located. Converging lines refer to the lines that appear to be parallel (as they actually are in reality), but if carried through on the picture plane would converge or meet at the vanishing point. These converging lines are the diagonal lines that give the work a sense of depth. Whatever falls above the horizon line will be seen from underneath by the viewer, while what falls below the horizon line will be seen from above by the viewer. If an object falls directly in front of the vanishing point, only the front will be visible – the viewer will be unable to see the sides, top, or underneath of the object. When using perspective all horizontal and vertical lines remain parallel to one another to avoid distortion of objects. *The Last Supper* (1495–98) by Leonardo da Vinci is an excellent example of one-point perspective.

Use of Visual Information in Art

Go to site

Online tutorial in the way various aspects of human perception are used by artists to create more realistic images. The tutorial contains examples from many famous artists and includes sections on shadow, interposition, relative size, and aerial perspective.

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perspiration

excretion of water and dissolved substances from the sweat glands of the skin of mammals. Perspiration has two main functions: body cooling by the evaporation of water from the skin surface, and excretion of waste products such as salts.

In 2001, German researchers discovered an antibiotic protein, dermcidin, that is exuded in sweat. Dermcidin was found to be effective against four common species of bacteria when tested.

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pertussis

medical name for whooping cough, an infectious disease mainly seen in children.

Childhood Infections - Pertussis (Whooping Cough)

Go to site

Useful information about whooping cough. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection, how it can be treated both at home and professionally, and what to do should the symptoms occur.

Peru Current

formerly Humboldt Current

cold ocean current flowing north from the Antarctic along the west coast of South America to southern Ecuador, then west. It reduces the coastal temperature, making the western slopes of the Andes arid because winds are already chilled and dry when they meet the coast.

Perutz, Max Ferdinand (1914-2002)

Austrian-born British biochemist who shared the Nobel Prize for Chemistry in 1962 with his co-worker John Kendrew for work on the structure of the haemoglobin molecule.

Perutz

(Image © Research Machines plc)

Max Perutz, lecturing at the Laboratory of Molecular Biology, Cambridge, *c.* 1985. He was chair of the laboratory from 1962, the year he shared the Nobel Prize for Chemistry for his work on the structure of the haemoglobin molecule.

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pessary

medical device designed to be inserted into the vagina either to support a displaced womb or as a contraceptive. The word is also used for a vaginal suppository used for administering drugs locally, made from glycerol or oil of theobromine, which melts within the vagina to release the contained substance - for example, a contraceptive, antibiotic, antifungal agent, or prostaglandin (to induce labour).

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pest

in biology, any insect, fungus, rodent, or other living organism that has a harmful effect on human beings, other than those that directly cause human diseases. Most pests damage crops or livestock, but the term also covers those that damage buildings, destroy food stores, and spread disease.

---

pesticide

any chemical used in farming, gardening, or in the home, to combat pests. Pesticides are of three main types: **insecticides** (to kill insects), **fungicides** (to kill fungal diseases), and **herbicides** (to kill plants, mainly those considered weeds). Pesticides cause a number of pollution problems through spray drift onto surrounding areas, direct contamination of users or the public, and as residues on food. The World Health Organization (WHO) estimates that thousands of people die annually worldwide from pesticide poisoning.

The safest pesticides include those made from plants, such as the insecticides pyrethrum and derris. Pyrethrins are safe and insects do not develop resistance to them. Their impact on the environment is very small as the ingredients break down harmlessly.

More potent are synthetic products, such as chlorinated hydrocarbons. These products, including DDT and dieldrin, are highly toxic to wildlife and often to humans, and their use is now restricted by law in some areas and is declining. Safer pesticides such as malathion are based on organic phosphorus compounds, but they still present hazards to health. An international treaty to ban persistent organic pollutants (POPs), including pesticides such as DDT, was signed in Stockholm, Sweden, in May 2001. The United Nations Food and Agriculture Organization reported in the same month that more than 500,000 tonnes of pesticide waste resides in dumps worldwide.

Molecular Expressions: The Pesticide Collection

Go to site

Fascinating collection of images showing what pesticides look like when recrystallized and photographed through a microscope. There is also an informative article about pesticides.

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petal

part of a flower whose function is to attract pollinators such as insects or birds. Petals are frequently large and brightly coloured and may also be scented. Some have a nectary at the base and markings on the petal surface, known as honey guides, to direct pollinators to the source of the nectar. In wind-pollinated plants, however, the petals are usually small and insignificant, and sometimes absent altogether. Petals are derived from modified leaves, and are known collectively as a corolla.

Some insect-pollinated plants also have inconspicuous petals, with large colourful bracts (leaflike structures) or sepals taking over their role, or strong scents that attract pollinators such as flies.

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petiole

in botany, the stalk attaching the leaf blade, or lamina, to the stem. Typically it is continuous with the midrib of the leaf and attached to the base of the lamina, but occasionally it is attached to the lower surface of the lamina, as in the nasturtium (a peltate leaf). Petioles that are flattened and leaflike are termed phyllodes. Leaves that lack a petiole are said to be sessile.

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petit Brabançon

smooth-haired form of the griffon Bruxelloise.

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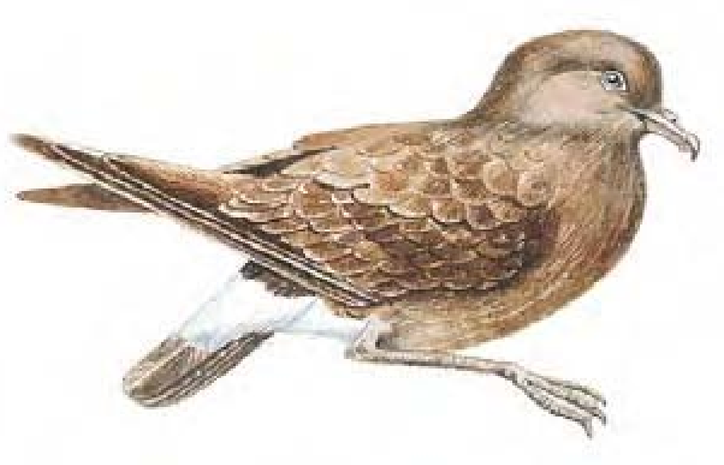
petrel

any of various families of seabirds in the order Procellariiforme, including the worldwide **storm petrels** (family Hydrobatidae), which include the smallest seabirds (some only 13 cm/5 in long), and the **diving petrels** (family Pelecanoididae) of the southern hemisphere. All have a hooked bill, rudimentary hind toes, tubular nostrils, and feed by diving underwater. They include fulmars and shearwaters.

Like other ground-nesting or burrow-nesting seabirds, petrels are vulnerable to predators such as rats that take eggs and nestlings. Several island species are in danger of extinction, including the **Bermuda petrel** *Pterodroma cahow* and the **Freira petrel** of Madeira *P. madeira*.

It is feared that 26 species are facing extinction, owing to habitat degradation, disturbance of breeding sites, and especially longline fishing, which kills up to 1,000 seabirds daily.

petrel



(Image © Research Machines plc)

Like all petrels, the Madeiran fork-tailed petrel has globular salt glands close to the eyes. About 100 species of petrels are known, most of which range over the cold southern seas. They are highly social birds, nesting in large colonies and feeding together in large, floating 'rafts'.

petrochemical

chemical derived from the processing of petroleum (crude oil).

Petrochemical industries are those that obtain their raw materials from the processing of petroleum and natural gas. Polymers, detergents, solvents, and nitrogen fertilizers are all major products of the petrochemical industries. Inorganic chemical products include carbon black, sulphur, ammonia, and hydrogen peroxide.

petrol

mixture of hydrocarbons derived from petroleum, mainly used as a fuel for internal-combustion engines. It is colourless and highly volatile.
Leaded petrol contains antiknock (a mixture of tetra ethyl lead and dibromoethane), which improves the combustion of petrol and the performance of a car engine. The lead from the exhaust fumes enters the atmosphere, mostly as simple lead compounds. There is strong evidence that it can act as a nerve poison on young children and cause mental impairment. This prompted a gradual switch to the use of **unleaded petrol** in the UK.

The changeover from leaded petrol gained momentum from 1989 owing to a change in the tax on petrol, making it cheaper to buy unleaded fuel. Unleaded petrol contains a different mixture of hydrocarbons from leaded petrol. Leaded petrol cannot be used in cars fitted with a catalytic converter.

In the USA, petrol is called gasoline, and unleaded petrol has been used for many years.

petroleum

or crude oil

natural mineral oil, a thick greenish-brown flammable liquid found underground in permeable rocks. Petroleum consists of hydrocarbons mixed with oxygen, sulphur, nitrogen, and other elements in varying proportions. It is thought to be derived from ancient organic material that has been converted by, first, bacterial action, then heat, and pressure (but its origin may be chemical also).

From crude petroleum, various products are made by fractional distillation and other processes; for example, fuel oil, petrol, kerosene, diesel, and lubricating oil. Petroleum products and chemicals are used in large quantities in the manufacture of detergents, artificial fibres, plastics, insecticides, fertilizers, pharmaceuticals, toiletries, and synthetic rubber.

Petroleum was formed from the remains of marine plant and animal life which existed many millions of years ago (hence it is known as a fossil fuel). Some of these remains were deposited along with rock-forming sediments under the sea where they were decomposed anaerobically (without oxygen) by bacteria which changed the fats in the sediments into fatty acids which were then changed into an asphaltic material called kerogen. This was then converted over millions of years into petroleum by the combined action of heat and pressure. At an early stage the organic material was squeezed out of its original sedimentary mud into adjacent sandstones. Small globules of oil collected together in the pores of the rock and eventually migrated upwards through layers of porous rock by the action of the oil's own surface tension (capillary action), by the force of water movement within the rock, and by gas pressure. This migration ended either when the petroleum emerged through a fissure as a seepage of gas or oil onto the Earth's surface, or when it was trapped in porous reservoir rocks, such as sandstone or limestone, in anticlines and other traps below impervious rock layers.

The modern oil industry originates in the discovery of oil in western Ontario in 1857 followed by Edwin Drake's discovery in Pennsylvania in 1859. Drake used a steam engine to drive a punching tool to 21 m/68 ft below the surface where he struck oil and started an oil boom. Rapid development followed in other parts of the USA, Canada, Mexico, and then Venezuela where commercial production began in 1878. Oil was found in Romania in 1860, Iran in 1908, Iraq in 1923, Bahrain in 1932, and Saudi Arabia and Kuwait in 1938.

The USA led in production until the 1960s, when the Middle East outproduced other areas, their immense reserves leading to a worldwide dependence on cheap oil for transport and industry. In 1961 the Organization of the Petroleum Exporting Countries (OPEC) was established to avoid exploitation of member countries; after OPEC's price rises in 1973, the International Energy Agency (IEA) was established in 1974 to protect the interests of oil-consuming countries. New technologies were introduced to pump oil from offshore and from the Arctic (the Alaska pipeline) in an effort to avoid a monopoly by OPEC. Global consumption of petroleum in 1993 was 23 billion barrels.

As shallow-water oil reserves dwindle, multinational companies have been developing deep-water oilfields at the edge of the continental shelf in the Gulf of Mexico. Shell has developed Mars, a 500-million-barrel oilfield, in 900 m/2,940 ft of water, and the oil companies now have the technology to drill wells of up to 3,075 m/10,000 ft under the sea. It is estimated that the deep waters of Mexico could yield 8-15 million barrels in total; it could overtake the North Sea in importance as an oil source.

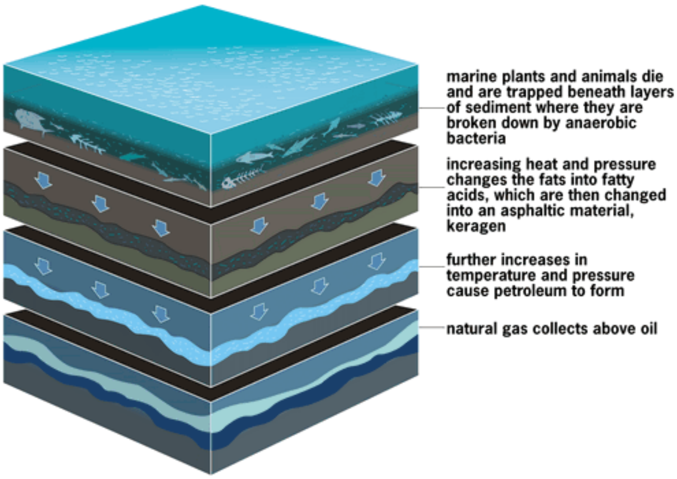
In Asia, the oil pipeline from Azerbaijan through Russia to the West, which is the only major pipeline from the Caspian Sea, closed during Russia's conflict with Chechnya but reopened in 1997.

pollution

The burning of petroleum fuel is one cause of air pollution. The transport of oil can lead to catastrophes – for example, the *Torrey Canyon* tanker lost off southwestern England in 1967, which led to an agreement by the international oil companies in 1968 to pay compensation for massive shore pollution. The 1989 oil spill in Alaska from the *Exxon Valdez* damaged the area's fragile environment, despite clean-up efforts. Drilling for oil involves the risks of accidental spillage and drilling-rig accidents. The problems associated with oil have led to the various alternative energy technologies.

A new kind of bacterium was developed during the 1970s in the USA, capable of 'eating' oil as a means of countering oil spills.

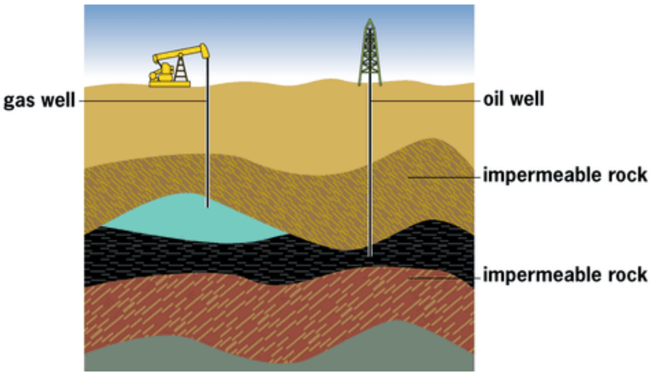
petroleum


marine plants and animals die and are trapped beneath layers of sediment where they are broken down by anaerobic bacteria
increasing heat and pressure changes the fats into fatty acids, which are then changed into an asphaltic material, keragen
further increases in temperature and pressure cause petroleum to form
natural gas collects above oil

(Image © Research Machines plc)

The formation of oil and natural gas. Oil forms when marine plants and animals die and accumulate in stagnant water lacking in oxygen. They are quickly buried by clay and so do not completely decay but form hydrocarbon-rich muds, broken down by anaerobic bacteria. Increasing heat and pressure transform the hydrocarbons into fatty acids, which are then changed into an asphaltic material, keragen. Further increases in temperature and pressure cause oil to form and natural gas collects above the oil.

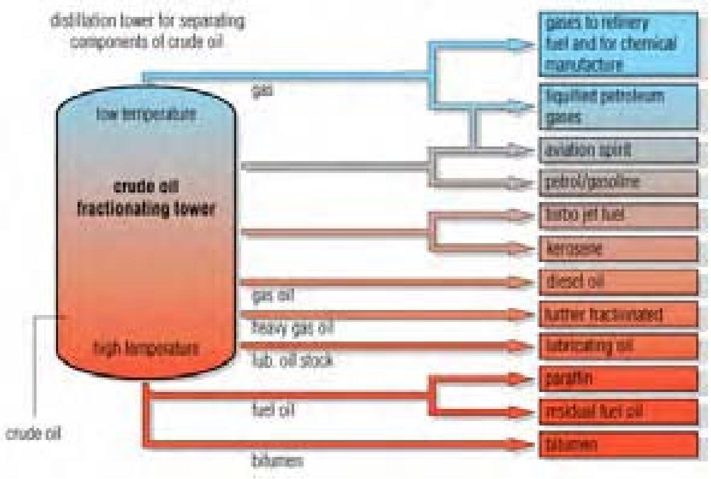
petroleum


gas well
oil well
impermeable rock
impermeable rock

(Image © Research Machines plc)

Deposits of oil and gas are found close together because gas is given off during the formation of oil.

petroleum


distillation tower for separating components of crude oil
gases to refinery fuel and for chemical manufacture
gas
liquified petroleum gases
low temperature
aviation spirit
petrol/gasoline
crude oil fractionating tower
turbo jet fuel
kerosene
diesel oil
gas oil
further fractionated
heavy gas oil
lubricating oil
high temperature
lub. oil stock
paraffin
fuel oil
residual fuel oil
crude oil
bitumen
bitumen

(Image © Research Machines plc)

Refining petroleum using a distillation column. The crude petroleum is fed in at the bottom of the column where the temperature is high. The gases produced rise up the column, cooling as they travel. At different heights up the column, different gases condense to liquids called fractions, and are drawn off.

---

petrology

branch of geology that deals with the study of rocks, their mineral compositions, their textures, and their origins.

Peugeot

France's second-largest car manufacturer, founded in 1885 when Armand Peugeot (1849-1915) began making bicycles; the company bought the rival firm Citroën in 1974 and the European operations of the American Chrysler Company in 1978.

In 1889 Armand Peugeot produced his first steam car and in 1890 his first petrol-driven car, with a Daimler engine. Peugeot's cars did well in races and were in demand from the public, and by 1900 he was producing a range of models. In the 1930s Peugeot sporting family cars sold widely. In 1978, after the acquisition of Chrysler in Europe, the Talbot marque was reintroduced.

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pewter

any of various alloys of mostly tin with varying amounts of lead, copper, or antimony. Pewter has been known for centuries and was once widely used for domestic utensils but is now used mainly for ornamental ware.

---

peyote

spineless cactus of northern Mexico and the southwestern USA. It has white or pink flowers. Its buttonlike tops contain **mescaline**, which causes hallucinations and is used by American Indians in religious ceremonies. (*Lophopora williamsii*, family Cactaceae.)

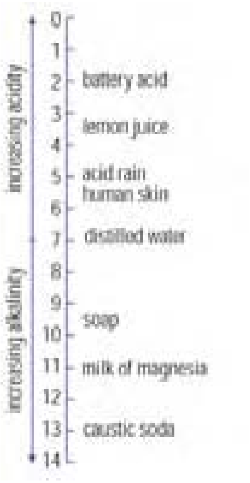
---

pH

scale from 0 to 14 for measuring acidity or alkalinity. A pH of 7 indicates neutrality, below 7 is acid, while above 7 is alkaline. Strong acids, such as those used in car batteries, have a pH of about 2; strong alkalis such as sodium hydroxide have a pH of about 13.

Acidic fruits such as citrus fruits are about pH 4. Fertile soils have a pH of about 6.5 to 7, while weak alkalis such as soap have a pH of about 9 to 10.

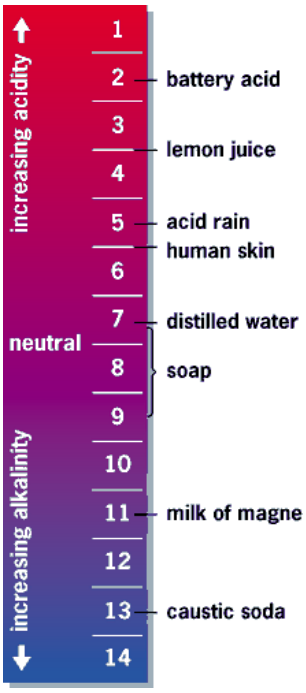
pH


increasing acidity
increasing alkalinity
0
1
2
battery acid
3
lemon juice
4
5
acid rain
human skin
6
7
distilled water
8
9
soap
10
11
milk of magnesia
12
13
caustic soda
14

(Image © Research Machines plc)

The pHs of some common substances. The lower the pH, the more acidic the substance; the higher the pH, the more alkaline the substance. A pH of 7 is neutral.

pH


increasing acidity
neutral
increasing alkalinity
1
2
battery acid
3
lemon juice
4
5
acid rain
human skin
6
7
distilled water
8
soap
9
10
11
milk of magne
12
13
caustic soda
14

(Image © Research Machines plc)

The pH levels of some common substances. The lower the pH, the more acidic the substance; the higher the pH, the more alkaline the substance.

Acidity or alkalinity of some common substances

The pH scale is used to measure the acidity or alkalinity of a substance. It runs from 0 to 14: a pH of 7 is neutral, a pH below 7 is acid, and a pH above 7 is alkaline.

Substance	pH
hydrochloric acid	0
digestive juices	0.9
accumulator acid	1.0
ant venom	2.0
lemon juice	2.3
apple juice	3.0
malt vinegar	3.5
soda water	4.0
rainwater	5.6
milk	6.6
pure water	7.0
blood	7.4

seawater	7.5
bicarbonate of soda	8.5
toothpaste	9.8
washing soda	11.5
ammonia solution	12.0
caustic soda	14.0

Acid and Base pH Tutorial

Go to site

Aimed at university students with no knowledge of this branch of chemistry, this well-designed tutorial takes you through the basics of acid-base chemistry, including interactive exercises to test your knowledge.

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phage

another name for a bacteriophage, a virus that attacks bacteria.

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phagocyte

type of leukocyte, or white blood cell, that can engulf a bacterium or other invading micro-organism. Phagocytes are found in blood, lymph, and other body tissues, where they also ingest foreign matter and dead tissue. A macrophage differs in size and lifespan.

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phalarope

any of a genus *Phalaropus* of small, elegant shorebirds in the sandpiper family (Scolopacidae). They have the habit of spinning in the water to stir up insect larvae. They are native to North America, the UK, and the polar regions of Europe.

The male phalarope is courted by the female and hatches the eggs. The female is always larger and more colourful.

---

phanerogam

obsolete term for a plant that bears flowers or cones and reproduces by means of seeds, that is an angiosperm and gymnosperm, or a seed plant. Plants such as mosses, fungi, and ferns were known as **cryptogams**.

Phanerozoic eon

(Greek phanero 'visible')

eon in Earth history, consisting of the most recent 570 million years. It comprises the Palaeozoic, Mesozoic, and Cenozoic eras. The vast majority of fossils come from this eon, owing to the evolution of hard shells and internal skeletons. The name means 'interval of well-displayed life'.

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pharmacology

study of the properties of drugs and their effects on the human body.

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pharyngitis

in medicine, an inflammatory condition that affects the wall of the pharynx and the throat. It is usually due to a viral infection. Symptoms include irritation and discomfort of the throat, which may be relieved by throat pastilles and gargles. Infections due to bacteria can be treated by antibiotics.

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pharynx

muscular cavity behind the nose and mouth, extending downwards from the base of the skull. Its walls are made of muscle strengthened with a fibrous layer and lined with mucous membrane. The internal nostrils lead backwards into the pharynx, which continues downwards into the oesophagus and (through the epiglottis) into the windpipe. On each side, a Eustachian tube enters the pharynx from the middle ear cavity.

The upper part (nasopharynx) is an airway, but the remainder is a passage for food. Inflammation of the pharynx is named pharyngitis.

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phase

in astronomy, apparent shape of the Moon or a planet when all or part of its illuminated hemisphere is facing the Earth.

As the Moon orbits the Earth its appearance from Earth changes as different amounts of its surface are illuminated by the Sun. During one orbit of the Earth (29.5 days – a lunar month) the Moon undergoes a full cycle of phases from new, to first quarter, to full, to last quarter.

The Moon does not reflect sunlight onto the Earth when it is between the Earth and the Sun, and the Moon is not seen. This is the new Moon phase. As the Moon orbits the Earth, part of the Moon reflects sunlight onto the Earth and a crescent is seen, starting from the right-hand side of the Moon. This is the waxing crescent phase. The half Moon phase occurs when half of the Moon's disc is illuminated as seen from Earth. As the Moon continues its orbit, gradually more of the Moon's surface becomes illuminated. At the waxing gibbous phase, three-quarters of the Moon's disc is visible. The full Moon phase occurs when the Earth is between the Moon and the Sun, and the Moon's disc is fully illuminated.

After the full Moon, gradually less of the Moon's surface is illuminated as it continues its orbit. It passes through the waning gibbous phase where three-quarters of its disc is visible, to the third quarter where half is seen, followed by the waning crescent, and finally the new Moon phase again.

Virtual Reality Moon Phase Pictures

Go to site

Image display of the current phase of the Moon, updated every four hours. You can also find the Moon phase for any date and time between AD 1800 and AD 2199.

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phase

in physics, a stage in an oscillatory motion, such as a wave motion: two waves are in phase when their peaks and their troughs coincide. Otherwise, there is a **phase difference**, which has consequences in interference phenomena and alternating current electricity.

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pheasant

any of various large, colourful Asiatic fowls of the family Phasianidae, order Galliformes, which also includes grouse, quail, and turkey. The typical pheasants are in the genus *Phasianus*, which has two species: the Japanese pheasant, *P. versicolor*, found in Japan, and the Eurasian ring-necked or common pheasant, *P. colchicus*, also introduced to North America. The genus is distinguished by the very long wedge-shaped tail and the absence of a crest. The plumage of the male common pheasant is richly tinted with brownish-green, yellow, and red markings, but the female is a camouflaged brownish colour. The nest is made on the ground. The male is polygamous.

Among the more exotically beautiful pheasants of other genera, often kept as ornamental birds, are the **golden pheasant** *Chrysolophus pictus* and **Lady Amherst's pheasant** *Chrysolophus amherstiae*, both from China, and the **argus pheasant** *Argusianus argus* of Malaysia, which has metallic spots or 'eyes' on the wings.

Reeves's pheasant *Symaticus reevesii*, a native of China, is over 2 m/6.6 ft in length, and has yellow and brown spangled plumage.

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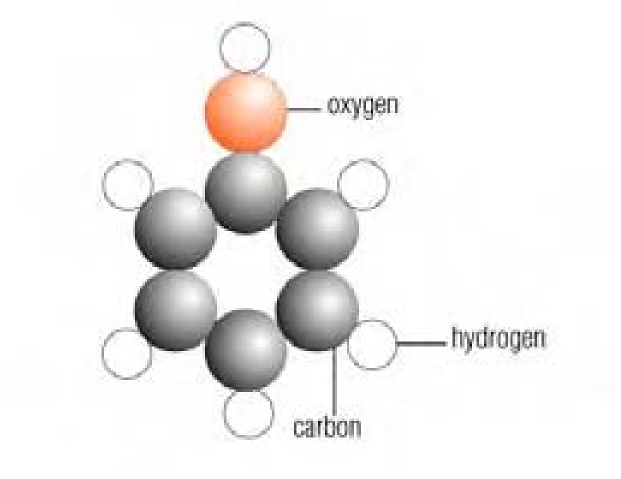
phenol

member of a group of aromatic chemical compounds with weakly acidic properties, which are characterized by a hydroxyl (OH) group attached directly to an aromatic ring. The simplest of the phenols, derived from benzene, is also known as phenol and has the formula C_6H_5OH. It is sometimes called **carbolic acid** and can be extracted from coal tar.

Pure phenol has a melting point of 41°C/105°F and consists of colourless, needle-shaped crystals, which take up moisture from the atmosphere and dissolve. It has a strong and characteristic smell and was once used as an antiseptic. It is, however, toxic by absorption through the skin.

phenol



(Image © Research Machines plc)

The phenol molecule with its ring of six carbon atoms and a hydroxyl (OH) group attached. Phenol was first extracted from coal tar in 1834. It is used to make phenolic and epoxy resins, explosives, pharmaceuticals, perfumes, and nylon.

phenotype

in genetics, visible traits, those actually displayed by an organism. The phenotype is not a direct reflection of the genotype because some alleles are masked by the presence of other, dominant alleles (see dominance). The phenotype is further modified by the effects of the environment (for example, poor nutrition stunts growth).

phenylanaline

one of the nine essential amino acids. Phenylketonuria is a rare genetic disease which results from the inability to metabolize the phenylalanine present in food.

phenylketonuria

inherited metabolic condition in which the liver of a child cannot control the level of phenylalanine (an amino acid derived from protein food) in the bloodstream. The condition must be detected promptly and a special diet started in the first few weeks of life if brain damage is to be avoided. Untreated, it causes stunted growth, epilepsy, and severe mental disability.

pheromone

chemical signal (such as an odour) that is emitted by one animal and affects the behaviour of others. Pheromones are used by many animal species to attract mates.

Science of Love

Go to site

Part of the Why Files project, published by the National Institute for Science Education (NISE) and funded by the National Science Foundation, this page provides a scientific answer to the age-old query 'why do fools fall in love?'. The highly readable text, laid out over ten pages, provides 'intriguing evidence that humans communicate with unconscious chemical signals', called pheromones. Numerous images and diagrams enhance the text throughout. The more tricky terms are linked to a glossary, and there is a comprehensive bibliography of sources for further research.

phlebitis

inflammation of the wall of a vein. It is sometimes associated with varicose veins or with a blockage by a blood clot (thrombosis), in which case it is more accurately described as thrombophlebitis.

Phlebitis may occur as a result of the hormonal changes associated with pregnancy, or due to long-term use of contraceptive pills, or following prolonged immobility (which is why patients are mobilized as soon as possible after surgery). If a major vein is involved, nearly always in a leg, the part beyond the blockage swells and may remain engorged for weeks. It is very painful. Treatment is with anticoagulant drugs and sometimes surgery, depending on the cause.

phloem

tissue found in vascular plants. Its main function is to transport sugars and other food materials such as amino acids (see protein) from the leaves, where they are produced, to all other parts of the plant. This could be from the leaves to the roots to provide the chemicals needed for growth. However, it could be from a leaf and up to a developing fruit that is rich in sugars. The sugars are made by photosynthesis, which occurs in green parts of plants, such as leaves (see leaf). The amino acids are made from sugars and minerals, such as nitrate absorbed from the soil. Phloem tissue is usually found close to the other transport tissue in plants, xylem, which transports water and minerals. In non-woody plants phloem and xylem are found in bundles, such as the veins of a leaf.

Phloem is composed of sieve elements and their associated companion cells, together with some sclerenchyma and parenchyma cell types. Sieve elements are long, thin-walled cells joined end to end, forming sieve tubes; large pores in the end walls allow the continuous passage of nutrients. Phloem is usually found in association with xylem, the water-conducting tissue, but unlike the latter it is a living tissue.

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phlox

any of a group of plants native to North America and Siberia. Phloxes are small with alternate leaves and clusters of showy white, pink, red, or purple flowers. (Genus *Phlox*, family Polemoniaceae.)

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phobia

excessive irrational fear of an object or situation – for example, agoraphobia (fear of open spaces and crowded places), acrophobia (fear of heights), and claustrophobia (fear of enclosed places). Behaviour therapy is one form of treatment.

A **specific phobia** is a severe dislike of a particular thing, including objects, animals or situations. Specific phobias start in childhood (particularly animal phobias) and early adulthood. They are more common in women than men.

Complex phobias have more complicated contributing factors and include agoraphobia and social phobia. These phobias are more disabling. Agoraphobia typically starts between the ages of 18 and 28. Social phobia usually onsets between 11 and 16 years.

Phobias

Fear	Name of phobia
animals	zoophobia
bacteria	bacteriophobia, bacillophobia
beards	pogonophobia
bees	apiphobia, melissophobia
being alone	monophobia, autophobia, eremophobia
being buried alive	taphophobia
being seen by others	scopophobia
being touched	haphephobia, aphephobia
birds	ornithophobia
blood	h(a)ematophobia, h(a)emophobia
blushing	ereuthrophobia, erythrophobia
books	bibliophobia
cancer	cancerophobia, carcinophobia
cats	ailurophobia, gatophobia
chickens	alektorophobia
childbirth	tocophobia, parturiphobia
children	paediphobia
cold	cheimatophobia, frigophobia
colour	chromatophobia, chromophobia, psychrophobia
criticism	enissophobia
crossing bridges	gephyrophobia
crossing streets	dromophobia
crowds	demophobia, ochlophobia
darkness	achluophobia, nyctophobia, scotophobia
dawn	eosophobia
daylight	phengophobia
death, corpses	necrophobia, thanatophobia
defecation	rhypophobia
deformity	dysmorphophobia
dirt, contamination	mysophobia
disease	nosophobia, pathophobia

disorder	ataxiophobia
dogs	cynophobia
draughts	anemophobia
dreams	oneirophobia
drinking	dipsophobia
drugs	pharmacophobia
dust	amathophobia, koniphobia
eating	phagophobia
enclosed spaces	claustrophobia
everything	pan(t)ophobia
facial hair	trichopathophobia
faeces	coprophobia
failure	kakorraphiaphobia
fatigue	kopophobia, ponophobia
fears	phobophobia
fire	pyrophobia
fish	ichthyophobia
flying, the air	aerophobia
fog	homichlophobia
food	sitophobia
foreign languages	xenoglossophobia
freedom	eleutherophobia
germs	spermophobia
ghosts	phasmophobia
glass	hyalophobia
god	theophobia
going to bed	clinophobia
graves	taphophobia
hair	chaetophobia, trichophobia, hypertrichophobia
heart conditions	cardiophobia
heat	thermophobia
heaven	ouranophobia
heights	acrophobia, altophobia
hell	hadephobia, stygiophobia
horses	hippophobia
human beings	anthropophobia
ice, frost	cryophobia
illness	nosemaphobia, nosophobia
imperfection	atelophobia
infinity	apeirophobia
inoculations, injections	trypanophobia
insanity	lyssophobia, maniaphobia
insects	entomophobia
itching, or the insects that cause itching	acarophobia
jealousy	zelophobia
lakes	limnophobia
large objects	macrophobia
leaves	phyllophobia
leprosy	leprophobia
lice	pediculophobia
lightning	astraphobia
machinery	mechanophobia
many things	polyphobia
marriage	gamophobia
meat	carnophobia
men	androphobia
metals	metallophobia
mice	musophobia
mirrors	eisoptrophobia, catoptrophobia
money	chrometophobia
monsters, monstrosities	teratophobia
motion	kinesophobia, kinetophobia
music	musicophobia
names	onomatophobia
needles, sharp objects	belonephobia

night, darkness	achluophobia
noise	phonophobia
novelty	cainophobia, cenotophobia, neophobia
nudity	gymnotophobia
number 13	triskaidekaphobia, terdekaphobia
odours	osmophobia
open spaces	agoraphobia
pain	algophobia, odynophobia
parasites	parasitophobia
physical love	erotophobia
pleasure	hedonophobia
pointed instruments	aichmophobia
poison	toxiphobia, toxophobia, iophobia
poverty	peniaphobia
pregnancy	maieusiophobia
punishment	poinephobia
rain	ombrophobia
responsibility	hypegiaphobia
ridicule	katagalophobia
rivers	potamophobia
robbery	harpaxophobia
rust	iophobia
sacred things	hierophobia
satan	satanophobia
school	scholionophobia
sea	thalassophobia
semen	spermatophobia
sex	genophobia
sexual intercourse	coitophobia
shadows	sciophobia
shock	hormephobia
sin	hamartiophobia
sinning	peccatophobia
skin	dermatophobia
sleep	hypnophobia
small objects	microphobia
smell	olfactophobia
smothering, choking	pnigerophobia
snakes	ophidiophobia, ophiophobia
snow	chionophobia
sound	akousticophobia
speaking	laliophobia, lalophobia
speed	tachophobia
spiders	arachn(e)ophobia
standing	stasiphobia
stars	siderophobia
stillness	eremophobia
stings	cnidophobia
strangers	xenophobia
sun	heliophobia
symbols	symbolophobia
technology	technophobia
thinking	phronemophobia
thunder	astraphobia, brontophobia, keraunophobia
travel	hodophobia
trees	dendrophobia
vehicles	amaxophobia, ochophobia
venereal disease	cypridophobia
vomiting	emetophobia
walking	basiphobia
wasps	spheksophobia
water	hydrophobia, aquaphobia
weakness	asthenophobia
wind	ancraophobia
women	gynophobia

words	logophobia
work	ergophobia, ergasiophobia
worms	helminthophobia
wounds, injury	traumatophobia
writing	graphophobia

Phobos

one of the two moons of Mars, discovered in 1877 by the US astronomer Asaph Hall. It is an irregularly shaped lump of rock, cratered by meteorite impacts. Phobos is 27 × 22 × 19 km/17 × 13 × 12 mi in size, and orbits Mars every 0.32 days at a distance of 9,400 km/5,840 mi from the planet's centre. It is thought to be an asteroid captured by Mars's gravity.

Phobos is named after a son of Ares and Aphrodite from Greek mythology. Phobos has been photographed by three separate probes - Mariner 9 in 1971, Viking 1 in 1977, and Phobos in 1988. A Russian probe called Phobos-Grunt is scheduled to be launched toward Phobos in 2009. ('Grunt' means 'ground' - the probe will return a Phobos soil sample.)

phon

unit of loudness, equal to the value in decibels of an equally loud tone with frequency 1,000 Hz. The higher the frequency, the louder a noise sounds for the same decibel value; thus an 80-decibel tone with a frequency of 20 Hz sounds as loud as 20 decibels at 1,000 Hz, and the phon value of both tones is 20. An aircraft engine has a loudness of around 140 phons.

phosphate

salt or ester of phosphoric acid. Incomplete neutralization of phosphoric acid gives rise to acid phosphates (see acid salt and buffer). Phosphates are used as fertilizers, and are required for the development of healthy root systems. They are involved in many biochemical processes, often as part of complex molecules, such as ATP.

phospholipid

any lipid consisting of a glycerol backbone, a phosphate group, and two long chains. Phospholipids are found everywhere in living systems as the basis for biological membranes.

One of the long chains tends to be hydrophobic and the other hydrophilic (that is, they interrelate with water in opposite ways). This means that phospholipids will line up the same way round when in solution.

phosphor

any substance that is phosphorescent, that is, gives out visible light when it is illuminated by a beam of electrons or ultraviolet light. The light emission persists briefly after the stimulus ends - compare with **fluorescence**. The television screen is coated on the inside with phosphors that glow when beams of electrons strike them. Fluorescent lamp tubes are also phosphor-coated. Phosphors are also used in Day-Glo paints, and as optical brighteners in detergents.

phosphorescence

emission of light by certain substances after they have absorbed energy, whether from visible light, other electromagnetic radiation such as ultraviolet rays or X-rays, or cathode rays (a beam of electrons). When the stimulating energy is removed phosphorescence persists for more than 0.1 nanoseconds before ceasing (unlike fluorescence, which stops immediately). See also luminescence.

phosphoric acid

acid derived from phosphorus and oxygen. Its commonest form (H_3PO_4) is also known as orthophosphoric acid, and is produced by the action of phosphorus pentoxide (P_2O_5) on water. It is used in rust removers and for rust-proofing iron and steel.

phosphorus

chemical symbol P

(Greek phosphoros 'bearer of light')

highly reactive, non-metallic element, atomic number 15, relative atomic mass 30.9738. It occurs in nature as phosphates (commonly in the form of the mineral apatite), and is essential to all life, because phosphate groups are an essential part of DNA. Compounds of phosphorus are used in fertilizers, various organic chemicals, for matches and fireworks, and in glass and steel.

Phosphorus was first identified in 1674 by German alchemist Hennig Brand (born *c.* 1630), who prepared it from urine. The element has three allotropic forms (see allotropy): a black powder; a white-yellow, waxy solid that ignites spontaneously in air to form the poisonous gas phosphorus pentoxide; and a red-brown powder that neither ignites spontaneously nor is poisonous.

photocell

or photoelectric cell

device for measuring or detecting light or other electromagnetic radiation, since its electrical state is altered by the effect of light. In a **photoemissive** cell, the radiation causes electrons to be emitted and a current to flow (photoelectric effect); a **photovoltaic** cell causes an electromotive force to be generated in the presence of light across the boundary of two substances. A **photoconductive** cell, which contains a semiconductor, increases its conductivity when exposed to electromagnetic radiation.

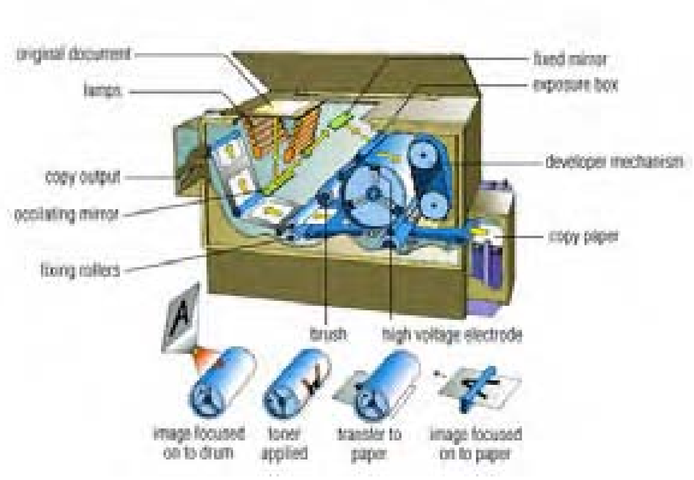
Photocells are used for photographers' exposure meters, burglar and fire alarms, automatic doors, and in solar energy arrays.

photocopier

machine that uses some form of photographic process to reproduce copies of documents or illustrations. Most modern photocopiers, as pioneered by the Xerox Corporation, use electrostatic photocopying, or xerography ('dry writing').

Additional functions of photocopiers include enlargement and reduction, copying on both sides of the sheet of paper, copying in colour, collating, and stapling.

photocopier



(Image © Research Machines plc)

At the heart of the photocopier is a metal drum on which an image is formed. The toner is attracted to the image by static electricity. As the paper moves past the drum, the image is transferred to the paper. The image is fixed by heating and pressing the toner into the paper.

photodiode

semiconductor *p-n* junction diode used to detect light or measure its intensity. The photodiode is encapsulated in a transparent plastic case that allows light to fall onto the junction. When this occurs, the reverse-bias resistance (high resistance in the opposite direction to normal current flow) drops and allows a larger reverse-biased current to flow through the device. The increase in current can then be related to the amount of light falling on the junction.

Photodiodes that can detect small changes in light level are used in alarm systems, camera exposure controls, and optical communication links.

photodynamic therapy

PDT

in medicine, therapy used to destroy cancer cells by the action of bright light and oxygen. PDT involves two stages: first a photosensitizer (light sensitive chemical) is injected into the body, where it accumulates in the tumour; the patient is then exposed to a bright light source which the photosensitizer absorbs and transfers as light energy to oxygen molecules within the cells. The energized oxygen (singlet oxygen) then destroys the tumour cells. The treatment is most successful in tumours easily exposed to a light source, such as those on the skin or in the mouth. PDT can eradicate 90% of skin tumours if applied at an early stage.

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photoelectric cell

alternative name for photocell.

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photoelectric effect

process by which electromagnetic radiation, including visible light, incident on a material releases an electric charge. It is commonly thought of as the emission of electrons from a substance (usually a metallic surface) when it is struck by photons (quanta of electromagnetic radiation), usually those of visible light or ultraviolet radiation.

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photography

process for reproducing permanent images on light-sensitive materials by various forms of radiant energy, including visible light, ultraviolet, infrared, X-rays, atomic radiations, and electron beams.

Photography was developed in the 19th century; among the pioneers were Louis Daguerre in France and William Henry Fox Talbot in the UK. Colour photography dates from the early 20th century.

The most familiar photographic process depends upon the fact that certain silver compounds (called halides) are sensitive to light. A photographic film is coated with these compounds and, in a camera, is exposed to light. An image, or picture, of the scene before the camera is formed on the film because the silver halides become activated (light-altered) where light falls but not where light does not fall. The image is made visible by the process of developing, made permanent by fixing, and, finally, is usually printed on paper. Motion-picture photography uses a camera that exposes a roll of film to a rapid succession of views that, when developed, are projected in equally rapid succession to provide a moving image.

Photography: key dates

1515	Leonardo da Vinci describes the camera obscura.
1750	The painter Canaletto uses a camera obscura as an aid to his painting in Venice.
1790	Thomas Wedgwood in England makes photograms - placing objects on leather, sensitized using silver nitrate.
1826	Nicéphore Niepce, a French doctor, produces the world's first photograph from nature on pewter plates with a camera obscura and an eight-hour exposure.
1838	As a result of his earlier collaboration with Niepce, L J M Daguerre produces the first daguerreotype camera photograph.
1839	Daguerre is awarded an annuity by the French government and his process is given to the world.
1840	Invention of the Petzval lens, which reduces exposure time by 90%. John Herschel uses sodium thiosulphate as a fixer for silver halides.
1841	William Henry Fox Talbot's calotype process is patented - the first multicopy method of photography using a negative/positive process, sensitized with silver iodide.
1844-46	Fox Talbot publishes the first photographic book, *The Pencil of Nature*.
1845	David Hill and Robert Adamson begin to use calotypes for portraits in Edinburgh, Scotland.
1851	Fox Talbot uses a one-thousandth of a second exposure to demonstrate high-speed photography. Invention of the wet-collodion-on-glass process and the waxed-paper negative. Photographs are displayed at the Great Exhibition in London, England.
1852	The London Society of Arts exhibits 779 photographs.
1855	Roger Fenton makes documentary photographs of the Crimean War from a specially constructed caravan with portable darkroom.
1858	Nadar takes the first aerial photographs from a balloon.
1859	Nadar in Paris makes photographs underground using battery-powered arc lights.
1860	Queen Victoria is photographed. Abraham Lincoln is photographed for political campaigning purposes.
1861	The single-lens reflex plate camera is patented by Thomas Sutton. The principles of three-colour photography are demonstrated by Scottish physicist James Clerk Maxwell.
1870	Julia Margaret Cameron uses long lenses for her distinctive portraits.
1871	Gelatin-silver bromide is developed.
1878	In the USA Eadweard Muybridge analyses the movements of animals through sequential photographs, using a series of cameras.
1879	The photogravure process is invented.
1880	A silver bromide emulsion is fixed with hypo. Photographs are first reproduced in newspapers in New York using the half-tone engraving process. The first twin-lens reflex camera is produced in London. Gelatin-silver chloride paper is introduced.

1884	George Eastman produces flexible negative film.
1889	The Eastman Company in the USA produces the Kodak No 1 camera and roll film, facilitating universal, hand-held snapshots.
1891	The first telephoto lens. The interference process of colour photography is developed by the French doctor Gabriel Lippmann.
1897	The first issue of Alfred Stieglitz's *Camera Notes* in the USA.
1904	The autochrome colour process is patented by the Lumière brothers.
1905	Alfred Stieglitz opens the gallery '291' in New York, USA, promoting photography. Lewis Hine uses photography to expose the exploitation of children in US factories - as a result, laws to protect them are passed.
1907	The autochrome process begins to be factory-produced.
1914	Oskar Barnack designs a prototype Leica camera for Leitz in Germany.
1924	Leitz launches the first 35-mm camera, the Leica, delayed because of World War I. It becomes very popular with photojournalists because it is quiet, small, dependable, and has a range of lenses and accessories.
1929	Rolleiflex produces a twin-lens reflex camera in Germany.
1935	In the USA, Mannes and Godowsky invent Kodachrome transparency film, which produces sharp images and rich colour quality. Electronic flash is invented in the USA.
1936	*Life* magazine, significant for its photojournalism, is first published in the USA.
1940	Multigrade enlarging paper by Ilford is made available in the UK.
1942	Kodacolour negative film is introduced.
1945	The zone system of exposure estimation is published in the book *Exposure Record* by Ansel Adams.
1947	Polaroid black and white instant process film is invented by Dr Edwin Land, who sets up the Polaroid corporation in Boston, Massachusetts. The principles of holography are demonstrated in England by Dennis Gabor.
1955	Kodak introduces Tri-X, a black and white 200 ISO film.
1959	The zoom lens is invented by the Austrian firm of Voigtlander.
1960	The laser is invented in the USA, making holography possible. Polacolor, a self-processing colour film, is introduced by Polaroid, using a 60-second colour film and dye diffusion technique.
1963	Cibachrome, paper and chemicals for printing directly from transparencies, is made available by Ciba-Geigy of Switzerland. One of the most permanent processes, it is marketed by Ilford in the UK.
1966	The International Center of Photography is established in New York.
1969	Photographs are taken on the Moon by US astronauts.
1970	A charge-coupled device is invented at Bell Laboratories in New Jersey, USA, to record very faint images (for example in astronomy). Rencontres Internationales de la Photographie, the annual summer festival of photography with workshops, is founded in Arles, France.
1971	Opening of the Photographers' Gallery, London, and the Photo Archive of the Bibliothéque Nationale, Paris.
1972	The SX70 system, a single-lens reflex camera with instant prints, is produced by Polaroid.
1975	The Center for Creative Photography is established at the University of Arizona.
1980	Ansel Adams sells an original print, *Moonrise: Hernandez*, for $45,000, a record price, in the USA. *Voyager 1* sends photographs of Saturn back to Earth across space.
1983	The National Museum of Photography, Film and Television opens in Bradford, England.
1985	The Minolta Corporation in Japan introduces the Minolta 7000 - the world's first body-integral autofocus single-lens reflex camera.
1988	The electronic camera, which stores pictures on magnetic disc instead of on film, is introduced in Japan.
1990	Kodak introduces PhotoCD, which converts 35-mm camera pictures (on film) into digital form and stores them on compact disc (CD) for viewing on TV.
1992	Japanese company Canon introduces a camera with autofocus controlled by the user's eye. The camera focuses on whatever appears at the centre of the image in the viewfinder. *Girl with a Leica* by Russian photographer Aleksandr Rodchenko sells for £115,500 at Christie's, London - a world-record price for a photograph.
1996	Corbis, a company owned by Bill Gates, buys the exclusive rights to 2,500 photographs by Ansel Adams.

American Museum of Photography

Go to site

Site of the American Museum of Photography, containing a lot of material, as well as information about the museum itself. The latest exhibitions are listed and many photographs are available to download. This is primarily a museum of US photographers, but is a great resource for any photographer.

Around the World in the 1890s

Go to site

Part of the American Memory presentation of the US Library of Congress, this page features hundreds of images by US photographer William Henry Jackson and is part of the World's Transportation Commission Photograph Collection. Found here are images taken during Jackson's travels through North Africa, Asia, Australia, and Oceania - including photos of the local inhabitants; city, street, landscape, and harbour scenes; plus all manner of transportation types, including elephants, sleds, camels, sedan chairs, horses, rickshaws, and railroads. The collection can be browsed by keyword and subject, or you can select a country from the trip itinerary. Click on the images to increase their size.

Exposure: A Beginners Guide to Photography

Go to site

Introduction to the world of photography including a 'Crash course', as well as sections with 'A few easy tricks to jazz up your pictures' and an explanation of exposure theory. To help out with the latter, there is a 'sim-cam', allowing you to experiment with f-number and shutter speed for an image and see the results without wasting a lot of film.

History of Photography

Go to site

From the early pioneers to the establishment of photography as we know it, this site provides a thorough account of the gradual development of photography. There are numerous internal links to important characters, techniques, and descriptions of important processes and styles. It also provides a useful bibliography and information on the Royal Photographic Society.

National Museum of Photography, Film, and Television

Go to site

Details of collections, events, and forthcoming exhibits at the National Museum of Photography, Film, and Television, in Bradford, England. The educational section of this Web site includes resources based around the exhibitions which are sorted by Key Stage.

Photo.net

Go to site

Useful site for those interested in photography. As well as a series of exhibitions, this site includes advice on buying a camera, what film to use, and lots of technical advice to help you achieve the results you want.

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photogravure

printing process that uses a plate prepared photographically, covered with a pattern of recessed cells in which the ink is held. See gravure.

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photolysis

chemical reaction that is driven by light or ultraviolet radiation. For example, the light reaction of photosynthesis (the process by which green plants manufacture carbohydrates from carbon dioxide and water) is a photolytic reaction.

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photometer

instrument that measures the intensity of light (electromagnetic radiation in the visible range), usually by comparing relative intensities from different sources. Bunsen's grease-spot photometer of 1844 compares the intensity of a light source with that of a known source by using each source to illuminate one half of a translucent area. Modern photometers use photocells, as in a photographer's exposure meter. A photomultiplier can also be used as a photometer.

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photomultiplier

instrument that detects low levels of electromagnetic radiation (usually visible light or infrared radiation) and amplifies it to produce a detectable electrical signal.

One type resembles a photocell with an additional series of coated electrodes (dynodes) between the cathode and anode. Radiation striking the cathode releases electrons (primary emission) which hit the first dynode, producing yet more electrons (secondary emission), which strike the second dynode. Eventually this produces a measurable signal up to 100 million times larger than the signal produced in the first stage by the time it leaves the anode. Similar devices, called image intensifiers, are used in television camera tubes that 'see' in the dark.

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photon

in physics, the elementary particle or 'package' (quantum) of energy in which light and other forms of electromagnetic radiation are emitted. The photon has both particle and wave properties; it has no charge, is considered massless but possesses momentum and energy. It is one of the gauge bosons, and is the carrier of the electromagnetic force, one of the fundamental forces of nature.

According to quantum theory the energy of a photon is given by the formula $E = hf$, where h is Planck's constant and f is the frequency of the radiation emitted.

Beam Me Up: Photons and Teleportation

Go to site

Part of a larger site maintained by *Scientific American*, this page reports on the amazing research conducted by physicists at the University of Innsbruck, Austria, who have turned science fiction into reality by teleporting the properties of one photon particle to another. Learn how quantum teleportation was accomplished and find out what the likelihood is that people will soon be teleporting themselves. The text includes hypertext links to further information, and there is also a list of related links at the bottom of the page.

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photoperiodism

biological mechanism that determines the timing of certain activities by responding to changes in day length. The flowering of many plants is initiated in this way. Photoperiodism in plants is regulated by a light-sensitive pigment, **phytochrome**. The breeding seasons of many temperate-zone animals are also triggered by increasing or declining day length, as part of their biorhythms.

Autumn-flowering plants (for example, chrysanthemum and soybean) and autumn-breeding mammals (such as goats and deer) require days that are shorter than a critical length; spring-flowering and spring-breeding ones (such as radish and lettuce, and birds) are triggered by longer days.

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photosensitivity

in medicine, skin sensitivity to sunlight characterized by rashes occurring on exposure. Abnormal skin sensitivity may result from the use of some cosmetics or medicines that contain photosensitizers.

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photosphere

visible surface of the Sun, which emits light and heat. About 300 km/200 mi deep, it consists of incandescent gas at a temperature of 5,800 K (5,530°C/9,980°F).

Rising cells of hot gas produce a mottling of the photosphere known as **granulation**, each granule being about 1,000 km/620 mi in diameter. The photosphere is often marked by large, dark patches called sunspots.

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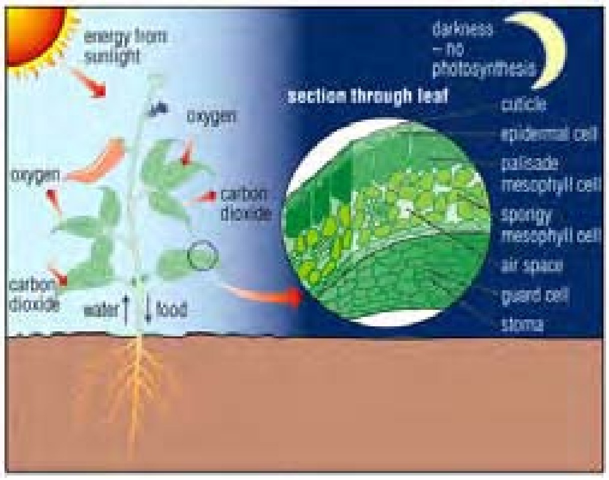
photosynthesis

process by which green plants trap light energy from sunlight in order to combine carbon dioxide and water to make high-energy chemicals – glucose and other carbohydrates. The simple sugar glucose provides the basic food for both plants and animals. For photosynthesis to occur, the plant must possess chlorophyll (the green chemical that absorbs the energy from the sunlight) and must have a supply of carbon dioxide and water. Photosynthesis takes place inside chloroplasts, which contain the enzymes and chlorophyll necessary for the process. They are found mainly in the leaf cells of plants. The by-product of photosynthesis, oxygen, is of great importance to all living organisms, and virtually all atmospheric oxygen has originated from photosynthesis.

Through photosynthesis, plants are able to make some of their own food – this is one way in which the nutrition of plants differs from that of animals. The glucose they produce may be converted to starch and stored. Starch can then be converted back to glucose to provide energy for the plant at a later stage, for example during the night.

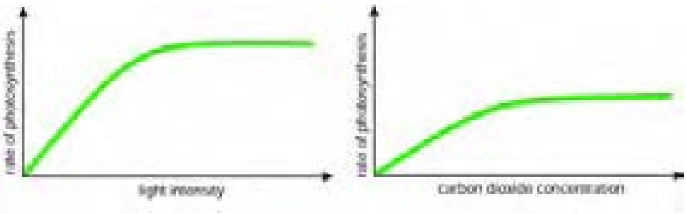
photosynthesis



(Image © Research Machines plc)

Process by which green plants and some bacteria manufacture carbohydrates from water and atmospheric carbon dioxide, using the energy of sunlight. Photosynthesis depends on the ability of chlorophyll molecules within plant cells to trap the energy of light, in order to split water molecules, giving off oxygen as a by-product. The hydrogen of the water molecules is then used to reduce carbon dioxide to simple carbohydrates.

photosynthesis



(Image © Research Machines plc)

Graphs to show the effects of light and carbon dioxide concentration on photosynthesis rates. In each case the rates increase rapidly at first then reach a ceiling, indicating that they are being affected by another limiting factor, for example temperature.

Introduction to Photosynthesis and its Applications

Go to site

Good general introduction to photosynthesis, including a discussion of the basics, illustrated with photographs and diagrams. This is followed by a more detailed explanation of photosynthetic electron transfer, carbon fixation, and the effects of increasing exposure to carbon dioxide. Helpful pictures aid in visualizing the processes.

Photosynthesis

Go to site

Increase your understanding of how light energy is converted into different forms of chemical energy during photosynthesis. The user can browse through the tutorials before attempting the tests.

Photosynthesis Directory

Go to site

Helpful introduction to photosynthesis detailing its 'evolution and discovery' and clear explanations of light and dark reactions. Also includes information and a diagram on the structure and function of the chloroplast.

Plant Photobiology Notes

Go to site

Clear, well-designed resource on photobiology, the branch of biology that studies the interaction of plants and light. This evolving site contains helpful pages on the basics of photobiology and the various types of radiation present in the environment.

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phototropism

movement of part of a plant toward or away from a source of light. Leaves are positively phototropic, detecting the source of light and orientating themselves to receive the maximum amount.

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phrenology

study of the shape and protuberances of the skull, based on the now discredited theory of the Austrian physician Franz Josef Gall that such features revealed measurable psychological and intellectual traits.

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phyllite

metamorphic rock produced under increasing temperature and pressure, in which minute mica crystals are aligned so that the rock splits along their plane of orientation, the resulting break being shiny and smooth. Intermediate between slate and schist, its silky sheen is an identifying characteristic.

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phyllotaxis

arrangement of leaves on a plant stem. Leaves are nearly always arranged in a regular pattern and in the majority of plants they are inserted singly, either in a **spiral** arrangement up the stem, or on **alternate** sides. Other principal forms are opposite leaves, where two arise from the same node, and whorled, where three or more arise from the same node.

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phylloxera

plant-eating insect of the family Phylloxeridae, closely related to the aphids.

The grape, or vine phylloxera *Phylloxera vitifolia*, a native of North America, is a notorious pest of grapevines, forming galls on roots and leaves, which damage the plant. European vines are markedly susceptible and many French vineyards suffered from the arrival of the pest in Europe in the late 19th century, when nearly 2 million hectares of vineyards were destroyed. In 1993 infestation became apparent in Californian vineyards, threatening a loss of 20,000 hectares by the end of the century. Phylloxera is very resistant to treatment, as there are no natural enemies and it is difficult to treat with pesticide because of its depth within the soil. Phylloxera insects (hemipterans) may be destroyed by spraying with carbon disulphide or petroleum.

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phylogeny

historical sequence of changes that occurs in a given species during the course of its evolution. It was once erroneously associated with ontogeny (the process of development of a living organism).

Tree of Life

Go to site

Project designed to present information about the phylogenetic relationships and characteristics of organisms, illustrating the diversity and unity of living organisms.

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phylum

plural phyla

major grouping in biological classification. Mammals, birds, reptiles, amphibians, fishes, and tunicates belong to the phylum Chordata; the phylum Mollusca consists of snails, slugs, mussels, clams, squid, and octopuses; the phylum Porifera contains sponges; and the phylum Echinodermata includes starfish, sea urchins, and sea cucumbers. In classifying plants (where the term 'division' often takes the place of 'phylum'), there are between four and nine phyla depending on the criteria used; all flowering plants belong to a single phylum, Angiospermata, and all conifers to another, Gymnospermata. Related phyla are grouped together in a kingdom; phyla are subdivided into classes.

There are around 35 different phyla (a number subject to change as new research makes rearrangements of the phylogenetic tree necessary).

Classification of plants by phyla

Phylum	Examples	Number of species
Angiospermophyta	all flowering plants	230,000
Bryophyta	hornworts, liverworts, mosses	24,000
Coniferophyta	all conifers	550
Cycadophyta	cycads	100
Filicinophyta/Pteridophyta	ferns	12,000
Ginkgophyta	*Ginkgo*	1
Gnetophyta	*Welwitschia* and other gnetophytes	70
Lycopodophyta/Lycophyta	club mosses	1,000
Psilophyta	whisk ferns	12
Sphenophyta	horsetails	20

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physical chemistry

branch of chemistry concerned with examining the relationships between the chemical compositions of substances and the physical properties that they display. Most chemical reactions exhibit some physical phenomenon (change of state, temperature, pressure, or volume, or the use or production of electricity), and the measurement and study of such phenomena has led to many chemical theories and laws.

Physical chemistry includes the fields of thermodynamics, electrochemistry, quantum chemistry, and kinetics. Many of the analytical techniques used in other chemical disciplines have their roots in physical chemistry.

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physics

branch of science concerned with the laws that govern the structure of the universe, and the investigation of the properties of matter and energy and their interactions. Before the 19th century, physics was known as **natural philosophy**.

Classical physics consisted of the study of heat, light, electricity, magnetism, optics, acoustics, and mechanics. Since the turn of the 20th century quantum mechanics and relativity have transformed all areas of physics. Today, physics is often divided into branches such as nuclear physics, particle physics, quantum physics, theoretical physics, and solid-state physics. The study of the planets, stars, and their interactions is known as astrophysics, the physics of the Earth is called geophysics, and the study of the physical laws relating to living organisms is called biophysics.

Biology

ancient times

Like so much else, the systematic study of living things began with the Greeks. Earlier cultures such as those in Egypt and Babylon in the Near East, and the early Indian and Chinese civilizations in Asia, had their own approaches to the study of Nature and its products. But it was the Greeks who fostered the attitudes of mind and identified the basic biological problems and methods from which modern biology has grown. Enquiry begun by Greek philosophers such as Alcmaeon (born *c.* 535 BC) and Empedocles (*c.* 492-*c.* 432 BC) culminated in the biological work of Greek polymath Aristotle (384-323 BC) and the medical writings of the Greek physician Hippocrates (*c.* 460-377 BC) and his followers.

natural philosophy

Aristotle was an original thinker of enormous power and energy who wrote on physics, cosmology, logic, ethics, politics, and many other branches of knowledge. He also wrote several biological works which laid the foundations for comparative anatomy, taxonomy (classification), and embryology. He was particularly fascinated by sea creatures; he dissected many of these as well as studying them in their natural habitats. Aristotle's approach to anatomy was functional: he believed that questions about structure and function always go together and that each biological part has its own special uses. Nature, he insisted, does nothing in vain. He therefore thought it legitimate to enquire about the ultimate purposes of things. This teleological approach has persisted in biological work until the 20th century. In addition, Aristotle studied reproduction and embryological development, and he established many criteria by which animals could be classified. He believed that animals could be placed on a vertical, hierarchical scale ('scale of being'), extending from humans down through quadrupeds, birds, snakes, and fishes to insects, molluscs, and sponges. Hierarchical thinking (as reflected in the terms 'higher' and 'lower' organisms) is still present in biology. One of Aristotle's pupils, the Greek philosopher and scientist Theophrastus (*c.* 372-287 BC), founded for botany many of the fundamentals that Aristotle had established for zoology.

What Aristotle achieved for biology, Hippocrates and his followers contributed for medicine: they established a naturalistic framework for thinking about health and disease. Unlike earlier priests and doctors, they did not regard illness as the result of sin, or as a divine punishment for misdeeds. They were keen observers whose most influential explanatory framework saw disease as the result of an imbalance in one of the four physiologically active humours (blood, phlegm, black bile, and yellow bile). The humours were schematically related to the four elements (earth, air, fire, and water) of Greek natural philosophy. Each person was supposed to have his or her own dominant humour, although different humours tended to predominate at different times of life (such as youth and old age) or seasons of the year. The therapy of Hippocrates aimed at restoring the ideal balance through diet, drugs, exercise, change of life style, and so on.

Galen's influence on medicine

After the classical period of Greek thought, the most important biomedical thinker was Greek physician, anatomist and physiologist Galen (*c.* 129-*c.* 199), who combined Hippocratic humoralism with Aristotle's tendency to think about the ultimate purposes of the parts of the body. Galen should not be blamed for the fact that later doctors thought that he had discovered everything, so that they had no need to look at biology and medicine for themselves. In fact, Galen was a shrewd anatomist and the most brilliant experimental physiologist of antiquity. For most of that time, human dissection was prohibited and Galen learnt his anatomy from other animals such as pigs, elephants, and apes. It took more than a thousand years before it was discovered that some of the structures which he had accurately described in other animals (such as the five-lobed liver and the rete mirabile network of veins in the brain) were not present in the human body. Like that of Aristotle, Galen's anatomy was functional, and often his tendency to speculate went further than sound observation would have permitted, as when he postulated invisible pores in the septum of the heart which were supposed to allow some blood to seep from the right ventricle to the left.

the Renaissance

Following Galen's death at the end of the 2nd century and the collapse of the Roman Empire, biology and medicine remained stagnant for a thousand years. Most classical writings were lost to the European West, to be preserved and extended in Constantinople and other parts of the Islamic Empire. From the 12th century these texts began to be rediscovered in southern Europe – particularly in Italy, where universities were also established. For a while scholars were content merely to translate and comment on the works of men such as Aristotle and Galen, but eventually an independent spirit of enquiry arose in European biology and medicine. Human dissections were routinely performed from the 14th century and anatomy emerged as a mature science from the fervent activity of Belgian physician Andreas Vesalius (1514-1564), whose *De Humani Corporis Fabrica/On the Fabric of the Human Body* (1543) is one of the masterpieces of the Scientific Revolution. His achievement was to examine the body itself rather than relying simply on Galen; the illustrations in his work are simultaneously objects of scientific originality and of artistic beauty. The rediscovery of the beauty of the human body by Renaissance artists encouraged the study of anatomy by geniuses such as Italian, artist, inventor and scientist Leonardo da Vinci (1452-1519). Shortly afterwards, the English physician William Harvey (1578-1657) discovered the circulation of the blood and established physiology on a scientific footing. His little book *De Motu Cordis/On the Motion of the Heart* (1628) was the first great work on experimental physiology since the time of Galen. The eccentric wandering Swiss physician and chemist Paracelsus (1493-1541) had also deliberately set aside the teachings of Galen and other Ancients in favour of a fresh approach to Nature and medicine and to the search for new remedies for disease.

the age of discovery

While these achievements were happening in medicine, anatomy, and physiology, other areas of biology were not stagnating. Voyages of exploration alerted naturalists to the existence of many previously unknown plants and animals and encouraged them to establish sound principles of classification, to create order out of the apparently haphazard profusion of Nature. Zoological and botanical gardens began to be established so that the curious could view wonderful creatures like the rhinoceros and the giraffe. And just as the Great World (Macrocosm) was revealing plants and animals unknown in Europe only a short time before, so the invention of the microscope in the 17th century gave scientists the opportunity of exploring the secrets of the Little World (Microcosm). The microscope permitted Dutch microscopist Anton van Leeuwenhoek (1632-1723) to see bacteria, protozoa, and other tiny organisms; it enabled English physicist Robert Hooke (1635-1703) to observe in a thin slice of cork regular structures which he called 'cells'. And it aided Italian physician Marcello Malpighi (1628-1664) to complete the circle of Harvey's concept of the circulation of the blood by first seeing it flowing through capillaries, the tiny vessels that connect the arterial and venous systems. Many of these microscopical discoveries were communicated to the Royal Society of London, one of several scientific societies established during the mid-17th century.

The full potential of the microscope as a biological tool had to wait for technical improvements effected in the early 19th century. But it also led scientists along some blind alleys of theory. Observations of sperm 'swimming' in seminal fluid provided some presumed evidence for a theory that was much debated during the 18th century, concerning the nature of embryological development. Aristotle had thought that the body's organs (heart, liver, stomach, and so on) only gradually appear once conception has initiated the growth of the embryo. Later scientists, including William Harvey, extended Aristotle's theory with new observations. But now the visualization of moving sperm suggested that some miniature, but fully formed organism was already present in the reproductive fluids of the male or female. The tiny *homunculi* were thought to be stimulated to growth by fertilization. If the homunculus was always there, it followed that its own reproductive parts contained all of its future offspring, which in turn contained its future offspring and so on, back to Adam and Eve (depending on whether the male or the female was postulated as the carrier). This doctrine, called preformationalism, was held by most 18th-century biologists, including Swiss physiologist Albrecht von Haller (1708-1777) and Italian physiologist Lazzaro Spallanzani (1729-1799), two of the century's greatest scientists. Both men, like virtually all scientists of the period, were devout Christians, and preformationalism did not conflict with their belief that God established regular, uniform laws which governed the development and functions of living things. They did not believe that inert matter could join together by accident to make a living organism. They rejected, for instance, the possibility of spontaneous generation, and Spallanzani devised some ingenious experiments designed to show that maggots found in rotting meat or the teeming life discoverable after jars of water are left to stand did not spontaneously generate. Haller, Spallanzani, Scottish anatomist John Hunter (1728-1793), and most other great 18th-century experimentalists held that the actions of living things could not be understood simply in terms of the laws of physics and chemistry. They were Vitalists, who believed that unique characteristics separated living from non-living matter. The special attributes of humans were often ascribed to the soul, and lower animals and plants were thought to possess more primitive animal and vegetable souls which gave them basic biological capacities such as reproduction, digestion, movement, and so on.

The systematic use of improved microscopes revolutionized the way in which biologists conceived organisms. In the closing years of the 18th century a French physician named Xavier Bichat (1771-1802), aided only with a hand lens, developed the idea that organs such as the heart and liver are not the ultimate functional units of animals. He postulated that the body can be divided into different kinds of tissues (such as nervous, fibrous, serous, and muscular tissue) which make up the organs. Increasingly, biologists and doctors began thinking in terms of smaller functional units, and microscopists, such as Scottish botanist Robert Brown (1773-1858), began noticing regular structures within these units, which we now recognize as cells. Brown called attention to the nucleus in the cells of plants in 1831 and by the end of the decade the German botanist Matthias Schleiden (1804-1881) and German physiologist Theodor Schwann (1810-1882) systematically developed the idea that all plants and animals are composed of cells. The cell theory was quickly established for adult organisms, but in certain situations - such as the earliest stages of embryological development or in the appearance of 'pus' cells in tissues after inflammation or injury - it appeared that new cells were actually crystallized out of an amorphous fluid which Schwann called the 'blastema'. The notion of continuity of cells was enlarged upon by the German pathologist Rudolf Virchow (1821-1902), who summarized it in his famous slogan 'All cells from cells'. The cell theory gave biologists and physicians a new insight into the architecture and functions of the body in health and disease.

micro-organisms and disease

Concern with single-celled organisms also lay behind the work of French chemist and microbiologist Louis Pasteur (1822-1895), which helped to establish the germ theory of disease. Pasteur trained as a chemist, but his researches into everyday processes such as the souring of milk and the fermentation of beer and wine opened for him a new understanding of the importance of yeast, bacteria, and other micro-organisms in our daily lives. It was Pasteur who finally convinced scientists that animals do not spontaneously generate on rotting meat or in infusions of straw; our skin, the air, and everything we come into contact with can be a source of these tiny creatures. After reading about Pasteur's work, English surgeon Joseph Lister (1827-1912) first conceived the idea that by keeping away these germs (as they were eventually called) from the wounds made during surgical operations, healing would be much faster and post-operative infection would be much less common. When in 1867 Lister published the first results using his new technique, antiseptic surgery was born. He spent much time developing the methods, which were taken up by other surgeons who soon realized that it was better to prevent infection altogether (asepsis) by carefully sterilizing their hands, instruments, and dressings. By the time Lister died, he was world famous and surgeons were performing operations that would have been impossible without his work.

After Lister drew attention to the importance of Pasteur's discoveries for medicine and surgery, Pasteur himself showed the way in which germs cause not only wound infections, but also many diseases. He first studied a disease of silkworms which was threatening the French silk industry; he then turned his attention to other diseases of farm animals and human beings. In the course of this research, he discovered that under certain conditions an organism could be grown which, instead of causing a disease, actually prevented it. He publicly demonstrated these discoveries for anthrax, then a common disease of sheep, goats, and cattle which sometimes also affected human beings. He proposed to call this process of protection 'vaccination', in honour of English biologist Edward Jenner (1749-1823), who in 1796 had shown how inoculating a person with cowpox (vaccinia) can protect against the deadly smallpox. Pasteur's most dramatic success came with a vaccine against rabies, a much-dreaded disease occasionally contracted after a bite from an infected animal.

By the 1870s, other scientists were investigating the role played by germs in causing disease. Perhaps the most important of them was German bacteriologist Robert Koch (1843-1910), who devised many key techniques for growing and studying bacteria, and who showed that tuberculosis and cholera - prevalent diseases of the time - were caused by bacteria. Immunology, the study of the body's natural defence mechanisms against invasion by foreign cells, was pioneered by another German bacteriologist, Paul

Ehrlich (1854-1915), who also began looking for drugs that would kill disease-causing organisms without being too dangerous for the patient. His first success, a drug named Salvarsan, was effective in the treatment of syphilis. Ehrlich's hopes in this area were not fully realized immediately, and it was not until the 1930s that the synthetic sulfa drugs, also effective against some bacterial diseases, were developed by German bacteriologist Gerhard Domagk (1895-1964) and others. Slightly earlier Scottish bacteriologist Alexander Fleming (1881-1955) had noticed that a mould called *Penicillium* inhibited the growth of bacteria on cultures. Fleming's observation was investigated during World War II by Australian-born British bacteriologist Howard Florey (1898-1968) and German-born British biochemist Ernst Chain (1906-1979), and since then many other antibiotics have been discovered or synthesized. But antibiotics are not effective against diseases caused by viruses; such infections can, however, often be prevented using vaccines. An example is poliomyelitis, vaccines against which were developed in the 1950s by Russian-born US viriologist Albert Sabin (1906-1993) and US microbiologist Jonas Salk (1914-1995).

Many of these advances in modern medical science are a direct continuation of discoveries made in the 19th century, although of course we now know much more about bacteria and other pathogenic microorganisms than did Pasteur and Koch.

modern biological sciences

The rapidly developing discipline of biochemistry became more and more dominant in 20th-century biology. Molecular biologists and chemists have been concerned with determining the structures of many large biological molecules, such as the muscle protein myoglobin by English biochemist John Kendrew (1917-1997) and Austrian-born British molecular biologist Max Perutz (1914-). In their researches they often interpreted the diffraction patterns produced when X-rays pass through these complex molecules, a technique pioneered by English chemist and crystallographer Dorothy Hodgkin (1910-1994).

Molecular biology is only one of several new biological disciplines to be developed during the past century. The oldest of these, biochemistry, was established in Britain by English biochemist Frederick Gowland Hopkins (1861-1947) who, along with Polish-born US biochemist Casimir Funk (1884-1967) and US biochemist and nutritionist Elmer McCollum (1879-1967), is remembered for his fundamental work in the discovery of vitamins, substances that help to regulate many complex bodily processes. Other biochemists such as Czech-born US biochemists Carl Cori (1896-1984) and Gerty Cori (1896-1957) have studied the ways in which organisms make use of the energy gained when food is broken down. Many of these internal processes are also moderated by the action of hormones, one important example of which is insulin, discovered in the 1920s by Canadian physiologist Frederick Banting (1891-1941) and others.

Modern biologists also often use physics in their work, and biophysics is now an important discipline in its own right. English physiologist Archibald Hill (1886-1977) and German-born US biochemist Otto Meyerhof (1884-1951) pioneered in this area with their work on the release of heat when muscles contract. More recently, German-born British physiologist Bernhard Katz (1911-) has used biophysical techniques in studying the events at the junctions between muscles and nerves, and at the junctions between pairs of nerves (synapses). The events at synapses are initiated by the release of chemical substances such as adrenaline and acetylcholine, as was demonstrated by English physiologist Henry Dale (1875-1968) and German pharmacologist Otto Loewi (1873-1961). The way in which nerve impulses move along the nerve axon has been investigated by English physiologists Alan Hodgkin (1914-1998) and Andrew Huxley (1917-). For this work, they made use of the giant axon of the squid, an experimental preparation whose importance for biology was first shown by English zoologist John Young (1907-1997). The complicated way in which the nervous system operates as a whole was first rigorously investigated by English neurologist Charles Sherrington (1857-1952).

Another area of fundamental importance in modern biology and medicine is immunology. For instance, the discovery by Austrian-born US physician Karl Landsteiner (1868-1943) of the major human blood group system (A, B, and O) permitted safe blood transfusions. The development of the immune system - and the way in which the body recognizes foreign substances ('self' and 'not-self') has been investigated by such scientists as British immunologist Peter Medawar (1915-1987) and Australian immunologist Frank Macfarlane Burnet (1899-1985). Much of this knowledge has been important to transplant surgery, pioneered for kidneys by English surgeon Roy Calne (1930-) and for hearts by South African caardiothoracic surgeon Christiaan Barnard (1922-).

taxonomy and classification

Experimental biology was well established in the 18th century; another great area of 18th-century activity was classification. Again inspired by Aristotle, and drawing on the work of previous biologists such as the British naturalist John Ray (1627-1705). The Swedish botanist Carolus Linnaeus (1707-1778) spent a lifetime trying to bring order to the ever increasing number of plants and animals uncovered by continued exploration of the Earth and its oceans. His *Systema Naturae/System of Nature* (1735) was the first of many books in which he elaborated a philosophy of taxonomy and established the convention of binomial nomenclature still followed today. In this convention, all organisms are identified by their genus and species; thus human beings in the Linnaean system are *Homo sapiens*. Depending on the nature of the characteristics examined, however, plants and animals could be placed in a variety of groups, ranging from the kingdom at the highest level through phyla, classes, orders and families, and so on beyond the species to the variety and, finally, the individual. Naturalists had traditionally accepted that the species was the most significant taxonomic category, Christian doctrine generally holding that God had specially created each individual species. It was also assumed that the number of species existing was fixed during the Creation, as described in the Book of Genesis - no new species having been created and none becoming extinct. Linnaeus, however, believed that God had created genera and that it was possible that new species had emerged during the time since the original Creation.

Although still based on the Linnaean system, modern taxonomists use a range of methods in describing and classifying species, and these may now include biochemical and genetic comparison, in addition to the more traditional consideration of morphological characteristics. The extent to which classification can, or even should, seek to reflect evolutionary relatedness continues to the present day. Classification is necessarily an abstraction, being a 'snapshot' in an evolutionary process, but is nevertheless essential as a tool for describing and studying organisms. With increasing pressure on habitats, and a rising rate of human-induced extinctions, the need to build up a detailed inventory of species is ever more urgent.

palaeontology and evolution

Some 18th-century naturalists such as French naturalist Georges Buffon (1707-1788) began to suggest that the Earth and its inhabitants were far older than the 6,000 or so years inferred from the Bible. General acceptance of a vastly increased age of the Earth, and of the reality of biological extinction, awaited the work of early 19th-century scientists such as French zoologist Georges Cuvier (1769-1832), whose reconstructions of the fossil remains of large vertebrates like the mastodon and dinosaurs found in the Paris basin and elsewhere so stirred both the popular and scientific imaginations of his day. Despite Cuvier's work on the existence of life on Earth for perhaps millions of years, he firmly opposed the notion that these extinct creatures might be the ancestors of animals alive today. Rather he believed that the extent to which any species might change (variability) was fixed and that species themselves could not change much over time. His contemporary and scientific opponent, French naturalist Jean Baptiste Lamarck (1744-1829), argued however that species do change over time. He insisted that species never become extinct; instead they are capable of change as new environmental conditions and new needs arise. According to this argument, the ancestors of the giraffe need not have had such a long neck, which instead might have slowly developed as earlier giraffelike creatures stretched their necks to feed on higher leaves. Lamarck believed that physical characteristics and habits acquired after birth could - particularly if repeated from generation to generation - become inherited and thus inborn in the organism's offspring. We still call the doctrine of the inheritance of acquired characteristics 'Lamarckianism', although most naturalists before Lamarck had already believed it. It continued to be generally accepted (for instance, by English naturalist Charles Darwin (1809-1882)) until late in the 19th century. The debates between Cuvier and Lamarck were part of the new possibilities opened up by the revolution in thinking about the age of the Earth and of life on it.

Charles Darwin was not the first to suggest that biological species can change over time, but his book *The Origin of Species* (1859) first presented the idea in a scientifically plausible form. As a young man, Darwin spent five years (1831-36) on HMS *Beagle*, during which he studied fossils, animals, and geology in many parts of the world, particularly in South America. By 1837 he had come to believe the fact of evolution; in 1838 he hit upon its mechanism: natural selection. This principle makes use of the fact that organisms produce more offspring than can survive to maturity. In this struggle for existence, those offspring with characteristics best suited to their particular environment will tend to survive. In this way, Nature can work on the normal variation which plants and animals show and, under changing environmental conditions, significant change can occur through selective survival.

Darwin knew that his ideas would be controversial so he initially imparted them to only a few close friends, such as the Scottish geologist Charles Lyell (1797-1875) and the English botanist Joseph Hooker (1817-1911). For 20 years he continued quietly to collect evidence favouring the notion of evolution by natural selection, until in 1858 he was surprised to receive a short essay from Welsh naturalist Alfred Russel Wallace (1823-1913), then in Malaya, perfectly describing natural selection. Friends arranged a joint Darwin-Wallace publication, and then Darwin abandoned a larger book he was writing on the subject to prepare instead *The Origin of Species*. In it he marshalled evidence from many sources, including palaeontology, embryology, geographical distribution, ecology (a word coined only later), and hereditary variation. Darwin did not have a very clear idea of how variations occur, but his work convinced a number of scientists, including English scientist and humanist Thomas Huxley (1825-1895), German zoologist Ernst Haeckel (1834-1919) and English scientist, inventor, and explorer Francis Galton (1822-1911), Darwin's cousin. Huxley became Darwin's chief publicist in Britain, Haeckel championed Darwin's ideas in Germany, and Galton quietly absorbed the evolutionary perspective into his own work in psychology, physical anthropology, and the use of statistics and other forms of mathematics in the life sciences.

genetics

Meanwhile, unknown to Darwin (and largely unrecognized during his lifetime), an Austrian monk named Gregor Mendel (1822-1884) was elucidating the laws of modern genetics through his studies of inheritance patterns in pea plants and other common organisms. Mendel's work on the inheritance patterns of peas was published in 1866, but had little influence on biological thinking until 1900. Then it was scrutinized by Dutch botanist and geneticist Hugo de Vries (1848-1935), German biologist Karl Erich Correns (1864-1933), and by the Austrian scientist Erich von Tschermak-Seysenegg (1871-1962). Their work signalled the start of serious research into heredity. Mendel studied characteristics that were inherited as a unit; this enabled scientists to understand such phenomena as dominance and recessiveness in these units, called 'genes' in 1909 by the Danish biologist W L Johannsen (1859-1927). By 1900, when de Vries, English geneticist William Bateson (1861-1926), and others were recognizing the importance of Mendel's pioneering work, much more was known about the microscopic appearances of cells both during adult division (mitosis) and reduction division (meiosis). In addition, German zoologist August Weismann (1834-1914) had developed notions of the continuity of the inherited material (which he called the 'germ plasm') from generation to generation, thus suggesting that acquired characteristics are not inherited. Only a few scientists in the 20th century, such as the Soviet botanist Trofim Lysenko (1898-1976), have continued to believe in Lamarckianism, for modern genetics has accumulated overwhelming evidence that characteristics such as the loss of an arm or internal muscular development do not change the make-up of reproductive cells. In 1906, Bateson introduced the word 'genetics'. He demonstrated that certain inherited traits tend to be transmitted as a group, thus establishing the concept of genetic linkage. In 1909 he used the term 'allele' for alternate forms of a gene.

It is now believed that new inheritable variations occur when genes mutate. The study of this process and of the factors (such as X-rays and certain chemicals) that can make the occurrence of mutations likely was pioneered by geneticists such as US geneticists Thomas Hunt Morgan (1866-1945) and Herman Muller (1890-1967). They did much of their work with fruit flies (*Drosophila*). While these and other scientists were showing that genes are located on chromosomes - strands of darkstaining material in the nuclei of cells - other researchers were trying to determine the exact nature of the hereditary substance itself. Originally it was thought to be a protein, but in 1953 English molecular biologist Francis Crick (1916-) and US biologist James Watson (1928-) were able to show that it is dioxyribonucleic acid (DNA). Their work was an early triumph of molecular biology, a branch of the science that has grown enormously since the 1950s.

Scientists now know a great deal about how DNA works. Among those who have contributed are US biologist George Beadle (1903-1989), US microbiologist Edward Tatum (1909-1975), French biochemist Jacques Monod (1910-1976), US geneticist Joshua Lederberg (1925-), and New Zealand-born British biochemist Maurice Wilkins (1916-). In the mid-20th century the chemical link between the gene and the expression of that gene in the organism was beginning to be unravelled. This link proved to be the production by the gene of a specific protein, called an enzyme, which has a particular effect in the cell in which it is produced. In 1941, Beadle and Tatum established the gene-enzyme hypothesis, showing that one gene was responsible for the production of one specific enzyme (known famously as 'one gene, one enzyme').

genetic engineering

Genetic engineering consists of a collection of methods used to manipulate genes. The first of these techniques dates back to 1952 when Joshua Lederberg found that bacteria exchange genetic material contained in a body he called a plasmid. The next year it was established that plasmids were rings of DNA free from the main DNA in the chromosome of the bacteria. The next step was taken by Werner Arber (1929–), who studied viruses (called bacteriophages) which infect bacteria. He found that bacteria resist phages by splitting the phage DNA using enzymes. By 1968 Arber had discovered the enzymes produced by bacteria that split DNA at specific locations. In addition, he found that different genes that have been split at the same location by one of the restriction enzymes, as they are called, will recombine when placed together in the absence of the enzyme. The resulting product is called recombinant DNA.

In 1973 Stanley H Cohen (1922–) and US organic chemist Herbert W Brown (1912–) combined restriction enzymes with plasmids in the first genetic engineering experiment. They cut a chunk out of a plasmid found in the bacterium *Eschericia coli* and inserted in the gap a gene created from a different bacterium. In 1976 Indian chemist Har Gobind Khorana (1922–) and co-workers constructed the first artificial gene to function naturally when inserted into a bacterial cell.

In 1995 a team at the Institute for Genomic Research in Gaitherburg, Maryland, USA, unveiled the first complete genetic blueprint for a free-living organism – a bacterium *Haemophilus influenza*. In theory, the blueprint, consisting of 1.8 million genetic instructions, would allow scientists to construct the bacterium from scratch. The achievement demonstrates the speed of the DNA decoding techniques used by genetic researchers.

A logical progression from such research resulted in the production of useful genetically engineered products. In 1977, the US biochemist Herbert Boyer (1936–), of the firm Genentech, fused a segment of human DNA (deoxyribonucleic acid) into the bacterium *Escherichia coli*, allowing it to produce a human protein (in this case somatostatin). This was the first commercially produced genetically engineered product.

Now this technology has moved on, to the point where genetically engineered bacteria and yeasts are used almost routinely to produce useful products such as human growth hormone and insulin. These essential drugs were amongst the first genetically engineered products to go on sale.

In recent years it has become possible to use genetic engineering techniques to alter the genetic makeup of plants. This offers the possibility of creating new varieties of species, notably crops, with specific new characteristics. For example, resistance to low temperatures can be introduced to crops from warm climates, so they may be grown successfully elsewhere, as can resistance to insect pests and virus diseases. Work is under way with cassava (a staple tropical crop) to introduce disease resistance, and to increase its protein content. Genetically modified (GM) crops are now produced in many parts of the world, and are beginning to appear in shops alongside their more 'natural' relatives.

genetics and medicine

The application of genetic engineering to medicine has progressed rapidly. The Human Genome Organization was established 1988 in Washington, DC, with the aim of mapping the complete sequence of human DNA. In 1985 the first human cancer gene was isolated by US researchers. In 1993 the gene for Huntington's disease was discovered.

The first person to undergo gene therapy (in September 1990) was a four-year-old girl suffering from a rare enzyme (ADA) deficiency that cripples the immune system. A healthy ADA gene was inserted into a virus that had been rendered harmless. The virus was inserted into a blood-forming cell taken from the child's bone marrow. This cell reproduced, creating millions of cells containing the missing gene. Finally these cells were infused into the child's bloodstream, to be carried to the bone marrow where they produced healthy blood cells complete with the ADA gene. This was only partially successful in that the child still required additional treatment with synthetic ADA.

The final years of the 20th century saw further developments in genetic engineering, many of which have important implications for medicine. It is now possible to produce what are known as transgenic animals, by injecting genes from one animal into the fertilized egg of another. This technique was first perfected in 1981 by scientists at Ohio University, USA, who injected genes from one animal into the fertilized egg of a mouse. The resulting transgenic mouse then has the foreign gene in many of its cells, and the gene is passed on to its offspring, creating permanently altered (transgenic) animals. In 1982, for example, a gene controlling growth was transferred from a rat to a mouse, producing a transgenic mouse which grew to double its normal size.

Such transgenic techniques promise to benefit medicine, and in particular transplant surgery. One of the major problems in surgery has been in transplanting organs – the main difficulties being the supply of suitable organs, and the process of rejection by the host. Transgenic pigs have now been bred which incorporate some human genes which reduce the risk of tissue rejection when the pigs' organs are transplanted into human patients, in a process called xenotransplantation.

Parallel research has established that it may soon be possible to grow kidneys which are derived from embryo kidney cells. If successful, these techniques could simultaneously address the twin problems of supply and rejection of human organs. Nevertheless, such research has raised difficult ethical problems which have yet to be fully resolved.

Many of the rapid advances in animal genetic engineering are of direct medical benefit to people. Examples of products now able to be manufactured from engineered animals are: human blood clotting factors, from sheep and goats; human growth hormone and beta-interferon from cattle; and humanized organs for transplant from pigs. Beta-interferon is used to treat multiple sclerosis.

human evolution

The 20th century saw major discoveries of human fossils, which helped to shed light on the evolution of our own species. Around the turn of the century, fossils of a species called *Homo erectus* (Java Man) were discovered. This humanlike creature (hominid) lived between 0.5 and 1.5 million years ago. In the

1920s and 1930s, an even older form was discovered, and named in a separate genus *Australopithecus*. This hominid lived between about 1 and 2 million years ago.

Since the 1950s, even older forms of *Australopithecus* have come to light, in Africa. More recently, in 1994, *Australopithecus ramidus* has been dated at 4.4 million years old. This form was probably mainly vegetarian and lived in a woodland habitat. Like humans, it walked upright on its hind legs.

In the 1960s and 70s, a form regarded as intermediate between modern humans (*Homo sapiens*) and *Australopithecus* was found in Africa. This was named in 1964, by British archaeologist, anthropologist and palaeontologist Louis Leakey (1903–1972), South African anatomist and physical anthropologist Philip Tobias (1925-), and others, *Homo habilis* (Handy Man), after its apparent use of stone tools. The fossils came from the now famous Olduvai Gorge in Tanzania, and have been dated at between 1.6 and 2 million years ago.

Various further finds of *Homo erectus* (named for its humanlike upright stance) have been made, in Africa and in Europe, mainly in northern Kenya, but also in Algeria, Morocco, Ethiopia, and South Africa. The most likely story emerging is that this form originated in Africa, then spread to Europe and Asia. *Homo erectus* probably used tools made of wood, such as handaxes, and were hunters and gatherers, with a mixed diet.

The techniques of genetics and biochemistry were also applied to physical anthropology, and analyses of protein and DNA from fossils and living humans and apes were undertaken. These studies revealed that modern humans are more closely related to chimpanzees and pygmy chimpanzees (bonobos) than either are to gorillas, gibbons, and orangutans. They also helped shed light on the evolutionary pathways on the fossil hominid line.

Analysis of DNA and fossils suggests that modern humans are only a few hundred thousand years old, and that the evolutionary split between humans and apes occurred between 5 and 8 million years ago, probably in Africa. Our own species, *Homo sapiens* (Wise Man) emerged as recently as around 400,000 years ago. All living people are closely related, and probably share a common ancestor in Africa.

A form of human, *Homo neanderthalensis*, known as Neanderthal Man (from the Neander valley in Germany where it was first discovered) evolved in Europe around 200,000 years ago. A genetic analysis carried out on DNA extracted from fossil Neanderthal bones indicated in 1997 that Neanderthals shared a common ancestor with modern humans no later than 600,000 years ago, and proved conclusively that they were not our direct ancestors but represent a separate evolutionary line.

extinction and the discovery of new species

More than 99.9% of all evolutionary lines that once existed on Earth have become extinct, so extinction has loomed large in the history of life on Earth, and continues to feature in the natural world today. On the other hand, our knowledge of the natural world is still so sparse that species are still being discovered and described.

Discoveries by palaeontologists and geologists have helped to explain the apparently catastrophic extinctions which seem to have occurred from time to time in the distant past. The most famous of these was the relatively sudden demise of the dinosaurs towards the end of the Cretaceous period.

Analysis of a clay layer in deposits dated at the boundary of the Cretaceous and Tertiary periods by US physicists Walter and Luis Alvarez in 1980 revealed unusually rich traces of the heavy metal iridium. It was then found that this enriched iridium layer was present in similar aged deposits worldwide. The Alvarezes proposed the theory that this was caused by the impact on the Earth of a large asteroid, which might have had other ecological effects which explain the sudden extinction of many creatures, including the dinosaurs.

US palaeontologists looked at other mass extinctions of the past, and found that these were periodic, happening around every 26 million years. They developed the theory that something periodically disturbed the cloud of comets (known as the Oort cloud) at the edge of our Solar System, causing some of the comets to fall towards the Sun, occasionally hitting the Earth or other planets.

As we reach the end of the 20th century, new species of animals and plants are still being discovered and described. Expeditions to tropical rainforests routinely find undescribed insects, notably beetles, but there have also been recent discoveries of new vertebrates, even some quite large mammals. For example, a new species of whale from Chile was described in 1996, and a new species of muntjac deer from Vietnam in 1997 and another in 1999.

In 1995 a new phylum (a group of creatures that share a distinct body plan) was discovered. The phylum, Cycliophora, is only the 36th ever described for all the 1.5 million or so named organisms. Most other phyla were described in the 1800s. A single species has so far been assigned to the phylum. *Symbion pandora* is a tiny creature found clinging to the mouthparts of Norwegian lobsters by zoologists at the University of Copenhagen.

Physics

introduction

Physics is a branch of science in which the theoretical and the practical are firmly intertwined. It has been so since ancient times, as physicists have striven to interpret observation or experiment in order to arrive at the fundamental laws that govern the behaviour of the universe. Physicists aim to explain the manifestations of matter and energy that characterize all things and processes, both living and inanimate, extending from the grandest of galaxies down to the most intimate recesses of the atom. The history of physics has not been a straight and easy road to enlightenment. The exploration of new directions sometimes leads to dead ends. New ways of looking at things may result in the overthrow of a previously accepted system. Not Aristotle's system, nor Newton's, nor even Einstein's was 'true'; rather statements, or 'laws', in physics satisfy contemporary requirements or – in the existing state of knowledge – contemporary possibilities. The question that physicists ask is not so much 'Is it true?' as 'Does it work?' Physics has many strands – such as mechanics, heat, light, sound, electricity, and magnetism – and, although they are often pursued separately, they are also all ultimately interdependent. To pursue the history of physics, therefore, it is necessary to follow several separate chains of discovery and then to find the links between them. The story is of frustration and missed opportunities as well as of genius and perseverance. But however complex it may appear, all physicists seek or have sought to play a part in the evolution of an ultimate explanation of all the effects that occur throughout the universe. That goal may be unattainable but the thrust towards it has kept physics as alive and vital today as it was when it originated in ancient times.

force and motion

The development of an understanding of the nature of force and motion was a triumph for physics, one which marked the evolution of the scientific method. As in most other branches of physics, this development began in ancient Greece. The earliest discovery in physics, apart from observations of effects like magnetism, was the relation between musical notes and the lengths of vibrating strings. The religious philosopher Pythagoras (*c.* 582-*c.* 497 BC) found that harmonious sounds were given by strings whose lengths were in simple numerical ratios, such as 2:1, 3:2 and 4:3. From this discovery the belief grew that all explanations could be found in terms of numbers. This was developed by mathematician and philosopher Plato (*c.* 427-*c.* 347 BC) into a conviction that the cause underlying any effect could be expressed in mathematical form. The motion of the heavenly bodies, Plato reasoned, must consist of circles, since these were the most perfect geometric forms.

atoms

Reason also led the philosopher Democritus (*c.* 470-*c.* 380 BC) to propose that everything consisted of minute indivisible particles called atoms. The properties of matter depend on the characteristics of the atoms of which it is composed, and the atoms combine in ways that are determined by unchanging fundamental laws of nature.

Aristotle's four elements

A third view of the nature of matter was given by the Greek polymath Aristotle (384-322 BC), who endeavoured to interpret the world as he observed it, without recourse to abstractions such as atoms and mathematics. Aristotle reasoned that matter consisted of four elements - earth, water, air and fire - with a fifth element, the ether, making up the heavens. Motion occurred when an object sought its rightful place in the order of elements, rocks falling through air and water to the earth, air rising through water as bubbles and fire through air as smoke. There was value in all these approaches and physics has absorbed them all to some degree. Plato was essentially correct; only his geometry was wrong, the planets following elliptical, not circular, orbits. Atoms do exist as Democritus foretold and they do explain the properties of matter. Aristotle's emphasis on observation (though not his reasoning) was to be a feature of physics and many other sciences, notably biology, of which he may be considered the founder.

Archimedes' scientific method

These ideas were, however, mainly deductions based solely on reason. Few of them were given the test of experiment to prove that they were right. Then came the achievements of mathematician and physicist Archimedes (*c.* 287-212 BC), who discovered the law of the lever and the principle of flotation by measuring the effects that occur and deduced general laws from his results. He was then able to apply his laws, building pulley systems and testing the purity of the gold in King Hieron's crown by a method involving immersion. Archimedes thus gave physics the scientific method. All subsequent principal advances made by physicists were to take the form of mathematical interpretations of observations and experiments. Archimedes developed the method in founding the science of statics - how forces interact to produce equilibrium. But an understanding of motion lay a long way off. In the centuries following the collapse of Greek civilization in around AD 100, physics marked time. The Arabs kept the Greek achievements alive, but they made few advances in physics, while in Europe the scientific spirit was overshadowed by the 'Dark Ages'. Then in about 1200, the spirit of enquiry was rekindled in Europe by the import of Greek knowledge from the Arabs. Unfortunately, progress was hindered somewhat by the fact that Aristotle's ideas, particularly his views on motion, prevailed. Aristotle had assumed that a heavy object falls faster than a light object simply because it is heavier. He also argued that a stone continues to move when thrown because the air displaced by the stone closes behind it and pushes the stone. This explanation derived from Aristotle's conviction that nature abhors a vacuum (which is why he placed a fifth element in the heavens).

gravity and Newton's laws of motion

Aristotle's ideas on falling bodies were probably first disproved by the Flemish scientist Simon Stevinus (1548-1620), who is believed to have dropped unequal weights from a height and found that they reached the ground together. At about the same time Italian physicist and astronomer Galileo (1564-1642) measured the speeds of 'falling' bodies by rolling spheres down an inclined plane and discovered the laws that govern the motion of bodies under gravity. This work was brought to a brilliant climax by English physicist and mathematician Isaac Newton (1642-1727), who in his three laws of motion achieved an understanding of force and motion, relating them to mass and recognizing the existence of inertia and momentum. Newton thus explained why a stone continues to move when thrown; and he showed the law of falling bodies to be a special case of his more general laws. Newton went on to derive, from existing knowledge of the motion and dimensions of the Earth-Moon system, a universal law of gravitation which provided a mathematical statement for the laws of planetary motion discovered empirically by the German astronomer Johann Kepler (1571-1630). Newton's laws of motion and gravitation, which were published in 1687, were fundamental laws which sought to explain all observed effects of force and motion. This triumph of the scientific method heralded the Age of Reason - not the Greek kind of reasoning, but a belief that all could be explained by the deduction of fundamental laws upheld by observation or experiment. It was to result in an explosion of scientific discovery in physics that has continued to the present day. In the field of force and motion, important advances were made with the discovery of the law governing the pendulum and the principle of conservation of momentum by Dutch physicist and astronomer Christiaan Huygens (1629-1695) and the determination of the gravitational constant by English natural philosopher Henry Cavendish (1731-1810).

the behaviour of matter

Physics is basically concerned with matter and energy, and investigation into the behaviour of matter also originated in ancient Greece with Archimedes' work concerning flotation. As with force and motion, Simon Stevinus made the first post-Greek advance with the discovery that the pressure of a liquid depends on its depth and area. This achievement was developed by French mathematician and physicist Blaise Pascal (1623-1662), who found that pressure is transmitted throughout a liquid in a closed vessel, acting perpendicularly to the surface at any point. Pascal's principle is the basis of hydraulics. Pascal also investigated the mercury barometer invented in 1643 by the Italian physicist and mathematician Evangelista Torricelli (1608-1647) and showed that air pressure supports the mercury column and that there is a vacuum above it, thus disproving Aristotle's contention that a vacuum cannot exist. The immense pressure that the atmosphere can exert was subsequently demonstrated in several sensational experiments by German physicist Otto von Guericke (1602-1686). Solid materials were also investigated. The fundamental law of elasticity was discovered by English physicist Robert Hooke (1635-1703) in 1678 when he found that the stress (force) exerted is proportional to the strain (elongation) produced. English physicist and physician Thomas Young (1773-1829) later showed that a given material has a constant, known as Young's modulus, that defines the strain produced by a particular stress. The effects that occur with fluids (liquids or gases) in motion were then explored. Swiss philosopher and mathematician Daniel Bernoulli (1700-1782) established hydrodynamics with his discovery that the pressure of a fluid depends on its velocity. Bernoulli's principle explains how lift occurs and led eventually to the invention of heavier-than-air flying machines. It also looked forward to ideas of the conservation of energy and the kinetic theory of gases. Other important advances in our understanding of fluid flow were later made by Irish physicist George Stokes (1819-1903), who discovered the law that relates motion to viscosity, and Austrian physicist Ernst Mach (1838-1916) and German physicist Ludwig Prandtl (1875-1953), who investigated the flow of fluids over surfaces and made discoveries vital to aerodynamics.

the effects of light

The Greeks were aware that light rays travel in straight lines, but they believed that the rays originate in the eyes and travel to the object that is seen. Euclid (*c.* 330-260 BC), Hero (lived AD 60) and Ptolemy (lived 2nd century AD) were of this opinion although, recognizing that optics is essentially a matter of geometry, they discovered the law of reflection and investigated refraction. Optics made an immense stride forward with the work of Arabian scientist Alhazen (*c.* 965-1038), who was probably the greatest scientist of the Middle Ages. Alhazen recognized that light rays are emitted by a luminous source and are then reflected by objects into the eyes. He studied images formed by curved mirrors and lenses and formulated the geometrical optics involved. Alhazen's discoveries took centuries to filter into Europe, where they were not surpassed until the 17th century. The refracting telescope was then invented in Holland in 1608 and quickly improved by Galileo and Kepler, and in 1621 Dutch physicist Willebrord Snel (1580-1626) discovered the laws that govern refraction.

the discovery of the spectrum

The next major steps forward were taken by Newton, who not only invented the reflecting telescope in 1668, but a couple of years earlier found that white light is split into a spectrum of colours by a prism. Newton published his work on optics in 1704, provoking great controversy with his statement that light consists of a stream of particles. Huygens had put forward the view that light consists of a wave motion, an opinion reinforced by the discovery of diffraction by Italian physicist Francesco Grimaldi (1618-1663). Such was Newton's reputation, however, that the particulate theory held sway for the following century. In 1801 Young discovered the principle of interference, which could be explained only by assuming that light consisted of waves. This was confirmed in 1821, when French physicist Augustin Fresnel (1788-1827) showed from studies of polarized light, which had been discovered by another French physicist Étienne Malus (1775-1812) in 1808, that light is made up of a transverse wave motion, not longitudinal as had previously been thought. Newton's discovery of the spectrum remained little more than a curiosity until 1814, when German physicist and optician Joseph von Fraunhofer (1787-1826) discovered that the Sun's spectrum is crossed by the dark lines now known as Fraunhofer lines. Fraunhofer was unable to explain the lines, but he did go on to invent the diffraction grating for the production of high-quality spectra and the spectroscope to study them. An explanation of the lines was provided by the German physicist Gustav Kirchhoff (1824-1887), who in 1859 showed that they are caused by elements present in the Sun's atmosphere. With German chemist Robert Bunsen (1811-1899), Kirchhoff discovered that elements have unique spectra by which they can be identified, and several new elements were found in this way. In 1885, Swiss mathematics teacher Johann Balmer (1825-1898) derived a mathematical relationship governing the frequencies of the lines in the spectrum of hydrogen. This later proved to be a crucial piece of evidence for revolutionary theories of the structure of the atom. Meanwhile, several scientists investigated the phenomenon of colour, notably Young, German physicist and physiologist Hermann von Helmholtz (1821-1894) and Scottish physicist James Clerk Maxwell (1831-1879). Their research led to the establishment of the three-colour theory of light, which showed that the eye responds to varying amounts of red, green, and blue in light and mixes them to give particular colours. This led directly to colour photography and other methods of colour reproduction used today.

the speed of light

The velocity of light was first measured accurately in 1862 by French physicist Jean Foucault (1819-1868), who obtained a value within 1% of the correct value. This led to a famous experiment performed by German-born US physicist Albert Michelson (1852-1931) and US physicist and chemist Edward Morley (1838-1923) in which the velocity of light was measured in two directions at right angles. Their purpose was to test the theory that a medium called the **ether** existed to carry light waves. If it did exist, then the two values obtained would be different. The Michelson-Morley experiment, performed in 1881 and then again in 1887, yielded a negative result both times (and on every occasion since), thus proving that the ether does not exist. More important, the Michelson-Morley experiment showed that the velocity of light is constant regardless of the motion of the observer. From this result, and from the postulate that all motion is relative, German-born US theoretical physicist Albert Einstein (1879-1955) derived the special theory of relativity in 1905. The principal conclusion of special relativity is that in a system moving relative to the observer, length, mass and time vary with the velocity. The effects become noticeable only at velocities approaching light; at slower velocities, Newton's laws hold good. Special relativity was crucial to the formulation of new ideas of atomic structure and it also led to the idea that mass and energy are equivalent, an idea used later to explain the great power of nuclear reactions. In 1915 Einstein published his general theory of relativity, in which he showed that gravity distorts space. This explained an anomaly in the motion of Mercury, which does not quite obey Newton's laws, and it was dramatically confirmed in 1919 when a solar eclipse revealed that the Sun's gravity was bending light rays coming from stars.

electricity and magnetism

The phenomena of electricity and magnetism are believed to have been first studied by the ancient Greek philosopher Thales (624-546 BC), who was considered by the Greeks to be the founder of their science. Thales found that a piece of amber picks up light objects when rubbed, the action of rubbing thus producing a charge of static electricity. The words 'electron' and 'electricity' came from this discovery, *elektron* being the Greek word for amber. Thales also studied the similar effect on each other of pieces of lodestone, a magnetic mineral found in the region of Magnesia. It is fitting that the study of electricity and magnetism originated together, for the later discovery that they are linked was one of the most important ever made in physics. No further progress was made, however, for nearly 2,000 years. The strange behaviour of amber remained no more than a curiosity, though magnets were used to make compasses. From this, French scientist and scholar Petrus Peregrinus (lived 13th century) discovered the existence of north and south poles in magnets and realized that they attract or repel each other. English physician and physicist William Gilbert (1544-1603) first explained the Earth's magnetism and also investigated electricity, finding other substances besides amber that produce attraction when rubbed. Then French chemist Charles Du Fay (1698-1739) discovered that substances charged by rubbing may repel as well as attract in a similar way to magnetic poles, and US scientist Benjamin Franklin (1706-1790) proposed that positive and negative charges are produced by the excess or deficiency of electricity. French physicist Charles Coulomb (1763-1806) measured the forces produced between magnetic poles and between electric charges and found that they both the same inverse square law.

the invention of the battery

A major step forward was taken in 1800, when Italian physicist Alessandro Volta (1745-1827) invented the battery. A source of current electricity was now available and in 1820 Danish physicist Hans Oersted (1777-1851) found that an electric current produces a magnetic field. This discovery of electromagnetism was immediately taken up by English physicist Michael Faraday (1791-1867), who realized that magnetic lines of force must surround a current. This concept led him to discover the principle of the electric motor in 1821 and electromagnetic induction in 1831, the phenomenon in which a changing magnetic field produces a current. This was independently discovered by US physicist Joseph Henry (1797-1878) at the same time.

electrical theory

Meanwhile, important theoretical developments were taking place in the study of electricity. In 1827, French physicist André Ampère (1775-1836) discovered the laws relating magnetic force to electric current and also properly distinguished current from tension, or EMF. In the same year, German physicist Georg Ohm (1789-1854) published his famous law relating current, EMF and resistance. Kirchhoff later extended Ohm's law to networks, and he also unified static and current electricity by showing that electrostatic potential is identical to EMF. In the 1830s, German mathematician, physicist, and philosopher Carl Gauss (1777-1855) and German physicist Wilhelm Weber (1804-1891) defined a proper system of units for magnetism; later they did the same for electricity. In 1845 Faraday found that materials are paramagnetic or diamagnetic, and Irish physicist Lord Kelvin (1824-1907) developed Faraday's work into a full theory of magnetism. An explanation of the cause of magnetism was finally achieved in 1905 by French physicist Paul Langevin (1872-1946), who ascribed it to electron motion. Electricity and magnetism were finally brought together in a brilliant theoretical synthesis by James Clerk Maxwell. From 1855 to 1873 Maxwell developed the theory of electromagnetism to show that electric and magnetic fields are propagated in a wave motion and that light consists of such an electromagnetic radiation. Maxwell predicted that other similar electromagnetic radiations must exist and, as a result, German physicist Heinrich Hertz (1857-1894) produced radio waves in 1888. X-rays and gamma rays were discovered accidentally soon after.

the nature of heat and energy

The first step towards measurement - and therefore an understanding - of heat was taken by Galileo, who constructed the first crude thermometer in 1593. Gradually these instruments improved and in 1714 Polish-born Dutch physicist Daniel Fahrenheit (1686-1736) invented the mercury thermometer and devised the Fahrenheit scale of temperature. This was replaced in physics by the Celsius or Centigrade scale proposed by Swedish astronomer, mathematician, and physicist Anders Celsius (1701-1744) in 1742. At this time, heat was considered to be a fluid called caloric that flowed into or out of objects as they got hotter or colder, and even after 1798 when US-born physicist Count Rumford (Benjamin Thompson; 1753-1814) showed the idea to be false by his observation of the boring of cannon, it persisted. Earlier Scottish physicist and chemist Joseph Black (1728-1799) had correctly defined the quantity of heat in a body and the latent heat and specific heat of materials, and his values had been successfully applied to the improvement of steam engines. In 1824, French physicist Sadi Carnot (1796-1832), also a believer in the caloric theory, found that the amount of work that can be produced by an engine is related only to the temperature at which it operates. Carnot's theorem, though not invalidated by the caloric theory, suggested that, since heat gives rise to work, it was likely that heat was a form of motion, not a fluid. The idea also grew that energy may be changed from one form to another (that is from heat to motion) without a change in the total amount of energy involved. The interconvertibility of energy and the principle of the conservation of energy were established in the 1840s by several physicists. German physicist Julius Mayer (1814-1878) first formulated the principle in general terms and obtained a theoretical value for the amount of work that may be obtained by the conversion of heat (the mechanical equivalent of heat). Helmholtz gave the principle a firmer scientific basis and English physicist James Joule (1818-1889) made an accurate experimental determination of the mechanical equivalent. German theoretical physicist Rudolf Clausius (1822-1888) and Kelvin developed the theory governing heat and work, thus founding the science of thermodynamics. This enabled Kelvin to propose the absolute scale of temperature that now bears his name. The equivalence of heat and motion led to the kinetic theory of gases, which was developed by Scottish physicist John Waterston (1811-1883), Clausius, Maxwell, and Austrian theoretical physicist Ludwig Boltzmann (1844-1906) between 1845 and 1868. It gave a theoretical description of all effects of heat in terms of the motion of molecules.

heat radiation - quantum theory

During the 19th century it also came to be understood that heat may be transmitted by a form of radiation. Pioneering theoretical work on how bodies exchange heat had been carried out by Swiss physicist Pierre Prévost (1751-1839) in 1791, and the Sun's heat radiation had been discovered to consist of infrared rays by German-born British astronomer William Herschel (1738-1822) in 1800. In 1862 Kirchhoff derived the concept of the perfect black body - one that absorbs and emits radiation at all frequencies. In 1879 Austrian physicist Josef Stefan (1835-1893) discovered the law relating the amount of energy radiated by a black body to its temperature, but physicists were unable to relate the frequency distribution of the radiation to the temperature. This increases as the temperature is raised, causing an object to glow red, yellow and then white as it gets hotter. English physicist Lord Rayleigh

(1842-1919) and German physicist Wilhelm Wien (1864-1928) derived incomplete theories of this effect, and then in 1900 another German physicist Max Planck (1858-1947) showed that it could be explained only if radiation consisted of indivisible units, called quanta, whose energy was proportional to their frequency. Planck's quantum theory revolutionized physics. It showed that heat radiation and other electromagnetic radiations including light must consist of indivisible particles of energy and not of waves as had previously been thought. In 1905 Einstein found a ready explanation of the photoelectric effect using quantum theory, and the theory was experimentally confirmed by German-born US physicist James Franck (1882-1964) in the early 1920s.

low temperature physics

Another advance in the study of heat that took place in the same period was the production of low temperatures. In 1852 Joule and Kelvin found the effect named after them is used to produce refrigeration by adiabatic expansion of a gas, and Scottish physicist and chemist James Dewar (1842-1923) developed this effect into a practical method of liquefying gases from 1877 onwards. Dutch physicist Heike Kamerlingh-Onnes (1853-1926) first produced temperatures within a degree of absolute zero and in 1911 he discovered superconductivity. A theoretical explanation of superconductivity had to await the work of US physicists John Bardeen (1908-1991), Leon Cooper (1930-), and John Schrieffer (1931-). Their ideas, the 'BCS theory', explained superconductivity as the result of electrons coupling in pairs, called Cooper pairs, that do not undergo scattering by collision with atoms in a conductor. In 1986 IBM researchers in Zurich, Georg Bednorz (1950-) and Alex Müller (1927-), produced superconductivity in metallic ceramics at relatively high temperatures, around 35K. The theoretical explanation of high-temperature superconductivity was still being developed in the early 1990s. In 1995 scientists at the University of Colorado discovered a new form of matter when they used lasers and magnetic fields to cool rubidium atoms to within 20 billionths of a degree of absolute zero. For a brief time, the atoms lost their individuality and behaved as if they were part of a single giant atom. This type of material is called a Bose-Einstein condensate.

sound

Sound is the one branch of physics that was well established by the Greeks, especially by Pythagoras. They surmised, correctly, that sound does not travel through a vacuum, a contention proved experimentally by Guericke in 1650. Measurements of the velocity of sound in air were made by French physicist and philosopher Pierre Gassendi (1592-1655) and in other materials by German physicist August Kundt (1839-1894). Another German physicist, Ernst Chladni (1756-1827), studied how the vibration of surfaces produces sound waves, and in 1845 Austrian physicist Christian Doppler (1803-1853) discovered the effect relating the frequency (pitch) of sound to the relative motion of the source and observer. The Doppler effect is also produced by light and other wave motions and has proved to be particularly valuable in astronomy.

the structure of the atom

The existence of atoms was proved theoretically by chemists during the 19th century, but the first experimental demonstration of their existence and the first estimate of their dimensions was made by French physicist Jean Perrin (1870-1942) in 1909. The principal direction taken in physics in this century has been to determine the inner structure of the atom. It began with the discovery of the electron in 1897 by English physicist J J Thomson (1856-1940), who showed that cathode rays consist of streams of minute indivisible electric particles. The charge and mass of the electron were then found by Irish mathematical physicist John Townsend (1868-1937) and US physicist Robert Millikan (1868-1953).

radioactivity

Meanwhile, another important discovery had been made with the detection of radioactivity by French physicist Antoine Becquerel (1852-1908) in 1896. Three kinds of radioactivity were found; these were named alpha, beta, and gamma by New Zealand-born British physicist Ernest Rutherford (1871-1937). Becquerel recognized in 1900 that beta particles are electrons. In 1903 Rutherford explained that radioactivity is caused by the breakdown of atoms. In 1908 he identified alpha particles as helium nuclei, and in association with German physicist Hans Geiger (1882-1945) produced the nuclear model of the atom in 1911, proposing that it consists of electrons orbiting a nucleus. Then in 1914 Rutherford identified the proton and in 1919 he produced the first artificial atomic disintegration by bombarding nitrogen with alpha particles. Rutherford's pioneering elucidation of the basic structure of the atom was aided by developments in the use of X-rays, which had been discovered in 1895 by German physicist Wilhelm Röntgen (1845-1923). In 1912 German physicist Max von Laue (1879-1960) produced diffraction in X-rays by passing them through crystals, showing X-rays to be electromagnetic waves, and English physicist Lawrence Bragg (1890-1971) developed this method to determine the arrangement of atoms in crystals. His work influenced English physicist Henry Moseley (1887-1915), who in 1914 found by studying X-ray spectra that each element has a particular atomic number, equal to the number of protons in the nucleus and to the number of electrons orbiting it. In 1913, Danish physicist Niels Bohr (1885-1962) achieved a brilliant synthesis of Rutherford's nuclear model of the atom and Planck's quantum theory. He showed that the electrons must move in orbits at particular energy levels around the nucleus. As an atom emits or absorbs radiation, it moves from one orbit to another and produces or gains a certain number of quanta of energy. In so doing the quanta give rise to particular frequencies of radiation, producing certain lines in the spectrum of the radiation. Bohr's theory was able to explain the spectral lines of hydrogen and their relationship, found earlier by Balmer.

wave-particle theory

These discoveries, made so quickly, seemed to achieve an astonishingly complete picture of the atom, but more was to come. In 1923, French physicist Louis de Broglie (1892-1987) described how electrons could behave as if they made up waves around the nucleus. This discovery was developed into a theoretical system of wave mechanics by Austrian physicist Erwin Schrödinger (1887-1961) in 1926 and experimentally confirmed in the following year. It showed that electrons exist both as particles and waves. Furthermore it reconciled Planck's quantum theory with classical physics by indicating that electromagnetic quanta or photons, which were named and detected experimentally in X-rays by US physicist Arthur Compton (1892-1962) in 1923, could behave as waves as well as particles. A prominent figure in the study of atomic structure was German physicist Werner Heisenberg (1901-1976), who showed in 1927 that the position and momentum of the electron in the atom cannot be known precisely, but only found with a degree of probability or uncertainty. His uncertainty principle follows from wave-particle duality and it negates cause and effect, an uncomfortable idea in a science that strives to reach laws of universal application. The next step was to investigate the nucleus. A series of discoveries of nuclear particles accompanying the proton were made, starting in 1932 with the discovery of the positron by US physicist Carl Anderson (1905-1991) and the neutron by English physicist James Chadwick (1891-1974). This work was aided by the development of particle accelerators, beginning with the voltage multiplier built by English physicist John Cockcroft (1897-1967) and Irish physicist Ernest Walton (1903-1995), which achieved the first artificial nuclear transformation in 1932. It led to the discovery of nuclear fission by German radiochemist Otto Hahn (1879-1968) in 1939 and the production of nuclear power by Italian-born US physicist Enrico Fermi (1901-1954) in 1942. Fusion power, the release of energy by combining lighter nuclei into heavier ones, was achieved in the first hydrogen bomb, exploded in 1952. The struggle to harness fusion energy for peaceful purposes still continues. The development of accelerators has continued until it has produced the largest scientific instrument ever built. The Large Electron-Positron (LEP) collider at CERN, the European Laboratory for Particle Physics near Geneva, Switzerland, is a ring 27 km/16 mi in circumference. Bunches of particles are accelerated to close to the speed of light, and then circulate, perhaps for hours, in storage rings, before being allowed to collide head-on with another stream of particles circulating in the opposite direction. Early in the 21st century the LEP's tunnel will also house the Large Hadron Collider (LHC) which will accelerate protons and other particles through a trillion volts.

particle physics

Much of modern physics has been concerned with the behaviour of elementary particles. The first major theory in this area was quantum electrodynamics (QED), developed by US physicists Richard Feynman (1918-1988) and Julian Schwinger (1918-1994), and by Japanese physicist Sin-Itiro Tomonaga (1906-1979). This theory describes the interaction of charged subatomic particles in electric and magnetic fields. It combines quantum theory and relativity and considers charged particles to interact by the exchange of photons. QED is remarkable for the accuracy of its predictions - for example, it has been used to calculate the value of some physical quantities to an accuracy of ten decimal places, a feat equivalent to calculating the distance between New York and Los Angeles to within the thickness of a hair. By 1960 the existence of around 200 elementary particles had been established, some of which did not behave as theory predicted. They did not decay into other particles as quickly as theory predicted, for example. To explain these anomalies, US theoretical physicist Murray Gell-Mann (1929-) developed a classification for elementary particles, called the eightfold way. This scheme predicted the existence of previously undetected particles. The omega-minus particle found in 1964 confirmed the theory. In the same year Gell-Mann suggested that some elementary particles were made up of smaller particles called quarks which could have fractional electric charges. This idea explained the eightfold classification and now forms the basis of the standard model of elementary particles and their interactions. The details of the standard model have been confirmed by experiment. In 1991 experiments at CERN, the European particle physics laboratory at Geneva, confirmed the existence of three generations of elementary particles, each with two quarks and leptons (light particles) as predicted by the standard model. In 1995 researchers at Fermilab discovered the top quark, the final piece of evidence in support of the standard model. Quantum chromodynamics (QCD) is the mathematical theory, similar in many ways to quantum electrodynamics, which describes the interactions of quarks by the exchange of particles called gluons. The mathematics involved is very complex and although a number of successful predictions have been made, as yet the theory does not compare in accuracy with QED. The success of the mathematical methods of QED and QCD encouraged others to use these methods to unify the theory of the fundamental forces. Pakistani theoretical physicist Abdus Salam (1926-1996) and US physicists Steven Weinberg (1933-) and Sheldon Glashow (1932-) demonstrated that at high energies the electromagnetic and weak nuclear force could be regarded as aspects of a single combined force, the electroweak force. This was confirmed in 1983 by the discovery of new particles predicted by the theory. In the 1980s a mathematical theory called string theory was developed, in which the fundamental objects of the universe were not pointlike particles but extremely small stringlike objects. These objects exist in a universe of ten dimensions, although for reasons which are not yet understood, only three space dimensions and one time dimension are discernible. There are many unresolved difficulties, but some physicists think that string theory, or some variant of it, could develop into a 'theory of everything' that explains space-time, together with the elementary particles and their interactions, within one comprehensive framework.

the convergence of particle physics and cosmology

Physical theory, even in its incomplete state, can give an account of the history of the universe from a fraction of a second after its birth. The Big Bang took place about 15 billion years ago. Cosmologists work out what happened at each succeeding instant by using the knowledge gained in particle accelerators, where the energies involved in particle collisions momentarily equal those prevailing at various stages of the Big Bang. At the birth of the universe space, time, matter, and energy appeared together: the first split second was a chaos of radiation and particles existing fleetingly, in a universe swelling from the size of an atom. Though the universe had a limited volume, there was nothing outside it - space curved back on itself in a way that only the equations of relativity can describe. The cosmic fireball expanded, thinned, and cooled. Present-day theories can be applied only back to a time 10^{-43} second after the beginning: before this, time and space are ripped apart by the incredible density and temperature (10^{32}K) of the universe. There was only one 'superforce' acting, and we have no theory to deal with it yet. After this time, gravity appeared as a separate force. At 10^{-35} second the strong force separated out. At 10^{-12} second, electromagnetism split off from the weak force. The universe was a soup of exotic particles, including single quarks, as well as high-energy gamma photons. When the universe was a millionth of a second old, its temperature had fallen to 10 trillion K, and quarks began to combine, forming protons, neutrons, and mesons. As the temperature fell still further these were able to combine and stay together, forming various types of light nuclei. This process ceased after three minutes when the expanding plasma had thinned and cooled too much. It was a few hundred thousand years later that fell into orbits around the nuclei to form atoms.

physics in the 21st century

Beyond the orbit of the Moon, the Next Generation Space Telescope (NGST) will probe the early universe, and its results are bound to pose new problems for physics. Satellite systems using laser beams 5 million km/3 million mi long may be set in space to search for gravity waves - ripples in space-time from violent events in the universe, such as the explosion of stars or the merging of black holes. With such equipment physicists will address the many problems still unsolved at the turn of the century. For example, are matter and antimatter true 'mirror-images' of one another? Experimental results suggesting that they behave slightly differently in certain interactions were reported in 1999. Such a difference could explain why antimatter had almost completely disappeared from the universe within fractions of a second of the

Big Bang, despite the fact that matter and antimatter should have been produced in equal amounts initially. But physicists are sure that the matter we can directly observe is only a fraction of all the matter that exists. Some of the unknown 'dark matter' reveals its presence by its gravitational effects on the movements of galaxies. Some of it may be just cold, dark ordinary matter, mostly hydrogen gas. But physicists conjecture that it may consist of an undiscovered form of matter, WIMPs, or weakly interacting massive particles. These would interact with each other and with ordinary matter by gravitation alone. The search is on for such matter, both in the laboratory and in space. Evidence was reported in 1998 that the expansion of the universe is accelerating. According to conventional physics the gravitational pull of the galaxies on each other should slow down the expansion. But if the new results are right, then there is a repulsive force between masses that increases with distance, and which is driving the galaxies apart ever faster. Even without such phenomena to complicate things, the standard model of elementary particle interactions has many difficulties. For example, many quantities, such as the masses of the particles and the strengths of the interactions, are unexplained. The search is on for the Higgs boson, a particle whose existence was suggested by the British theoretical physicist Peter Higgs (1929-), as well as physicists in Belgium. If the Higgs boson is found it will explain how the masses of particles arise. The fact that elementary particles fall into three generations is another mystery that physicists hope to solve soon.

Physics in the 20th Century

1900 crisis in physics

Throughout the 19th century the science of physics moved from success to success. By the end of the century the edifice seemed to be essentially complete. The universe obeyed the laws of gravitation and mechanics that the English physicist Isaac Newton (1642-1727) had discovered in the 17th century. Intrinsic to every body was its mass: the greater its mass, the more sluggishly it reacted to an imposed force, and also the stronger the force of gravitation with which it acted on every other body in the universe. Gravitation held the universe together on the astronomical scale. Another great group of phenomena, electricity and magnetism, was described by the elegant equations of the Scottish theorist James Clerk Maxwell (1831-1879). It had been known since the work of his compatriot, the experimentalist Michael Faraday (1791-1867), earlier in the century, that electricity and magnetism are linked: an electric current creates a magnetic field, while changes in a magnetic field set up electric currents. In the 1860s and 1870s Maxwell showed how a rapid vibration of an electrical charge or a magnet would cause a disturbance in the electrical and magnetic fields to spread as a wave, travelling at the speed of light. A German physicist, Heinrich Hertz(1857-1894), detected these waves in 1887, created by a repetitive electric spark a few metres away. Maxwell's work made it clear that light was an electromagnetic wave, and that there was an infinite range of electromagnetic radiations with wavelengths longer or shorter than those of visible light. The two domains of gravitation and electromagnetism were separate. But the concept of energy provided a partial link between them. The energy of a system was its ability to do work. A moving bullet possessed kinetic energy, or energy of motion, because it could splinter wood in being brought to a stop. A mass of steam possessed heat energy because it could drive a steam engine. Coal possessed chemical energy because it could be burned to generate the heat to turn water into steam. Electromagnetic radiation possessed energy because it could warm matter. In turn, heat energy or electrical energy was used up in generating electromagnetic radiation. Energy was like a currency passing through physical processes, never altering in quantity and prescribing exactly how much of one kind of process (say, a chemical reaction) could be exchanged for how much of another (say, an amount of heat). The law of conservation of energy - stated as there is no change in the total energy in the universe - was taken to be unchallengeable. There was progress, too, in describing the structure of matter. Although some serious scientists still denied the reality of atoms, they were a minority. Chemical reactions could be explained in terms of the linking up and separating of atoms. Much of the behaviour of gases could be explained by assuming that they were crowds of billiard-ball-like atoms bouncing off the walls of their container. The size, mass and numbers of atoms could be calculated from careful physical and chemical measurements. However, there were some huge gaps in the edifice of physics waiting to be closed. For example, physicists had no idea what caused the chemical differences between atoms. In fact, though it was barely realized at the time, science had gained its first glimpse inside the atom with the studies of cathode rays made in 1897 by the English physicist J J Thomson (1856-1840). These rays were seen to stream through low-pressure gas in a glass vessel when a high electrical potential difference was applied between two terminals mounted inside the vessel. Thomson bent the path of the rays with electric and magnetic fields and showed that they were made up of 'particles of electricity'. The mass of these 'particles of electricity' was 1/1836 the mass of the nucleus of the lightest element, hydrogen.

Since these 'electrons' were identical, whatever their source, Thomson suggested that they are components of all atoms, and that ordinary electrical currents are streams of electrons in movement. This was just one step towards explaining the properties of the atoms of the scores of known elements. But crises were developing in the theory of electromagnetism. Light and other radiations did not behave as they should. Delicate experiments by the US experimentalists Albert A Michelson(1852-1931) and Edward W Morley (1838-1923) failed to reveal any effect on light rays of the movement of the Earth around the Sun. The analogy here is to think of a river 5 m/16 ft wide. A boat that travels from one bank to the other and back, at a steady speed relative to the river, travels 10 m/33 ft. A boat that travels 5 m downstream and 5 m back upstream, at the same steady speed relative to the river, also travels 10 m. However the two trip times are measurably different. At the time it was believed that light waves travelled through 'the ether'. Furthermore, the speed of movement of a light source - such as a star - had no discernible effect on the speed of light. There were experiments by other workers, too, that had similarly puzzling results. Another problem was to explain the spectrum - the pattern of wavelengths - that is emitted by hot bodies. At low temperatures most of this radiation is in the infrared; at the temperature of the Sun, most is emitted in the visible spectrum; for much higher temperatures, the peak is in the ultraviolet. Electromagnetic theory could not explain this. But few physicists thought in 1900 that this and the other problems of their science would need to be solved by revolution.

time, space, and gravity

In 1905 a young German-born physicist who had taken Swiss nationality, Albert Einstein (1879-1955), published three scientific papers. One concerned Brownian motion, the dance of tiny particles such as pollen grains in a liquid, visible through a microscope. Einstein explained this as being due to the bombardment of the particles by the ceaseless motion of the molecules of the liquid, and his work made it possible to calculate how many molecules there are in a given mass of the liquid. This work was of major importance, but the other papers were epoch-making. One concerned electromagnetic radiation, and is dealt with in the next section. The third revolutionized our conceptions of space and time themselves. Einstein was unaware of the experimental results of Michelson and Morley but started his work from Maxwell's important equations. These equations, named after Scottish physicist James Clerk Maxwell, showed that oscillating electric charges should produce what are now called electromagnetic waves with a speed similar to that found for light. Einstein made the apparently impossible assumption that the speed of light is the same for all observers, whatever their movement and whatever the movement of the light source. This technically applies only to light in a vacuum; light is slowed down when travelling through a medium such as air or water. It followed from this that time and space must be different for different observers. Einstein worked out just how they differed. An observer on the ground, John, regards processes in, say, a fast-moving spacecraft as running slow. Jane, in the spacecraft, finds the same about processes on the ground – they are running slow relative to her. In addition, each finds all lengths and distances in the other system to be contracted in the direction of movement. Einstein calculated the degree of contraction and of 'time dilation' that must occur. For two observers moving at the huge speed of 30,000,000 ms^{-1}, one tenth of the speed of light, with respect to each other, the rates of clocks and the lengths of measuring rods are altered by just half of one percent. But at 99% of the speed of light, lengths in the direction of movement are shrunk to one seventh of their original length, and all processes are slowed to one seventh. These ideas could explain why the Michelson-Morley experiment showed no result. Relative to an observer beyond the Earth and not sharing its motion, the experimental apparatus, everything else on Earth, and the Earth itself, are all shortened in the direction of the Earth's movement. Detailed analysis shows that this just compensates for the effects on apparent speed of the light rays that would be expected classically. Other results followed. The apparent mass of an object is no longer a constant, as in Newtonian physics, but increases with speed. The amount of energy required to boost it to the speed of light is infinite, and so this is a limiting speed that no physical object can attain. Einstein was able to show that, simply put, mass and energy were equivalent. His most famous, yet often misquoted and misunderstand, equation$E=mc^2$, shows that changing the energy of an object will result in a change in its mass. Einstein's special theory of relativity, as this work came to be called, was so convincing that physicists around the world took it up immediately. Mathematical analysis by the Hungarian-born US physicist Eugene Wigner (1902-1995) brought out how closely space and time are interlinked in relativity theory, and the word 'space-time' was coined to describe this intimate combination. The picture of a three-dimensional universe moving through time gave way to the picture of a four-dimensional space-time network of events, which different observers analyse in different ways into three dimensions of space and one of time. Einstein quickly took a further giant stride, in his 'general theory' of relativity, published during World War I. The general theory tackled gravitation. It viewed a body with mass, such as the Sun, as affecting space and time nearby. For example, relative to an observer on the Earth, clocks run slow in the strong gravity field of the Sun. The distortion of space-time also causes bodies with mass to tend to move towards each other. In the weak gravity fields that prevail over the large-scale universe they move in just the ways that Newton's theory predicts to a high degree of approximation. But differences arise for strong gravity fields. Relativity predicts that Mercury's orbit will differ from the one predicted by Newtonian theory – an effect known long before Einstein's theory. Einstein's general theory also predicts that light rays will be bent by a gravitational field. This prediction of the theory was confirmed by expeditions led by the English astronomers Andrew Crommelin (1865 – 1939) and Arthur Eddington (1882-1944). Measurements were taken from Sobral in northern Brazil and the island of Príncipe in the Gulf of Guinea on 29th May 1919. Einstein predicted a deflection of 1.74 seconds of arc. The results from Sobral gave the deflection as 1.98 ± 0.16 and those from Príncipe 1.61 ± 0.40 seconds of arc. More experimental confirmation of relativity has followed in abundance. Time dilation can be seen in today's particle accelerators. Most subatomic particles 'decay' into others in fractions of a second. Their lifetimes are seen to be greatly extended at the near-light speeds to which they are accelerated: their 'on-board clocks' are running slower relative to us. The brightest objects we know of are quasars, billions of light years from the Earth. They are powered by stars and interstellar matter falling into the powerful gravity field of a massive superdense object. A substantial part of the mass of the victims is turned into energy – in accordance with Einstein's ideas. The bending of light is dramatically displayed in gravitational lensing, which causes multiple images of some quasars, when a massive object, such as a cluster of galaxies, intervenes. In 1979 the first double image of a quasar, due to gravitational lensing, was observed.

radiation

In 1900 the German physicist Max Planck (1858-1947) suggested that electromagnetic radiation could not be given out or absorbed in arbitrary amounts but only in separate 'packets', called quanta, with energy proportional to frequency. Ultraviolet radiation had high frequency and could therefore be emitted and absorbed only in high-energy quanta. Infrared radiation had low frequency and therefore low-energy quanta. Visible-light quanta were intermediate in energy. This reduced the amount of radiation given out at higher frequencies because larger amounts of energy were needed to supply the higher-frequency quanta. Planck derived a formula specifying how much energy is radiated at each wavelength by a body for any temperature – that is, its spectrum. Einstein took this idea forward in 1905, the same year in which he published his special theory of relativity. He wanted to explain some puzzling behaviour of the newly discovered electrons. When light was shone onto certain metals, electrons were ejected. If the light was reduced in intensity, the number of electrons emitted decreased, not surprisingly. What was surprising was that the few electrons ejected by a faint light each had just as much energy as the many ejected by a bright light. Einstein accounted for this by putting to one side a century of experiment showing that light is a type of wave motion and proposing that it was behaving in these circumstances like a stream of bullets. A faint ray of light consists of fewer 'bullets' – but individually they have just as much energy and can knock an electron out of the metal with just as much energy. These 'light particles' came to be called 'photons'. The wave and particle aspects were linked by the fact that the energy of a photon was proportional to its frequency, as in Planck's theory. How light could simultaneously be a wave, in which energy is spread out over a large volume of space, and a stream of particles, in which the energy is gathered into one place, was incomprehensible. But for the moment, Einstein's picture was accepted as accounting for the photoelectric effect. In 1923 the US physicist Arthur Holly Compton (1892-1962) demonstrated the particle nature of X-rays, which had been discovered by the German physicist Wilhelm Konrad Röntgen (1845-1923) in 1895. X-rays have very short wavelengths and so their photons have high energy. Compton bounced X-ray photons off a stream of electrons. The scattered photons lost some energy, and so had longer wavelengths than the initial X-rays. The paths of the electrons struck by photons were altered. This effect now carries the name of its discoverer, the Compton effect.

The full gamut of electromagnetic radiations was explored as the 20th century passed. Atoms cannot be seen in even the most powerful visible-light microscopes because light wavelengths are too large. But X-ray wavelengths are of the same order as the spacing between atoms, about one nanometre. Two English experimentalists, Henry Bragg (1862-1942) and his son Lawrence(1890-1971), bounced X-rays off crystals and obtained complex patterns of bright and dark spots that could be deciphered to reveal the spacings and positions of atoms in the crystal surface. This process became known as X-ray crystallography and led to many discoveries including, in 1952, the structure of DNA by English biophysicist Rosalind

Franklin (1920-1958). Ultraviolet (UV) radiation has wavelengths ranging from about 13 nanometres (1 nanometre (1nm) is 10^{-9} m or 0.00000001 m) up to about 400 nanometres, the border of visible light. The astronomical sky can now be studied at UV wavelengths with detectors flown in satellites, flown above the atmosphere which absorbs much of the UV. Beyond the other end of the visible spectrum, astronomers study the sky at infrared (IR) wavelengths. Detectors have to be attached to telescopes on mountain tops or flown on satellites to avoid the IR-absorption of the atmosphere. The detectors themselves have to be chilled to reduce their own IR radiation. IR detectors are used in hosts of everyday devices, from TV remote controls to thermal imagers for detecting people buried under snow or debris. Radio waves were used first for wireless telegraphy, first demonstrated by the Italian electrical engineer Guglielmo Marconi in the 1890s. A number of engineers then developed means of enabling radio waves to carry speech and music. In 1920 the first true radio station began broadcasting in Pittsburgh, Pennsylvania, USA. By 1931 Russian-born US electronics engineer Vladimir Zworykin (1889-1981) at the RCA corporation had developed the fully electronic television system, in which an electron beam 'paints' the picture on the inside of a cathode ray tube. In World War II radio waves of very short wavelengths were developed to make radar possible. Even the use of visible light was transformed. Lasers were developed in the late 1950s by US physicist Theodore Maiman (1927-). Lasers generate light of unprecedented coherence and intensity. They are used for countless tasks requiring precision measurement, from finding the distance from the Earth to the Moon to measuring the profiles of car parts very accurately. Laser light is indispensable to making the three-dimensional images called holograms, which were invented in 1947 by Hungarian-born British physicist Dennis Gabor (1900-1979).

deeper into the atom

Thomson's discovery of the electron had been the first glimpse into the interior of the atom. The next came with a chance discovery by a French physicist, Henri Becquerel(1852-1908), in 1896. Becquerel found that compounds containing uranium gave out invisible radiations that could affect photographic film, even when the film was wrapped in light-excluding paper. This new radiation was soon found to be a mixture of three types of radiation. One, called alpha radiation, could be blocked by aluminium foil only a few thousandths of a centimetre thick and consisted of a stream of positively charged particles. These positively charged particles were later found to consist of two neutrons and two protons, making them nuclei of a helium atom. Another type, beta radiation, consisted of a stream of negatively charged particles, which were as penetrating as X-rays. Becquerel showed that these beta particles were fast-moving electrons. Whilst beta particles are indeed 'fast moving electrons' to be a beta particle it really needs to originate in the nucleus of an atom. The third type of radioactivity was more penetrating than X-rays and was not deflected by electric or magnetic fields. Named gamma radiation, it turned out to consist of electromagnetic radiation of wavelength even shorter than that of X-rays. Gamma radiation has found a role in medicine killing micro-organisms and sterilizing instruments Physicists and chemists worked to establish which substances in nature were radioactive and which were not. The Polish-born French physicist Marie Curie (1867-1934), assisted by her French husband Pierre Curie(1859-1906), separated a few grammes of highly radioactive material from several tonnes of the uranium ore pitchblende. In this tiny sample she found two new elements, which she named polonium and radium. Radium proved to be millions of times more radioactive than uranium. The radioactivity of an element did not depend at all on the substances with which that element was combined, nor on the surrounding conditions of temperature or pressure. Physicists suspected that it was a process originating within individual atoms and therefore unaffected by other atoms. The Cavendish Laboratory in Cambridge University was headed by a New Zealand-born physicist, Ernest Rutherford (1871-1937), one of the most brilliant experimentalists of all time. In 1907 two of his students, Hans Geiger (1882-1945), a German, and Ernest Marsden (1889-1970), a New Zealander, observed alpha particles passing through thin metal films. When they emerged, the alpha particles struck a plate coated with phosphorescent zinc sulphide, emitting tiny flashes of light that the experimenters painstakingly counted. Geiger and Marsden observed slight deflections of the electrons' paths, averaging less than one degree. Rutherford suggested that Marsden look to see whether any of the alpha particles were deflected backwards - that is, through an angle of 90° or greater. Marsden found that a tiny proportion - about one in 20,000 - were indeed bounced back by something they encountered in the gold foil. Rutherford said, 'It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you.' Rutherford realized that the alpha particles were being strongly repelled by something that had a relatively large mass and carried a concentration of positive charge. The positive charge and mass of the atom must be concentrated into a small region at the centre of the atom, which he called the nucleus. At the University of Manchester, another English physicist, H G J Moseley (1887-1915), studied the X-rays given out by atoms. He used a new theory of the structure of the atom put forward by a Danish student of Rutherford, Niels Bohr (1885-1962), which is described in the next section. Moseley was able to calculate the nuclear charge very accurately and found that, within the limits of experimental error, it was always a whole-number multiple of the charge on the electron. This number was equal to the atom's atomic number - its position in the periodic table. Thus titanium, element number 22, was measured to have a positive nuclear charge of 21.99 units. But how was the nucleus constructed? In 1919 Rutherford reported experiments in which high-speed alpha particles from a radioactive source collided with nitrogen atoms in the air and knocked out particles with a single positive charge. These particles were nuclei of hydrogen atoms and so had a mass approximately equal to a unit atomic weight. Later Rutherford dubbed these particles 'protons'. The proton seemed to be a building-block of the nucleus. Usually in these experiments the nitrogen nucleus absorbed an alpha particle, and then lost a proton while itself turning into an oxygen nucleus. This was the first experiment in which an atom of one element was artificially converted into an atom of another element. Another Cavendish physicist, James Chadwick (1891-1974), studied a mysterious penetrating radiation that certain elements, such as beryllium, gave out after being bombarded with fast alpha particles. He found that the radiation consisted of electrically uncharged particles with slightly more mass than the proton. Further experiment showed that the neutron is a fundamental particle, just as basic as the proton. The nucleus of the atom consists of protons and neutrons - the nucleus of the nitrogen atom, for example, contains seven protons and seven neutrons. The neutron is not stable: outside the nucleus it disintegrates, turning into a proton and emitting an electron. In 1933 the Italian theorist Enrico Fermi (1901-1954), explained how this is possible. Both the proton and the electron come into existence at the moment when the neutron ceases to exist - just as a photon comes into existence at the moment when an atom emits light. In the subatomic world the equivalence of mass and energy is observed and experimental evidence has never failed to support the view presented by Einstein.

quantum physics

The new discoveries brought a new crisis in physics. How could the solar-system atom survive for more than a fraction of a second? Just as the oscillating electrons in a radio transmitter's antenna give off radio waves, so the whirling electrons in the atom should have given off electromagnetic radiation and fallen into the nucleus. A young Danish physicist, Niels Bohr, produced a theory based on this fact while he was studying under Rutherford, who had moved to the University of Manchester. Bohr assumed that only those orbits are possible for which the energy is a whole-number multiple of a basic energy. Once again the idea of the quantum of energy was appearing in physics. On this assumption Bohr was able to calculate the permitted orbits in the simplest atom, that of hydrogen. He found the innermost, lowest-energy orbit to have a diameter of 10^{-12} m, in good agreement with the estimated size of the hydrogen atom. Bohr pictured the electron as being able to jump upwards from one orbit to another of higher energy, farther out, by absorbing the energy of a photon of just the right frequency. The electron could fall from outer orbits to inner ones, giving out energy in the form of electromagnetic waves. Bohr could calculate the wavelengths of light given out and absorbed by hydrogen. Details of the hydrogen spectrum had been put on a mathematical footing by the Swiss school teacher Johann Balmer (1825-1898), who, in 1855, discovered a simple mathematical formula that gave the spectral lines. This became known as the Balmer series. The results obtained by Bohr were found to be in agreement with the Balmer series In 1924 a French student of physics, Louis de Broglie (1892-1987), suggested in his doctoral thesis that associated with the electron and all other subatomic particles are pilot waves, their wavelengths related to the energy of the particle. The permitted orbits for the electrons in an atom were those where a whole number of wavelengths fitted precisely into the circumference of the orbit. The US physicists Clinton Davisson (1881-1958) and Lester Germer (1896-1971) demonstrated that electrons behave like waves when they are diffracted by crystals, in the same way that X-rays had been found to do. In 1926 the German physicist Erwin Schrödinger (1887-1961) derived an equation that was to be the key to the newly emerging physics. It describes the motion of any particle as a wave motion, in accordance with de Broglie's ideas, and successfully solved certain problems. In 1928 the British physicist Paul Dirac (1902-1984) applied relativity theory to the Schrödinger wave function and found that electrons have a property called spin. When an electric charge moves in a circle, it creates a magnetic field. Electrons in an atom do this, so that atoms are like tiny magnets. But individual electrons also behave like tiny magnets. This can be thought of as due to the electrons rotating, although it became increasingly clear that this kind of picture taken from the large-scale world could be misleading. Dirac went on to show that the electron must have a counterpart particle. At first it was thought that the proton must be this counterpart, but later it was realized that there must be an anti-electron, with the same mass but all its other properties - charge, spin and other properties later discovered - opposite to those of the electron. This particle was observed in 1932 by the US physicist Carl Anderson (1905-1991) and named the positron (for positive electron). Positrons are commonly produced in radioactivity, but are destroyed as soon as they encounter an ordinary electron. Every particle has its antiparticle: the negatively charged antiproton was discovered in 1955, the antineutron in 1956. The new quantum physics had many mysterious features. Werner Heisenberg (1901-1976), a German theorist, stated the uncertainty principle, or indeterminacy principle, according to which it is impossible to determine certain properties of particles precisely and simultaneously. For example, the position and momentum of an electron at a given moment cannot be measured precisely. You could observe an electron by firing X-rays at it, for instance, and observing the scattered X-rays, as Compton had done. Heisenberg analysed the disturbance of the electron by its collision with the X-ray, and showed that if the experiment was set up to measure velocity accurately, the momentum of the electron would be highly uncertain; if instead the position was measured accurately, the momentum would be uncertain.

Nineteenth-century physics had been deterministic - knowledge of the state of any system would allow its future to be predicted. The more accurately you measured its properties, the farther into the future you could predict what would happen in that system. The new quantum physics, by contrast, was probabilistic. For example, while it was possible to say that a radioactive atom had a 50% chance of decaying in, say, a year, it was fundamentally impossible to make any more definite prediction about when it would decay. Niels Bohr argued that it was wrong to regard quantum indeterminacy as a limitation on what we can discover about some underlying realities: it was meaningless to talk of an electron having a definite position and velocity. Among other things, this meant that Bohr's own early picture of the atom as containing electrons moving with definite speeds in definite orbits had to be abandoned. Similarly, it is meaningless to ask whether the electron is a particle or a wave: in some circumstances it behaves like one, in others it behaves like the other. Bohr's view has been generally accepted by physicists. Quantum physics grew even stranger in the decades following its birth in the 1920s and 1930s. The British theoretician John Bell (1928-1990) did important work in 1964 that showed how systems that have interacted with each other - for example, particles created in a subatomic process - remain 'entangled' when they separate, even if they travel light years apart. A major research effort is in progress to explore these effects.

the framework of matter

Quantum theory was highly successful in explaining chemical forces between atoms, despite the fact that the Schrödinger wave function could be solved only for a very few simple cases, such as the hydrogen atom.. For multi-electron atoms, only approximate solutions could be found. These represented electrons inside the atoms as 'electron clouds', called orbitals. The density of an orbital showed the probability that an electron would be found there. A number of orbitals formed a 'shell', containing electrons with roughly the same energy. In a normal atom electrons occupied the lowest available shells. The innermost shell could hold two electrons; the second eight; the third 18; and so on. Within the shells electrons can occupy slightly different energy levels. Increasingly, over the years since quantum mechanics was first developed in the 1920s and 1930s, experimental work and theoretical progress have mapped out the energy levels that the electrons occupy in the atoms of the 92 naturally occurring elements. The way in which atoms combine and redistribute their electrons has been explained. As well as chemical reactions, the chemical properties of materials have been further and further explained. Metals, for example, owe their characteristic properties to the fact that outermost electrons in the atoms become separated and form a 'sea' of electrons in the materials. These electrons can flow easily, making it easy for electric currents to flow through the metal, and also for heat to be conducted through it. Physicists studied matter in extreme conditions. At high temperatures, all substances form gases, in which atoms rush around separately. At higher temperatures still, the electrons are torn from the atoms in collisions. A fluid called a plasma is formed, consisting of negatively charged electrons mixed with positively charged ions - atoms that have lost some or all of their electrons. The motion of these charged particles creates magnetic fields that in turn affect the motion of the particles, so that the plasma's behaviour is very different from that of an ordinary gas. The Swedish physicist Hannes Alfvén (1908-1995) analysed and explained the behaviour of plasmas, which are important in nature: the air is turned into a plasma in lightning strokes, and the Sun and stars consist of plasma. Physicists also found that matter behaves strangely at low temperatures. In 1908 the Dutch physicist Heike Kamerlingh Onnes (1853-1926) liquefied helium at 4.2 K (-268.9°C/-452.0°F). A few years later he found that mercury became superconducting when cooled to such temperatures. It completely lost its electrical resistance, and a current could be set up in it that would circulate for ever if left undisturbed, without further energy needing to be put in. The explanation was provided by the BCS theory, named from the initials of the US physicists John Bardeen (1908-1991), Leon Cooper (1930-), and

John Schrieffer (1931-) who invented it in 1957. In 1937, the Russian physicist Pyotr Kapitza (1894-1984) discovered that when helium is cooled below 2.17 K (-270.98°C/-455.76°F), it becomes superfluid, flowing with zero resistance through tiny apertures, and flowing over the edges of any open container that it was kept in. BCS was not adequate to explain the phenomenon of 'high-temperature' superconductivity, discovered in certain complex ceramic materials in 1986 by the German physicist Georg Bednorz (1950-), and the Swiss physicist Karl Alex Müller(1927-). The race was on to find materials that would superconduct at room temperatures, which could create enormous savings in electricity supply. Superconducting magnets have been utilized in many applications, perhaps most notably in body scanners used for medical diagnosis.

particles, forces, and radiation

During the 20th century new forces were found to be at work in the heart of the atom. Radioactivity gave evidence of an astonishing new subatomic particle. When an electron or positron was emitted by a nucleus - a process called beta decay - some energy was generally found to be missing. In 1931 the Austrian-born Swiss physicist Wolfgang Pauli suggested that this energy was being carried off by an unknown uncharged particle, which was later called the neutrino, or 'little neutral one'. Its mass must be extremely small, and perhaps even zero. It reacted so rarely with other particles that one could travel through the entire Earth with only a tiny chance of interacting with any particle encountered on the way. In 1956 its existence was confirmed when floods of neutrinos from a nuclear reactor were seen to produce flashes of light in liquid. Trillions upon trillions of these particles flood through our bodies every second, completely unnoticed. The interaction responsible for beta decay is called the weak nuclear force. It is 10 billion times weaker than electromagnetism, but 10^{30} times stronger than gravitation. But there had to be another, far stronger interaction at work in the nucleus. The positively charged protons in the atomic nucleus repel each other with an enormous force. Some other force, with a range limited to the dimensions of the nucleus, must overcome this repulsion. In 1935 a Japanese physicist, Yukawa Hideki (1907-1981), suggested that protons and neutrons continually swapped identities by exchanging an electrically charged particle, now called the muon. Experimentalists thought they had found this particle when they discovered a new particle reaching the Earth's surface in cosmic rays from space. However, the muon, although 207 times as massive as the electron, was too light to be Yukawa's particle. In 1947 the pi-meson, or pion, was discovered, with a mass 274 times that of the electron. This is the particle that is exchanged between protons and neutrons. The force that this exchange gives rise to is called the strong nuclear force, or simply the strong force. It brought to four the number of fundamental interactions. The idea of forces arising from 'messenger' particles being exchanged was used when quantum theory was applied to electromagnetism. The US physicists Richard Feynman (1918-1988)and Julian Schwinger (1918-1994), and the Japanese physicist Sin-Itiro Tomonaga developed the theory of quantum electrodynamics (QED). QED deals with interactions between charged particles and between electromagnetic fields and charged particles. It treats electromagnetic interactions as the exchange of photons, which are the 'carriers' or 'messengers' of electromagnetic forces. To understand the strong and weak forces, and the structure of the atomic nucleus, it was necessary to go deeper into the nucleus. Rutherford and Chadwick had bombarded atoms with naturally occurring alpha particles. The English physicists John Cockcroft (1897-1967) and Ernest Walton (1903-1995) improved on this by building the first particle accelerator, which used an accelerating potential of 800 kV to accelerate the protons and fire them at target atoms, producing in 1932 the first artificially induced nuclear reactions. In 1931 the US physicist Ernest O Lawrence (1901-1958) invented the cyclotron, in which charged particles were whirled in a spiral path, building up energy from a series of voltage kicks twice in each revolution. Such machines were developed into huge instruments. LEP, the Large Electron-Positron collider at CERN, the European Laboratory for Particle Physics near Geneva, Switzerland, was a ring 27 km/17 mi in circumference. Bunches of particles were accelerated to close to the speed of light, and then circulated, perhaps for hours, in storage rings, before being allowed to collide head-on with another stream of particles circulating in the opposite direction. LEP functioned for 11 years before being closed in November 2000. The contributions of many theorists and large teams of experimentalists at the great accelerator laboratories built up a picture that is now called the standard model. According to the standard model, subatomic particles can be divided into three groups: hadrons, which interact through all the four fundamental interactions - gravitation, electromagnetism, and the weak and strong nuclear forces; leptons, which do not interact through the strong force, but do so through the three other interactions; and gauge bosons, or 'messenger' particles, which are 'carriers' of the interactions. The hadrons are not fundamental particles, but are made up of smaller particles called quarks, whose existence was suggested independently by the US physicists Murray Gell-Mann (1929-) and George Zweig in the early 1960s. We cannot see quarks singly because it would require far too much energy to tear one out of a hadron. However, their presence can be detected in the pattern of particles spraying out of a collision of particles. And it is possible that single quarks exist in cosmic rays, left over from the birth of the universe. A theory known as colour confinement suggests that the force between two quarks would be the same at a distance of 10^{-15} m as it is at 1 m/3.3 ft. Current accelerators have the energy to separate quarks to a distance of the order of 10^{-13} m and it is estimated that separating two quarks to 1 m would require an increase in energy of the order of 10^{12} times. Although the strong force between the protons and neutrons in a nucleus is 'carried' by pions, the pions themselves are made of pairs of quarks. The direct quark-quark interaction, in the nucleus and elsewhere, is carried by messenger particles called gluons. Leptons are elementary particles as far as we know: that is, they do not seem to be made of any other particles. They fall into three 'generations': these comprise the electron, the muon, and a third particle, the tau; a neutrino associated with each of these - the electron-neutrino, the muon-neutrino and the tau-neutrino; and the corresponding antiparticles of all these. In addition, each generation of leptons is matched with a pair of quarks. The three generations of Leptons and quarks can be shown as;

Leptons	Quarks
electron neutrino	up
electron	down
muon neutrino	charm
muon	strange
tau neutrino	top
tau	bottom

As described above, electromagnetism is carried by photons, and the strong force is carried by gluons. The weak force is carried by messenger particles called the W and Z bosons. Physicists believe that gravitation is carried by particles, and they have named them gravitons, but they have not yet been detected. During the 1960s the US physicists Sheldon Glashow (1932-) and Steven Weinberg (1933-), and the Pakistani physicist Abdus Salam (1926-1996) developed 'electroweak' theory, which gives a single description of the electromagnetic and weak interactions. Physicists speak of the electromagnetic and weak interactions as having been 'unified' by this work. Until his death, Einstein had tried and failed to weld gravitation and electromagnetism into a single force. Modern physicists now have four interactions to unify in this way. The electroweak theory is a step in this direction.

energy from atoms

When radioactivity was discovered, physicists realized that there were vast amounts of energy locked away inside the atoms, far greater than is released in the rearrangements of electrons that occur in chemical reactions. There was talk of the possibility of harnessing this energy, but no one knew how it could be done. In 1948 the Russian-born US physicist George Gamow (1904-1968) pointed out that at very high temperatures and pressures the nuclei of light atoms could be 'fused', or melded together, to yield heavier nuclei, whose mass would be slightly less than the sum of the masses of the original nuclei. The mass difference would be converted into energy in accordance with relativity theory. Gamow proposed this as the process that powers the Sun and other stars. These are made up predominantly of hydrogen, the lightest atom. At the centre of the Sun, the temperature is 15 million °C, and the density is 160 times the density of water. Here hydrogen is converted to helium. In 1938 a new source of nuclear energy was discovered. The German chemist Otto Hahn (1879-1968) and the Austrian physicist Lise Meitner (1878-1968) were puzzled by the strange results of an experiment in which they had bombarded uranium with neutrons. Meitner was forced by the takeover of her country by Nazi Germany to flee to Sweden. From there she published a paper, with her nephew Otto Frisch, suggesting a previously unsuspected type of nuclear breakdown, in which the nucleus of uranium (atomic number 92) broke into two nuclei of roughly equal size, such as barium (atomic number 56) and krypton (atomic number 36). Even before the paper appeared, her findings were reported informally in the United States by Niels Bohr while on a visit. Several physicists realized that the neutrons released in fission could trigger other fissions in a chain reaction, releasing enormous amounts of energy. In 1939, Albert Einstein added his signature to a letter written by two other physicists, the Hungarian Leo Szilard (1898-1964) and Eugene Wigner, Hungarian-born but now a naturalized US citizen. The letter was addressed to US president Theodore Roosevelt, warning him that the fission of uranium presented the possibility of an explosive device of great power. President Roosevelt authorized study of the question, in a research programme later called the Manhattan Project. In Britain, an Austrian physicist, Otto Frisch (1904-1979), and a German, Rudolf Peierls (1907-1995), alerted the government in early 1940. In late 1941, on the eve of the Japanese attack on Pearl Harbor, President Roosevelt authorized a major effort. A team led by the Italian-born US physicist Enrico Fermi began constructing a nuclear 'reactor', which would release fission energy in a controlled manner. The Chicago reactor, built in a squash court beneath a sports stadium at the University of Chicago, generated nuclear energy in December 1942. The building of bombs was carried out at Los Alamos, New Mexico. The first 'atom bomb,' using plutonium, an artificial element of atomic number 94, was test-fired in the New Mexico desert on 16 July 1945. The second, using uranium, was dropped on the Japanese city of Hiroshima on 6 August 1945. Three days later the city of Nagasaki was destroyed by a plutonium bomb. Japan surrendered on 14 August. After the war many designs of reactor were built: they generated heat that was carried away by a coolant fluid - water, a liquid metal, or a gas - to generate steam to drive turbines. Some used U-235 as fuel, some used plutonium. But hopes for the industry were blighted by growing public mistrust of nuclear energy. A series of accidents at nuclear stations in the United States, Britain and elsewhere eroded public confidence. On 26 April 1986, a nuclear reactor at Chernobyl, Ukraine, ran out of control and there was an explosion in the core. Officially 31 people died in the accident or from radiation poisoning later, but a radioactive cloud drifted across western Europe, leading to an unknown number of cancers in human beings. Legal restrictions have led to the end of new reactor building in the USA, home of the world's major nuclear industry. In other countries, notably France, nuclear energy is still of major importance. The 'hydrogen bomb', which exploits the other form of nuclear energy, fusion power, was first exploded on 1 November 1952. In the hydrogen bomb the temperature and pressure momentarily achieved by the explosion of a fission bomb causes nuclei of hydrogen to fuse to form helium. The first bomb was a few hundred times as powerful as the Hiroshima bomb. Later H-bombs were more powerful still. The struggle to harness fusion energy for peaceful purposes still continues. Most designs are based on the Russian tokamak, a torus (hollow ring) containing a plasma of deuterium (heavy hydrogen, whose nucleus contains one proton and one neutron). This is contained by a magnetic field so that it does not touch the walls and lose heat. A US design uses crossed laser beams to create pulses of high temperature in a small region of plasma. Pulses of energy have been extracted in both these designs, holding out the promise of industrial-scale use in the future.

physics and cosmology

While physicists were probing the atom, astronomers were extending their view across the universe. The US astronomer Edwin Hubble (1889-1953) calculated the distance to what was then called the Great Nebula in Andromeda. He established that this spiral 'nebula' (a Latin word meaning 'mist') was not a cloud of gas within the Galaxy, our system of stars, but a galaxy in its own right. According to modern measurements, it is about 2 million light years from us. (A light year is the distance that light travels in one year; since light travels at 300,000,000 ms^{-1}, a light year is approximately 10^{16} miles. The reach of modern optical and radio telescopes has extended until now the farthest objects detectable are about 10 billion light years away. Looking across this vast expanse of space is also looking back in time. We see the galaxy in Andromeda as it was 2 million years ago. The US astronomer Edwin Hubble analysed the light from the galaxies. He found that, apart from the closest galaxies, they all showed a red-shift in their light. That is, dark and bright lines in the visible spectrum were shifted towards the red end of the spectrum. This meant that the wavelengths of the light were lengthened in comparison with the same light from a source on Earth. The wavelengths of the invisible radiations from the galaxies were also lengthened. The farther the galaxy was from us, as estimated by its apparent brightness, the greater its red-shift. Hubble interpreted the red-shift as a result of the Doppler effect - the lengthening of a wave when the source is moving away from the observer. It is named after the 19th-century Austrian physicist Christian Johann Doppler. So the universe is expanding: the galaxies are rushing away from each other as if from some colossal primordial explosion. A Belgian churchman, the abbé Georges Lemaître, proposed that the universe had begun in the explosion of a single 'super-particle', which he called the 'primaeval atom'. The idea was developed by George Gamow. He suggested that the universe began with a hot plasma of protons, electrons and neutrons. Collisions among the particles built up larger and larger nuclei by the same fusion process that Gamow had suggested is occurring in the stars today. However, according to modern theory, only the lightest elements were formed in this 'Big Bang': various forms of hydrogen, helium and lithium. The heavier elements were built up billions of years later, in the stars. In 1967 the first quasar was identified. These objects pour out energy equal to that of an entire galaxy of hundreds of billions of stars, yet this is generated in a volume about the size of our Solar System. The only explanation theorists could find for this amazing energy output was the black hole. A black hole is an object whose gravity is so intense that no matter or light can escape from it. A star whose mass is a few times greater than that of the Sun explodes at the end of its life and can leave a black hole remnant. Much more massive black holes, lying at the centres of galaxies, power quasars. Stars and interstellar gas and dust fall into it and disappear from the view of the outside universe for ever. Inside the black hole, according to theory, occur some of the weirdest phenomena of Einstein's relativity, but any living creatures falling in would be torn apart in a fraction of a second before they could observe them. But matter on its way into the black hole forms a rotating disc of closely packed matter, glowing with frictionally generated heat. This intensely bright mass of matter is the quasar. The physical theory that can take us in imagination to the brink of a black hole can also take us back to the birth of the universe. The Big Bang took place about 15 billion years ago. Cosmologists work out what happened at each succeeding instant by using the knowledge gained in particle accelerators, where the energies involved in particle collisions momentarily equal those prevailing at various stages of the Big Bang. At the birth of the universe space, time, matter and energy appeared together: the first split second was a chaos of radiation and particles existing fleetingly, in a universe swelling from the size of an atom. Though the universe had a limited volume, there was nothing outside it – space curved back on itself in a way that only the equations of relativity can describe. The cosmic fireball expanded, thinned and cooled. Our theories can be applied only back to a time 10^{-43} second after the beginning: before this, time and space are ripped apart by the incredible density and temperature (10^{-32}deg) of the universe. There was only one 'superforce' acting, and we have no theory to deal with it yet. After this time, gravity appeared as a separate force. At 10^{-35} second the strong force separated out. At 10^{-12} second electromagnetism split off from the weak force. The universe was a soup of exotic particles, including single quarks, as well as high-energy gamma photons. When the universe was a millionth of a second old, its temperature had fallen to 10 trillion K, and quarks began to combine, forming protons, neutrons, and mesons. As the temperature fell still further these were able to combine and stay together, forming various types of light nuclei. This process ceased after three minutes when the expanding plasma had thinned and cooled too much. It was a few hundred thousand years later that electrons fell into orbits around the nuclei to form atoms.

physics in the 21st century

In the 21st century physics will become an ever costlier enterprise, demanding ever greater amounts of taxpayers' money. But the money will probably be forthcoming: ever since nuclear energy was discovered and applied, governments have understood that fundamental physics research is a rich source of new developments that can enrich and strengthen nations. Physicists will require still more sophisticated and costly instruments. CERN's 27-km/17-mi ring housing LEP (which was shut down in 2000), the Large Electron-Positron Collider, will accommodate the LHC, the Large Hadron Collider, which will accelerate protons and other hadrons through a trillion volts. Beyond the orbit of the Moon the Next Generation Space Telescope (NGST) will probe the early universe, and its results are bound to pose new problems for physics. Satellite systems using an array of laser beams spanning 500 million m/3 million mi (5×10^8 m) may be set up in space to search for gravity waves – ripples in space-time from violent events in the universe, such as the explosion of stars or the merging of black holes. With such equipment physicists will address the many problems that they were working on at the turn of the century. For example, are matter and antimatter true 'mirror-images' of one another? Experimental results suggesting that they behave slightly differently in certain interactions were reported in 1999. Such a difference could explain why antimatter had almost completely disappeared from the universe within fractions of a second of the Big Bang, despite the fact that matter and antimatter should have been produced in equal amounts initially. But physicists are sure that the matter we can directly observe is only a fraction of all the matter that exists. Some of the unknown 'dark matter' reveals its presence by its gravitational effects on the movements of galaxies. Some of it may be just cold, dark ordinary matter, mostly hydrogen gas. But physicists conjecture that it may consist of an undiscovered form of matter, WIMPs, or weakly interacting massive particles. These would interact with each other and with ordinary matter by gravitation alone. The search is on for such matter, both in the laboratory and in space. Evidence was reported in 1998 that the expansion of the universe is accelerating. According to conventional physics the gravitational pull of the galaxies on each other should slow down the expansion. But if the new results are right, then there is a repulsive force between masses that increases with distance, and which is driving the galaxies apart ever faster. The 'new force' with 'repulsive' gravity is being called quintessence.

Even without such phenomena to complicate things, the standard model of elementary-particle interactions has many difficulties. For example, many quantities, such as the masses of the particles and the strengths of the interactions, are unexplained. The search is on for the Higgs boson, a particle whose existence was suggested by the British theorist Peter Higgs (1929–) and two Belgian physicists, Robert Brout and François Englert. If it is found it will explain how the masses of particles arise, but 30 years of unsuccessfully smashing particles in giant accelerators casts doubt on its existence. The fact that elementary particles fall into three generations is another mystery that physicists hope to solve. Electromagnetism and the weak force have been 'unified' by electroweak theory; now it is necessary to unify this with the theory of the strong force, to form a grand unified theory, or GUT. Theorists are working intensively on string theory, according to which elementary particles are tiny vibrating 'strings', rather than points. According to string theory the universe has 10 or 11 dimensions, of which most 'rolled up' in the first instant of the Big Bang, leaving us with the three dimensions of space and one of time that we experience today. String theory offers the best hope of unifying all the fundamental interactions, including gravitation, to form the much heralded 'theory of everything' described by Stephen Hawking in *A Brief History of Time* (1988). In early 2004, Hawking announced his decision to abandon his search for it. But one thing is certain: even a 'theory of everything' would pose a vast range of new problems. The job of physicists will never be finished.

Nobel Prize for Physics

Year	Winner(s)[1]	Awarded for
1901	Wilhelm Röntgen (Germany)	discovery of X-rays
1902	Hendrik Lorentz (Netherlands) and Pieter Zeeman (Netherlands)	influence of magnetism on radiation phenomena
1903	Henri Becquerel (France)	discovery of spontaneous radioactivity
	Pierre Curie (France) and Marie Curie (France)	research on radiation phenomena

1904	John Strutt (Lord Rayleigh, UK)	densities of gases and discovery of argon
1905	Philipp von Lenard (Germany)	work on cathode rays
1906	Joseph J Thomson (UK)	theoretical and experimental work on the conduction of electricity by gases
1907	Albert Michelson (USA)	measurement of the speed of light through the design and application of precise optical instruments such as the interferometer
1908	Gabriel Lippmann (France)	photographic reproduction of colours by interference
1909	Guglielmo Marconi (Italy) and Karl Ferdinand Braun (Germany)	development of wireless telegraphy
1910	Johannes van der Waals (Netherlands)	equation describing the physical behaviour of gases and liquids
1911	Wilhelm Wien (Germany)	laws governing radiation of heat
1912	Nils Dalén (Sweden)	invention of light-controlled valves, which allow lighthouses and buoys to operate automatically
1913	Heike Kamerlingh Onnes (Netherlands)	studies of properties of matter at low temperatures
1914	Max von Laue (Germany)	discovery of diffraction of X-rays by crystals
1915	William Bragg (UK) and Lawrence Bragg (UK)	X-ray analysis of crystal structures
1916	no award	
1917	Charles Barkla (UK)	discovery of characteristic X-ray emission of the elements
1918	Max Planck (Germany)	formulation of quantum theory
1919	Johannes Stark (Germany)	discovery of Doppler effect in rays of positive ions, and splitting of spectral lines in electric fields
1920	Charles Guillaume (Switzerland)	discovery of anomalies in nickel-steel alloys
1921	Albert Einstein (Switzerland)	theoretical physics, especially law of photoelectric effect
1922	Niels Bohr (Denmark)	discovery of the structure of atoms and radiation emanating from them
1923	Robert Millikan (USA)	discovery of the electric charge of an electron, and study of the photoelectric effect
1924	Karl Siegbahn (Sweden)	X-ray spectroscopy
1925	James Franck (Germany) and Gustav Hertz (Germany)	discovery of laws governing the impact of an electron upon an atom
1926	Jean Perrin (France)	confirmation of the discontinuous structure of matter
1927	Arthur Compton (USA)	transfer of energy from electromagnetic radiation to a particle
	Charles Wilson (UK)	invention of the Wilson cloud chamber, by which the movement of electrically charged particles may be tracked
1928	Owen Richardson (UK)	work on thermionic phenomena and associated law
1929	Louis Victor de Broglie (France)	discovery of the wavelike nature of electrons
1930	Chandrasekhara Raman (India)	discovery of the scattering of single-wavelength light when it is passed through a transparent substance
1931	no award	
1932	Werner Heisenberg (Germany)	creation of quantum mechanics
1933	Erwin Schrödinger (Austria) and Paul Dirac (UK)	development of quantum mechanics
1934	no award	
1935	James Chadwick (UK)	discovery of the neutron
1936	Victor Hess (Austria)	discovery of cosmic rays
	Carl Anderson (USA)	discovery of the positron
1937	Clinton Davisson (USA) and George Thomson (UK)	diffraction of electrons by crystals
1938	Enrico Fermi (Italy)	use of neutron irradiation to produce new elements, and discovery of nuclear reactions induced by slow neutrons
1939	Ernest Lawrence (USA)	invention and development of the cyclotron, and production of artificial radioactive elements
1940	no award	
1941	no award	
1942	no award	
1943	Otto Stern (USA)	molecular-ray method of investigating elementary particles, and discovery of magnetic moment of proton
1944	Isidor Isaac Rabi (USA)	resonance method of recording the magnetic properties of atomic nuclei
1945	Wolfgang Pauli (Austria)	discovery of the exclusion principle
1946	Percy Bridgman (USA)	development of high-pressure physics
1947	Edward Appleton (UK)	physics of the upper atmosphere
1948	Patrick Blackett (UK)	application of the Wilson cloud chamber to nuclear physics and cosmic radiation
1949	Hideki Yukawa (Japan)	theoretical work predicting existence of mesons
1950	Cecil Powell (UK)	use of photographic emulsion to study nuclear processes, and discovery of pions (pi mesons)
1951	John Cockcroft (UK) and Ernest Walton (Ireland)	transmutation of atomic nuclei by means of accelerated subatomic particles
1952	Felix Bloch (USA) and Edward Purcell (USA)	precise nuclear magnetic measurements
1953	Frits Zernike (Netherlands)	invention of phase-contrast microscope
1954	Max Born (UK)	statistical interpretation of wave function in quantum mechanics
	Walther Bothe (West Germany)	coincidence method of detecting the emission of electrons
1955	Willis Lamb (USA)	structure of hydrogen spectrum
	Polykarp Kusch (USA)	determination of magnetic moment of the electron
1956	William Shockley (USA), John Bardeen (USA), and Walter Houser Brattain (USA)	study of semiconductors, and discovery of the transistor effect

1957	Tsung-Dao Lee (China) and Chen Ning Yang (China)	investigations of weak interactions between elementary particles
1958	Pavel Cherenkov (USSR), Ilya Frank (USSR), and Igor Tamm (USSR)	discovery and interpretation of Cherenkov radiation
1959	Emilio Segrè (USA) and Owen Chamberlain (USA)	discovery of the antiproton
1960	Donald Glaser (USA)	invention of the bubble chamber
1961	Robert Hofstadter (USA)	scattering of electrons in atomic nuclei, and structure of protons and neutrons
	Rudolf Mössbauer (West Germany)	resonance absorption of gamma radiation
1962	Lev Landau (USSR)	theories of condensed matter, especially liquid helium
1963	Eugene Wigner (USA)	discovery and application of symmetry principles in atomic physics
	Maria Goeppert-Mayer (USA) and Hans Jensen (Germany)	discovery of the shell-like structure of atomic nuclei
1964	Charles Townes (USA), Nikolai Basov (USSR), and Aleksandr Prokhorov (USSR)	work on quantum electronics leading to construction of oscillators and amplifiers based on maser-laser principle
1965	Sin-Itiro Tomonaga (Japan), Julian Schwinger (USA), and Richard Feynman (USA)	basic principles of quantum electrodynamics
1966	Alfred Kastler (France)	development of optical pumping, whereby atoms are raised to higher energy levels by illumination
1967	Hans Bethe (USA)	theory of nuclear reactions, and discoveries concerning production of energy in stars
1968	Luis Alvarez (USA)	elementary-particle physics, and discovery of resonance states, using hydrogen bubble chamber and data analysis
1969	Murray Gell-Mann (USA)	classification of elementary particles, and study of their interactions
1970	Hannes Alfvén (Sweden)	work in magnetohydrodynamics and its applications in plasma physics
	Louis Néel (France)	work in antiferromagnetism and ferromagnetism in solid-state physics
1971	Dennis Gabor (UK)	invention and development of holography
1972	John Bardeen (USA), Leon Cooper (USA), and John Robert Schrieffer (USA)	theory of superconductivity
1973	Leo Esaki (Japan) and Ivar Giaever (USA)	tunnelling phenomena in semiconductors and superconductors
	Brian Josephson (UK)	theoretical predictions of the properties of a supercurrent through a tunnel barrier
1974	Martin Ryle (UK) and Antony Hewish (UK)	development of radioastronomy, particularly the aperture-synthesis technique, and the discovery of pulsars
1975	Aage Bohr (Denmark), Ben Mottelson (Denmark), and James Rainwater (USA)	discovery of connection between collective motion and particle motion in atomic nuclei, and development of theory of nuclear structure
1976	Burton Richter (USA) and Samuel Ting (USA)	discovery of the psi meson
1977	Philip Anderson (USA), Nevill Mott (UK), and John Van Vleck (USA)	contributions to understanding electronic structure of magnetic and disordered systems
1978	Peter Kapitza (USSR)	invention and application of low-temperature physics
	Arno Penzias (USA) and Robert Wilson (USA)	discovery of cosmic background radiation
1979	Sheldon Glashow (USA), Abdus Salam (Pakistan), and Steven Weinberg (USA)	unified theory of weak and electromagnetic fundamental forces, and prediction of the existence of the weak neutral current
1980	James W Cronin (USA) and Val Fitch (USA)	violations of fundamental symmetry principles in the decay of neutral kaon mesons
1981	Nicolaas Bloembergen (USA) and Arthur Schawlow (USA)	development of laser spectroscopy
	Kai Siegbahn (Sweden)	high-resolution electron spectroscopy
1982	Kenneth Wilson (USA)	theory for critical phenomena in connection with phase transitions
1983	Subrahmanyan Chandrasekhar (USA)	theoretical studies of physical processes in connection with structure and evolution of stars
	William Fowler (USA)	nuclear reactions involved in the formation of chemical elements in the universe
1984	Carlo Rubbia (Italy) and Simon van der Meer (Netherlands)	contributions to the discovery of the W and Z particles (weakons)
1985	Klaus von Klitzing (West Germany)	discovery of the quantized Hall effect
1986	Ernst Ruska (West Germany)	electron optics, and design of the first electron microscope
	Gerd Binnig (West Germany) and Heinrich Rohrer (Switzerland)	design of scanning tunnelling microscope
1987	Georg Bednorz (West Germany) and Alex Müller (Switzerland)	superconductivity in ceramic materials
1988	Leon M Lederman (USA), Melvin Schwartz (USA), and Jack Steinberger (USA)	neutrino-beam method, and demonstration of the doublet structure of leptons through discovery of muon neutrino
1989	Norman Ramsey (USA)	measurement techniques leading to development of caesium atomic clock
	Hans Dehmelt (USA) and Wolfgang Paul (Germany)	ion-trap method for isolating single atoms
1990	Jerome Friedman (USA), Henry Kendall (USA), and Richard Taylor (Canada)	experiments demonstrating that protons and neutrons are made up of quarks
1991	Pierre-Gilles de Gennes (France)	work on disordered systems including polymers and liquid crystals; development of mathematical methods for studying the behaviour of molecules in a liquid on the verge of solidifying
1992	Georges Charpak (France)	invention and development of detectors used in high-energy physics
1993	Joseph Taylor (USA) and Russell Hulse (USA)	discovery of first binary pulsar (confirming the existence of gravitational waves)
1994	Clifford Shull (USA) and Bertram Brockhouse (Canada)	development of technique known as 'neutron scattering' which led to advances in semiconductor technology
1995	Frederick Reines (USA)	discovery of the neutrino
	Martin Perl (USA)	discovery of the tau lepton
1996	David Lee (USA), Douglas Osheroff (USA), and Robert Richardson (USA)	discovery of superfluidity in helium-3
1997	Claude Cohen-Tannoudji (France), William Phillips (USA), and Steven Chu (USA)	discovery of a way to slow down individual atoms using lasers for study in a near-vacuum

1998	Robert B Laughlin (USA), Horst L Störmer (USA), and Daniel C Tsui (USA)	discovery of a new form of quantum fluid with fractionally charged excitations
1999	Gerardus 't Hooft (Netherlands) and Martinus Veltman (Netherlands)	elucidating the quantum structure of electroweak interactions in physics
2000	Zhores I Alferov (Russia) and Herbert Kroemer (Germany)	development of semiconductor heterostructures, which lead to faster transistors and more efficient laser diodes
	Jack St Clair Kilby (USA)	co-invention of the integrated circuit
2001	Eric A Cornell (USA), Wolfgang Ketterle (Germany), and Carl E Wieman (USA)	the achievement of Bose-Einstein condensation in dilute gases of alkali atoms, and early fundamental studies of the condensates
2002	Raymond Davis, Jr (USA) and Masatoshi Koshiba (Japan)	pioneering contributions to astrophysics, particularly the detection of cosmic neutrinos
	Riccardo Giacconi (USA)	pioneering contributions to astrophysics which have led to the discovery of cosmic X-ray sources
2003	Alexei A Abrikosov (USA), Vitaly L Ginzburg (Russia), and Anthony J Leggett (USA)	pioneering contributions to the theory of superconductors and superfluids
2004	David J Gross (USA), H David Politzer (USA), and Frank Wilczek (USA)	discovery of asymptotic freedom in the theory of the strong interaction
2005	Roy J Glauber (USA)	contribution to the quantum theory of optical coherence
	John L Hall (USA), and Theodor W Hänsch (Germany)	contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique

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[1] Nationality given is the citizenship of recipient at the time award was made.

Physics: key dates

c. 400 BC	The first 'atomic' theory is put forward by the Greek philosopher Democritus.
c. 340	Arisotle adapts and elaborates an earlier theory of his earlier Greek compatriot Empedocles that all matter consists of four elements - earth, air, fire, and water - with a fifth element, ether, making up the heavens. He also develops ideas about motion.
c. 250	Archimedes' principle of buoyancy is established. Archimedes also discovers the principle of the lever.
c. 60	The Roman poet Lucretius writes *De rerum natura/On the Nature of Things*, which includes an exposition of the atomic theory of Democritus as interpreted by Epicurus, a Greek philosopher of the late 4th and early 3rd centuries.
AD 1250	Roger Bacon pioneers the use of empiricist methods in understanding physics.
1600	Magnetism is described by William Gilbert of England.
1608	Hans Lippershey, a Dutch lens-maker, patents the refracting telescope.
c. 1610	The principle of falling bodies descending to earth at the same speed is established by the Italian astronomer and physicist Galileo Galilei.
1642	The principles of hydraulics are put forward by French physicist and mathematician Blaise Pascal.
1643	The mercury barometer is invented by the Italian physicist Evangelista Torricelli.
1656	The pendulum clock is invented by Christiaan Huygens of the Netherlands.
1660	Robert Hooke discovers his law of elasticity, that the extension of a spring is proportional to the force.
1662	Boyle's law concerning the behaviour of gases is established by Irish physicist and chemist Robert Boyle.
c. 1665	The English physicist and mathematician Isaac Newton proposes the theory that the Earth exerts a constant force on falling bodies. This force is called gravity.
1685	Newton publishes his *Principia mathematica philosophiae naturalis/Principles of Natural Philosophy*, containing an outline of his system of mechanics and including his law of universal gravitation and his three laws of motion.
1690	The wave theory of light is propounded by Christiaan Huygens.
1704	The corpuscular theory of light is put forward by Newton.
1714	The mercury thermometer is invented by a Polish-born Dutch physicist, Daniel Fahrenheit. He also invents a temperature scale that is later refined to register the freezing point of water at 32° and its boiling point at 212°.
1724	Fahrenheit describes the phenomenon of supercooled water.
1729	English physicist Stephen Gray discovers that static electric charges exist on the surfaces of objects, not within them, and that electricity can pass from one object to another and over distances by means of conductors.
1733	French physicist Charles François de Cisternay du Fay discovers that there are two kinds of static electric charge and that like charges repel, while unlike charges attract.
1742	Anders Celsius, a Swedish astronomer, invents a centigrade temperature scale, fixing 0° as the boiling point of water and 100° as the freezing point. In 1743, these points are swapped to give the centigrade scale still in use.
1751	The American polymath Benjamin Franklin describes electricity as a fluid, differentiates between positive and negative electricity, and shows that electricity can magnetize and demagnetize iron. In 1752 he performs his famous experiment, flying a kite into a thunder cloud and proving that lightning is a form of electricity.
1764	Specific and latent heats are described by the Scottish chemist Joseph Black.
1771	The link between nerve action and electricity is discovered by the Italian physicist Luigi Galvani.
c. 1787	Charles's law relating the pressure, volume, and temperature of a gas is established by French physicist and chemist Jacques Charles.
1795	The metric system is adopted in France.
1798	The link between heat and friction is discovered by the American-born physicist Benjamin Thompson, Count Rumford.
1800	Italian physicist Alessandro Volta invents the Voltaic cell.
1801	Interference of light is discovered by the English physicist Thomas Young.

1808	The 'modern' atomic theory is propounded by the English chemist John Dalton.
1811	Avogadro's hypothesis relating volumes and numbers of molecules of gases is proposed by Italian chemist Amedeo Avogadro.
1814	Dark lines in the solar spectrum are mapped by the German physicist and optician Joseph von Fraunhofer, from whom they receive their name.
1815	Refraction of light is explained by French physicist Augustin Fresnel.
1820	The discovery of electromagnetism is made by Danish physicist Hans Oersted.
1821	The dynamo principle is described by the English physicist Michael Faraday.
1822	The laws of electrodynamics are established by the French physicist André Ampère.
1824	Thermodynamics as a branch of physics is foreshadowed in an essay on heat by the French physicist Sadi Carnot.
1826	French physiologist Henri Dutrochet discovers and explains osmosis.
1827	Ohm's law of electrical resistance is established by the German physicist Georg Ohm; Brownian movement (rapid movement resulting from molecular vibrations) is observed by the Scottish botanist Robert Brown in pollen grains suspended in a liquid.
1829	The law of gaseous diffusion is established by Scottish chemist and physicist Thomas Graham.
1831	Electromagnetic induction is discovered independently by Michael Faraday and US physicist Joseph Henry.
1834	Faraday discovers self-induction.
1836	English chemist John Frederic Daniell invents the Daniell cell, a device supplying a steady, long-lasting current through the chemical interaction between zinc and copper electrodes.
1842	The principle of conservation of energy is observed by German physicist Julius von Mayer.
c. 1847	The mechanical equivalent of heat is described by the English physicist James Joule.
1849	A measurement of the velocity of light is put forward by French physicist Armand Fizeau. Fizeau discovers in 1851 that light travels slower in water when the direction of the light beam is against the current of water than when it is following the current.
	Scottish mathematician and physicist William Thomson, later Lord Kelvin, invents the term 'thermodynamics' in an article on the theory of heat developed by Sadi Carnot.
1850	Rudolf Clausius publishes the first generalized statement of the second law of thermodynamics, later restated by him as 'In a closed system entropy tends to increase'.
1851	The rotation of the Earth is demonstrated by French physicist Jean Foucault using a pendulum.
	William Thomson, later Lord Kelvin, proposes the concept of absolute zero, the temperature at which all molecular movement stops. He determines this temperature to be -273°C/-459.4°F, which is later designated the zero point on a temperature scale named in his honour.
1858	Thomson invents the mirror galvanometer, an instrument for measuring small electric currents.
1859	Spectrographic analysis carried out by Robert Bunsen and Gustav Kirchhoff of Germany reveals that each chemical element is uniquely associated with a specific spectral line or set of lines.
1864	In his book *A Dynamic Theory of the Electromagnetic Field*, Scottish physicist James Clerk Maxwell presents the first mathematical treatment of electricity and magnetism using Faraday's idea of a field as a set of lines of force.
1873	Maxwell conceives light as electromagnetic radiation.
1877	A theory of sound as vibrations in an elastic medium is propounded by the English physicist John Strutt, 3rd Baron Rayleigh.
1880	Piezoelectricity is discovered by the French physicist Pierre Curie.
1887	The existence of radio waves is predicted by the German physicist Heinrich Hertz.
	The US physicists Albert Michelson and Edward Morley measure the velocity of light in two different directions in an attempt to detect the Earth's motion through the ether, the supposed medium allowing the propagation of light. They find no difference in the two measurements, indicating that the speed of light is constant and independent of the motion of the observer and that the ether does not exist.
1895	X-rays are discovered by the German physicist Wilhelm Röntgen.
1896	The French physicist Antoine Becquerel discovers that uranium gives off rays. This is the first observation of natural radioactivity.
1897	The English physicist Joseph Thomson discovers the electron.
1898	French physicists Marie and Pierre Curie discover that the element thorium gives off rays like uranium. Marie Curie names the phenomenon radioactivity.
1899	New Zealand-born physicist Ernest Rutherford discovers alpha and beta rays. Becquerel discovers in 1900 that beta rays in fact consist of electrons.
1900	Quantum theory is propounded by Max Planck of Germany; the discovery of gamma rays is made by French physicist Paul-Ulrich Villard.
1902	The English physicist and electrical engineer Oliver Heaviside discovers the ionosphere.
1904	The theory of radioactivity is put forward by Rutherford and English chemist Frederick Soddy.
1905	The German-born physicist Albert Einstein propounds his special theory of relativity.
1908	The Geiger counter is invented by German physicist Hans Geiger and Rutherford.
1911	Rutherford discovers the atomic nucleus.
1911	The Dutch physicist Heike Kamerlingh Onnes observes that mercury, when cooled to just above absolute zero, loses its electrical resistance. The phenomenon becomes known as superconductivity.
1913	The orbiting electron atomic theory is propounded by Danish physicist Niels Bohr.
1915	X-ray crystallography is pioneered by the English physicists William and Lawrence Bragg.
1916	Einstein puts forward his general theory of relativity; mass spectrography is pioneered by the English physicist William Aston.
1926	Wave mechanics is introduced by the Austrian physicist Erwin Schrödinger.
1927	The uncertainty principle of quantum physics is established by the German physicist Werner Heisenberg.
1931	The cyclotron is developed by US physicist Ernest Lawrence.

1932	James Chadwick of England discovers the neutron; the electron microscope is developed by the Russian-born US physicist Vladimir Zworykin.
1933	The positron, the antiparticle of the electron, is discovered by US physicist Carl Anderson.
1934	Artificial radioactivity is developed by the French physicists Frédéric and Irène Joliot-Curie.
1939	The discovery of nuclear fission is made by the German physicists Otto Hahn and Fritz Strassmann.
1942	The first controlled nuclear chain reaction is achieved by the Italian-born US physicist Enrico Fermi.
1956	The neutrino, an elementary particle, is discovered by Clyde Cowan and Fred Reines of the USA.
1960	The Mössbauer effect of atom emissions is discovered by German physicist Rudolf Mössbauer; the first laser and the first maser are developed by US physicist Theodore Maiman.
1964	Murray Gell-Mann and George Zweig of the USA discover and name the quark.
1967	English astronomers Jocelyn Bell (now Jocelyn Bell Burnell) and Antony Hewish discover pulsars (rapidly rotating neutron stars that emit pulses of energy).
1979	The discovery of the asymmetry of elementary particles is made by US physicists James W Cronin and Val L Fitch.
1982	The discovery of processes involved in the evolution of stars is made by the astrophysicists Subrahmanyan Chandrasekhar of India and William Fowler of the USA.
1983	Evidence of the existence of weakons (W and Z particles) is confirmed at CERN, the European centre for nuclear research, validating the link between the weak nuclear force and the electromagnetic force.
1986	The first high-temperature superconductor is discovered, able to conduct electricity without resistance at a temperature of -238°C/-396°F.
1989	CERN's Large Electron Positron Collider (LEP), a particle accelerator with a circumference of 27 km/16.8 mi, comes into operation.
1991	LEP experiments demonstrate the existence of three generations of elementary particles, each with two quarks and two leptons.
1995	The top quark is discovered at Fermilab. US researchers announce the discovery of a material which is superconducting at the temperature of liquid nitrogen - a much higher temperature than previously achieved. A new state of matter, a Bose-Einstein condensate, is created in Colorado.
1996	CERN physicists create the first atoms of antimatter (nine atoms of antihydrogen). The Lawrence Livermore National Laboratory, California, USA, produces a laser of 1.3 petawatts (130 trillion watts).
1997	A new subatomic particle, an exotic meson, is possibly discovered at Brookhaven National Laboratory, Upton, New York, USA. The exotic meson is made up of either a quark, an antiquark, and a gluon, or two quarks and two antiquarks. US physicists display the first atomic laser. It emits atoms that act like light waves.
1999	Scientists succeed in slowing down the speed of light from its vacuum speed of 299,792 km/186,282 mi per second to 61 km/38 mi per hour, opening up potential for the development of high-precision computer and telecommunications technologies, as well as for the advanced study of quantum mechanics.
2000	CERN scientists announce a new state of matter, a quark gluon plasma, produced when lead atoms are made to collide in a particle accelerator. It is 20 times as dense as nuclear matter and is believed to have existed about 10 microseconds after the Big Bang. In this new state of matter, quarks are not bound together but roam freely. The tau neutrino is discovered at Fermilab.

Amusement Park Physics

Go to site

Explaining 'the forces behind the fun', this site uses different amusement park rides to explain concepts such as force, inertia, and Newton's law of interaction.

Bang! Boing! Pop!

Go to site

Interactive learning with 'an emphasis on building physical intuition through interaction'. Students are encouraged to study this site at their own pace and monitor their progress through short tests.

Contributions of 20th-Century Women to Physics

Go to site

Not just a fanfare for female scientists, this site contains a searchable archive of physics research conducted by women in the 20th century. Other pages celebrate the work of early pioneers such as Agnes Pockels, and provide a history of early developments in areas such as nuclear physics.

Emilio Segrè Visual Archives

Go to site

This page includes thousands of historical photographs, slides, lithographs, engravings, and other visual materials mostly featuring physicists and astronomers of the 20th century. In addition to photos, you will find stories and quotes from such well known scientists as Albert Einstein, Marie Curie, Isaac Newton, Galileo, Enrico Fermi, Neils Bohr, and many others.

Eric Weisstein's World of Physics

Go to site

Searchable database of facts relating to physics compiled by Eric W Weisstein, an 'Internet Encyclopedist'. You can search by keywords or subject, and the key terms in each definition are linked to their own definition.

ExploreScience.com

Go to site

One of many sites promising to make physics fun, ExploreScience.com contains a wide variety of interactive (using Shockwave) physics activities that might actually succeed in doing so. Modules cover GCSE-relevant topics such as electricity and magnetism, wave motion, mechanics, optics, and astronomy.

Fizzics Fizzle

Go to site

Interactive guide to physics, for all stages of learning. As well as covering the major areas of study, there is a 'Cool topics' section for people interested in what is happening in physics today.

GCSE Bitesize Physics

Go to site

One-stop revision shop for GCSE physicists provided by the British Broadcasting Corporation (BBC) as part of an all-encompassing GCSE site. Covering all the major topics of the GCSE physics curriculum, the site offers 'revision bites' for those at the start of their pre-exam preparation, and 'test bites' for the more confident.

How Things Work

Go to site

Well-organized site providing answers to many questions relating to physics. There is a large database of previously asked questions that can be readily accessed. Run by the professor of physics at the University of Virginia, USA, the site is an essential point of reference for anybody with an interest in physics.

Learn Physics Today

Go to site

Divided into three online lessons of 'Mechanics', 'Lights and waves', and 'Electricity', this is a comprehensive physics Web site. It features interactive tests to assess learning progress, and a lesson summary page giving a quick overview of the topics. An online calculator must be chosen before any of the lessons are looked at, as this is needed in some of the calculations.

Maths and Physics Help Page

Go to site

Demystifying papers such as 'Think like a physicist' and 'The day the universe went all funny: an introduction to special relativity'.

NetScience: Physics

Go to site

Clearly presented site aimed at high school students. The site covers vectors, motion, forces, momentum, work, energy, and power.

New Scientist Planet Science: The Last Word Science Questions and Answers

Go to site

If you've ever wondered why the sky is blue or why penguins' feet do not freeze, come to this massive searchable archive of scientific information provided by readers of *New Scientist* magazine. For ease of searching, the archive is divided into nine sections, under headings such as 'The physical world' and 'Gadgets and inventions', each with an index of questions.

Phool Proof Physics

Go to site

Comprehensive physics site. This is a stylish site containing sections on a variety of physics topics including electromagnetism, waves, and electronic systems. Each section comprises textbook-style pages on numerous subjects and multiple choice quiz questions.

Physics 2000

Go to site

Stylish site on physics covering a range of topics under the four main headings of 'What is it?', 'Einstein's legacy', 'The atomic lab', and 'Science trek'. Each one is well illustrated and makes good use of interactive Java applets, bringing complex ideas to life.

Physics 4 Kids

Go to site

Covers five main areas of motion, thermodynamics, light, modern physics, and electricity. Each area contains clear, well-presented information on a number of topics.

Physics-related Information

Go to site

Excellent revision resource for GCSE physicists and above. This Web site contains explanations of and proofs for some of the major laws of physics, a guide to orders of magnitude, and links to some good related sites.

Physics Zone

Go to site

Searchable 'resource for learning introductory level, algebra-based physics' arranged by topic. The site uses text, animation, slide shows, and interactive (Shockwave) 'labs' to explore 'rotational and circular stuff', electricity, motion, and more.

Science Myths

Go to site

Debunking commonly held misconceptions relating to physics with good explanations of why they are not correct.

Science Whatzit

Go to site

Post a question to the physics Gremlin provided by the Oregon Museum of Science and Industry (OMSI), or browse a collection of answers to questions on every conceivable aspect of physics. Find out what fire weighs, how to un-pop popcorn, and what happens to a particle moving along a parabolic curve, plus much more.

The Physics of Amusement Parks

Go to site

Virtual amusement park where you can ride the 'Freefall splash', the 'Potential/kinetic coaster', the 'Centripetal carousel', or play 'Physics' arcade games, to help you learn about the physical forces behind the funfair phenomenon.

Thinkquest Visual Physics

Go to site

Well-presented Web site aiming to encourage the learning of physics through visual techniques. The topics of force, work, tension, torque, projectile, momentum, electricity, and kinematics are all covered and explained through interactive exercises. The exercises can be controlled to see the effects of changing different variables, such as the amount of friction. A Java-enabled browser is required to view the interactive exercises.

Zona Land

Go to site

Easy-to-follow site with emphasis on either 'More maths' or 'More science' depending on your preference. The site includes clear examples, definitions, and diagrams.

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physiology

branch of biology that deals with the functioning of living organisms, as opposed to anatomy, which studies their structures.

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physiotherapy

treatment of injury and disease by physical means such as exercise, heat, manipulation, massage, and electrical stimulation.

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phytomenadione

one form of vitamin K, a fat-soluble chemical found in green vegetables. It is involved in the production of prothrombin, which is essential in blood clotting. It is given to newborns to prevent potentially fatal brain haemorrhages.

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pi

symbol π

ratio of the circumference of a circle to its diameter. Pi is an irrational number: it cannot be expressed as the ratio of two integers, and its expression as a decimal never terminates and never starts recurring. The value of pi is 3.1415926, correct to seven decimal places. Common approximations to pi are 22/7 and 3.14, although the value 3 can be used as a rough estimation.

For example, a piece of string tied around the circumference of a mug will measure approximately three times the diameter of the mug.

pi

In 1853, the English mathematician William Shanks published the value of pi to 707 decimal places. The calculation had taken him 15 years and was surpassed only in 1945, when computations made on an early desk calculator showed that the last 180 decimal places he had calculated were incorrect.

Pi Through The Ages

Go to site

History of the calculation of the number pi. This site gives the figure that mathematicians from the time of Ptolemy to the present day have used for pi, and describes exactly how they calculated their figure. Also included are many historical asides, such as how calculation of pi led to a racial attack on an eminent professor in pre-war Germany. Reference publications for further reading are listed here, and there are also links to other pi-related Web sites.

Piaget, Jean (1896-1980)

Swiss psychologist whose studies of the development of thought processes in children have been influential in early-childhood research and on school curricula and teaching methods.

The subjects of Piaget's studies of intellectual development were his own children. He postulated four main stages in the development of mental processes: sensorimeter (birth to the age of two), preoperational (two to seven), concrete operational (seven to twelve), and formal operational, characterized by the development of logical thought.

Piccard, Auguste Antoine (1884-1962)

Swiss scientist. In 1931-32 he and his twin brother, **Jean Félix** (1884-1963), made ascents to 17,000 m/55,000 ft in a balloon of his own design, resulting in useful discoveries concerning stratospheric phenomena such as cosmic radiation. He also built and used, with his son **Jacques Ernest** (1922-), bathyscaphs for research under the sea.

PIC device

abbreviation for programmable interface controller

microcontroller that can be programmed to carry out specific tasks. The PIC contains a low-power microprocessor, together with a small amount of Flash RAM used to store the program and a smaller amount of working RAM in which the program data is held while running. PICs also contain all the necessary circuitry to connect to the outside world, plus timers and a section of EEPROM computer memory in which the processor's instruction set, or language, is stored.

An interface between a desktop personal computer (PC) and the microcontroller is used to program the PIC. Several kits are available that include such an interface, along with software to help generate the PIC instructions. PICs are useful in complex circuits as cost and the electrical circuit, printed circuit board (PCB), complexity can be greatly reduced compared to using discrete components.

pickling

method of preserving food by soaking it in acetic acid (found in vinegar), which stops the growth of moulds. In sauerkraut, lactic acid, produced by bacteria, has the same effect.

PID

abbreviation for pelvic inflammatory disease

serious gynaecological condition characterized by lower abdominal pain, malaise, and fever; menstruation may be disrupted; infertility may result. Treatment is with antibiotics. The incidence of the disease is twice as high in women using intrauterine contraceptive devices (IUDs).

PID is potentially life-threatening, and, while mild episodes usually respond to antibiotics, surgery may be necessary in cases of severe or recurrent pelvic infection. The bacterium *Chlamydia trachomatis* (see chlamydia) has been implicated in a high proportion of cases. The condition is increasingly common.

piezoelectric effect

property of some crystals (for example, quartz) to develop an electromotive force or voltage across opposite faces when subjected to tension or compression, and, conversely, to expand or contract in size when subjected to an electromotive force. Piezoelectric crystal oscillators are used as frequency standards (for example, replacing balance wheels in watches), and for producing ultrasound. Crystalline quartz is a good example of a piezoelectric material.

pig

any even-toed hoofed mammal of the family Suidae. They are omnivorous, and have simple, non-ruminating stomachs and thick hides. The Middle Eastern **wild boar** *Sus scrofa* is the ancestor of domesticated breeds; it is 1.5 m/4.5 ft long and 1 m/3 ft high, with formidable tusks, but not naturally aggressive. The smallest member of the pig family is the **pygmy hog** *Sus salvanus*. Males are 65 cm long (25 cm at the shoulder) and weigh 8-9 kg.

Wild pigs include the **babirusa** and the **wart hog**. The farming of domesticated pigs was practised during the Neolithic period in the Middle East and China at least 11,000 years ago and the pig was a common farm animal in ancient Greece and Rome. Over 400 breeds evolved over the centuries, many of which have all but disappeared in more recent times with the development of intensive rearing systems; however, different environments and requirements have ensured the continuation of a variety of types. The Berkshire, Chester White, Poland, China, Saddleback, Yorkshire, Duroc, and Razorback are the main surviving breeds. Modern indoor rearing methods favour the large white breeds, such as the Chester White and the originally Swedish Landrace, over coloured varieties, which tend to be hardier and can survive better outdoors. Since 1960, hybrid pigs, produced by crossing two or more breeds, have become popular for their heavy but lean carcasses.

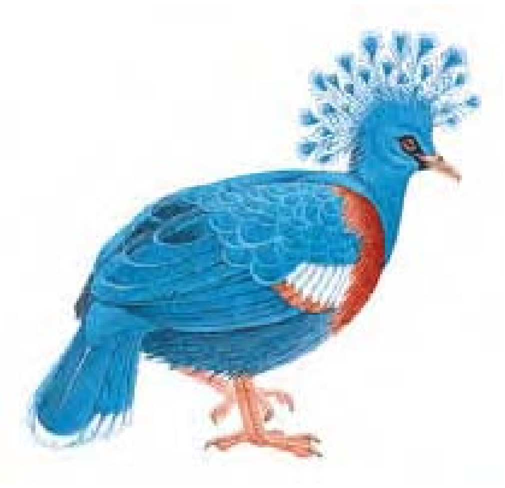
pigeon

or dove

bird of the family Columbidae, order Columbiformes, distinguished by its large crop, which becomes glandular in the breeding season and secretes a milky fluid ('pigeon's milk') that aids digestion of food for the young. There are many species and they are found worldwide.

New World species include the mourning-doves, which live much of the time on the ground. The fruit pigeons of Australasia and the Malay regions are beautifully coloured. In the USA, there were once millions of passenger pigeons *Ectopistes migratorius*, but they have been extinct since 1914.

pigeon



(Image © Research Machines plc)

The laughing dove *Stigmatopelia senegalensis* is found over the whole of Africa south of the Sahara and then eastwards as far as India. Throughout most of this region it is one of the most familiar garden birds, often becoming tame.

pigeon hawk

another name for the merlin, a small falcon.

pig iron

or cast iron

iron produced in a blast furnace. It contains around 4% carbon plus some other impurities.

pika

or mouse-hare

any small mammal of the family Ochotonidae, belonging to the order Lagomorpha (rabbits and hares). The single genus *Ochotona* contains about 15 species, most of which live in mountainous regions of Asia, although two species are native to North America.

Pikas have short, rounded ears, and most species are about 20 cm/8 in long, with greyish-brown fur and no visible tail. Their warning call is a sharp whistle. They are vegetarian and in late summer cut grasses and other plants and place them in piles to dry as hay, which is then stored for the winter.

Pikas can be divided into rock pikas and burrowing pikas. Rock pikas live in rocky territory alone or in pairs. Population densities are low and lifespan is about six years. Females have two or three young per year. Burrowing pikas are social animals and live in family groups at high densities in meadows or steppes, with a much shorter lifespan, of less than two years. Females have as many as twenty young per year, in several large litters.

Pikas do not hibernate, but stay mostly in their burrows, feeding on the hay piles that they have stocked up during the summer.

pike

any of a family Esocidae in the order Salmoniformes, of slender, freshwater bony fishes with narrow pointed heads and sharp, pointed teeth. The northern pike *Esox lucius*, of North America and Eurasia, may reach a length of 2.2 m/7 ft and a weight of 9 kg/20 lb.

Other kinds of pike include muskellunges, up to 2.2 m/7 ft long, and the smaller pickerels, both in the genus *Esox*.

pikeperch

any of various freshwater members of the perch family, resembling pikes, especially the walleye *Stizostedion vitreum*, common in Europe, western Asia, and North America. It reaches over 1 m/3 ft.

pilchard

any of various small, oily members of the herring family, Clupeidae, especially the commercial sardine of Europe *Sardina pilchardus*, and the California sardine *Sardinops sagax*.

In March 1995 a mystery virus or toxin began causing the deaths of millions of pilchards in the oceans south of Australia, killing adults over 12 cm/4.7 in long, but not appearing to harm fish feeding on the pilchards. In April a slick of dead pilchards 40 km/25 mi long was observed off Tasmania.

Pill, the

commonly used term for the contraceptive pill, based on female hormones. The combined pill, which contains synthetic hormones similar to oestrogen and progesterone, stops the production of eggs, and makes the mucus produced by the cervix hostile to sperm. It is the most effective form of contraception apart from sterilization, being more than 99% effective.

The **minipill** or progesterone-only pill prevents implantation of a fertilized egg into the wall of the uterus. The minipill has a slightly higher failure rate, especially if not taken at the same time each day, but has fewer side effects and is considered safer for long-term use. Possible side effects of the Pill include migraine or headache and high blood pressure. More seriously, oestrogen-containing pills can slightly increase the risk of a clot forming in the blood vessels. This risk is increased in women over 35 if they smoke. Controversy surrounds other possible health effects of taking the Pill. The evidence for a link with cancer is slight (and the Pill may protect women from some forms of cancer). Once a woman ceases to take it, there is an increase in the likelihood of conceiving identical twins.

pilotfish

small marine fish *Naucrates ductor* of the family Carangidae, which also includes pompanos. It hides below sharks, turtles, or boats, using the shade as a base from which to prey on smaller fish. It is found in all warm oceans and grows to about 36 cm/1.2 ft.

pimento

or allspice

any of several evergreen trees belonging to the myrtle family, found in tropical parts of the New World. The dried berries of the species *P. dioica* are used as a spice (see allspice). Also, a sweet variety of capsicum pepper (more correctly spelled **pimiento**). (Pimento genus *Pimenta*, family Myrtaceae.)

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pimpernel

any of a group of plants belonging to the primrose family, comprising about 30 species mostly native to Western Europe. The European scarlet pimpernel (*A. arvensis*) grows in cornfields, the small star-shaped flowers opening only in full sunshine. It is naturalized in North America. (Genus *Anagallis*, family Primulaceae.)

PIN

acronym for personal identification number

in banking, a unique number used as a password to establish the identity of a customer using an automatic cash dispenser. The PIN is normally encoded into the magnetic strip of the customer's bank card and is known only to the customer and to the bank's computer. Before a cash dispenser will issue money or information, the customer must insert the card into a slot in the machine (so that the PIN can be read from the magnetic strip) and enter the PIN correctly at a keyboard. This helps to prevent stolen cards from being used to obtain money from cash dispensers.

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pine

any coniferous tree of the genus *Pinus*, family Pinaceae. There are 70-100 species, of which about 35 are native to North America. These are generally divided into two groupings: the soft pines and the hard pines. The former have needles in bundles of five and stalked cones without prickles; for example, eastern white pine *P. strobus*. Hard pines usually have needles in bundles of two or three and prickly cones; for example, jack pine *P. banksiana*. The oldest living species is probably the bristlecone pine *P. aristata*, native to California, of which some specimens are said to be 4,600 years old.

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pineal body

or pineal gland

cone-shaped outgrowth of the vertebrate brain. In some lower vertebrates, it develops a rudimentary lens and retina, which show it to be derived from an eye, or pair of eyes, situated on the top of the head in ancestral vertebrates. In fishes that can change colour to match their background, the pineal perceives the light level and controls the colour change. In birds, the pineal detects changes in daylight and stimulates breeding behaviour as spring approaches. Mammals also have a pineal gland, but it is located deeper within the brain. It secretes a hormone, melatonin, thought to influence rhythms of activity, especially the circadian rhythm. In humans, it is a small piece of tissue attached by a stalk to the rear wall of the third ventricle of the brain.

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pineapple

large, juicy fruit of the pineapple plant, which belongs to the bromeliad family and is native to South and Central America but now cultivated in many other tropical areas, such as Hawaii and Queensland, Australia. The plant's mauvish flowers are produced in the second year, and afterwards join with their bracts (specialized leaves protecting the buds) to form the fleshy fruit, which looks like a giant cone. (Genus *Ananas comosus*, family Bromeliaceae.)

For export to world markets the fruits are cut unripe and lack the sweet juiciness typical of the canned pineapple (usually the smoother-skinned Cayenne variety), which is allowed to mature fully.

pineapple

(Image © Research Machines plc)

Pineapple plantation, Costa Rica. Native to South and Central America, pineapples are today cultivated in tropical and subtropical areas around the world, with Thailand being the main producer. The pineapple fruit ripens five to six months after the plant begins to flower.

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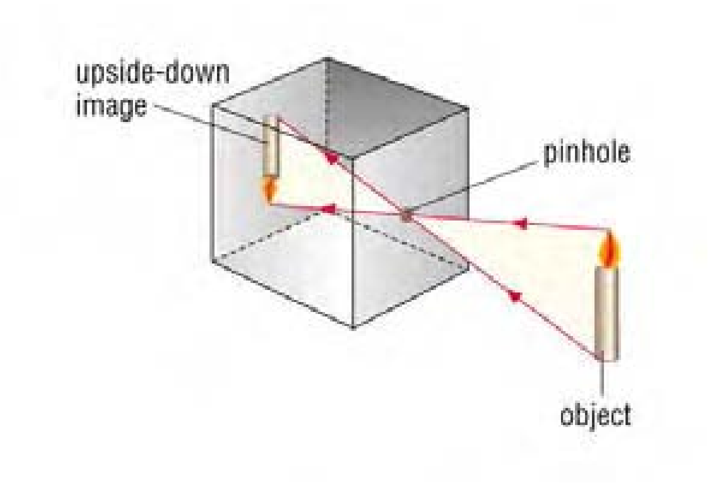
pinhole camera

simplest type of camera, in which a pinhole rather than a lens is used to form an image. Light passes through the pinhole at one end of a box to form an inverted image on the inside surface of the opposite end. A photographic film or plate fitted inside the box will, if exposed for a long time, record the image.

pinhole camera



(Image © Research Machines plc)

A pinhole camera has no lens but can nevertheless produce a sharp inverted image because only one ray from a particular point can enter the tiny pinhole aperture, and so no blurring takes place. However, the very low amount of light entering the camera also means that the film at the back must be exposed for a long time before a photographic image is produced; the camera is therefore only suitable for photographing stationary objects.

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pink

any of a group of annual or perennial plants that have stems with characteristic swellings (nodes) and scented flowers ranging in colour from white through pink to purple. Members of the pink family include carnations, sweet williams, and baby's breath (*Gypsophila paniculata*). (Genus *Dianthus*, family Carophyllaceae.)

Deptford pink (*D. armeria*), which has deep pink flowers with pale dots, is native to Europe and naturalized in the USA.

Pinker, Steven (1954-)

Canadian-born US physiologist and popular science writer. He is widely known for his work on how children acquire language and his advancement of the principles that language is an innate ability linked directly with the evolutionary process. He has written widely about language and the cognitive process both in scientific journals and in popular science books, including *The Language Instinct* (1994), *How the Mind*

Works (1996), and *The Blank Slate: The Modern Denial of Human Nature* (2002), in which he discusses the emotional, political, and moral influences that affect our perception of human nature.

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pinna

in botany, the primary division of a pinnate leaf. In mammals, the pinna is the external part of the ear.

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pinnate leaf

leaf that is divided up into many small leaflets, arranged in rows along either side of a midrib, as in ash trees (*Fraxinus*). It is a type of compound leaf. Each leaflet is known as a **pinna**, and where the pinnae are themselves divided, the secondary divisions are known as pinnules.

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pint

liquid or dry measure of volume or capacity. A liquid pint is equal to 16 fluid ounces or half a liquid quart (0.473 liter), while a dry pint is equal to half a dry quart (0.551 liter).

The British and Canadian imperial pint equals 0.568 liter.

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pinworm

nematode worm *Enterobius vermicularis*, an intestinal parasite of humans.

Childhood Infections - Pinworm

Go to site

Useful information about pinworm. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

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pion

or pi meson

in physics, a subatomic particle with a neutral form (mass 135 MeV) and a charged form (mass 139 MeV). The charged pion decays into muons and neutrinos and the neutral form decays into gamma-ray photons. They belong to the hadron class of elementary particles, and consist of pairs of quarks.

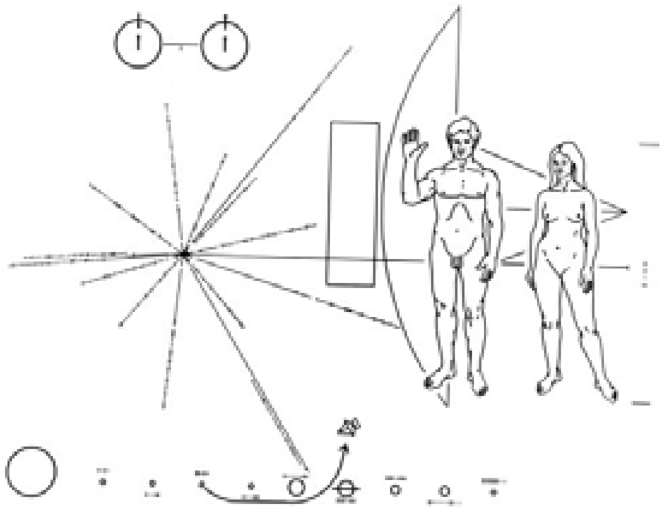
The mass of a charged pion is 273 times that of an electron; the mass of a neutral pion is 264 times that of an electron.

Pioneer

any of a series of US Solar System space probes launched 1958-78. The probes Pioneer 1-3, all launched in 1958, were intended Moon probes, but the launch of Pioneer 1A and Pioneer 2 failed, and Pioneer 1B and Pioneer 3 failed to reach their target, although they did fly deep enough into space to measure the Van Allen radiation belts. Pioneer 4 began to orbit the Sun after passing the Moon. Pioneer 5 (1960) was the first of a series to study the solar wind between the planets. Pioneer 6 (1965), Pioneer 7 (1966), Pioneer 8 (1967), and Pioneer 9 (1968) went into orbit around the Sun and monitored solar activity. Pioneer 10 (March 1972) was the first probe to reach Jupiter (December 1973) and to leave the Solar System (1983). Pioneer 11 (April 1973) passed Jupiter (December 1974) and was the first probe to reach Saturn (September 1979), before also leaving the Solar System. NASA ceased to operate Pioneer 10 in April 1997, but re-established contact in March 2002, when the probe had reached a distance of 11.9 billion km/7.4 billion mi from the Earth. The last signals from Pioneer 10 were received in January 2003. Pioneer 11 ceased to function in 1995.

Pioneer 10 and 11 carry plaques containing messages from Earth in case they are found by other civilizations among the stars. Pioneer Venus probes were launched May and August 1978. One orbited Venus, and the other dropped three probes onto the surface. The orbiter finally burned up in the atmosphere of Venus in 1992.

Pioneer



(Image © NASA)

The design etched into the gold-anodized plate carried by Pioneer 10 and Pioneer 11, and which might – in millions of years – be found by other intelligent spacefaring beings. The symbols are designed to identify the Solar System, show the position of Earth, the time the spacecraft was launched, and the type of creatures who built it. The man is shown making a gesture of goodwill.

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pipefish

any of various long-snouted, thin, pipelike marine fishes in the same family (Syngnathidae) as seahorses. The great pipefish *Syngnathus acus* grows up to 50 cm/1.6 ft. The male has a brood pouch for eggs and developing young, in which he carries the eggs from three to four different females. The eggs hatch in five to six weeks as tiny versions of the adults; there is no larval stage.

pipefish

When pipefish mate it is the female who penetrates the male. She inserts her eggs into his internal pouch using her protruding ovarian duct. He then fertilizes the eggs and carries them as they develop.

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pipette

device for the accurate measurement of a known volume of liquid, usually for transfer from one container to another, used in chemistry and biology laboratories.

A pipette may be a slender glass tube, often with an enlarged bulb, which is calibrated in one or more positions; or it may be a plastic device with an adjustable plunger, fitted with one or more disposable plastic tips.

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pipit

any of various sparrow-sized ground-dwelling songbirds of the genus *Anthus* of the family Motacillidae, order Passeriformes.

---

piranha

any South American freshwater fish of the genus *Serrusalmus*, in the same order as cichlids. They can grow to 60 cm/2 ft long, and have razor-sharp teeth; some species may rapidly devour animals, especially if attracted by blood.

Pisces

inconspicuous zodiac constellation, mainly in the northern hemisphere between Aries and Aquarius, near Pegasus. It is represented as two fish tied together by their tails. The Circlet, a delicate ring of stars, marks the head of the western fish in Pisces. The constellation contains the **vernal equinox**, the point at which the Sun's path around the sky (the **ecliptic**) crosses the celestial equator (see celestial sphere). The Sun reaches this point around 21 March each year as it passes through Pisces from mid-March to late April. In astrology, the dates for Pisces are between about 19 February and 20 March (see precession).

Piscis Austrinus

or Southern Fish

constellation of the southern hemisphere near Capricornus. Its brightest star is the first-magnitude Fomalhaut.

pistachio

deciduous tree of the cashew family, native to Europe and Asia, whose green nuts are eaten salted or used to enhance and flavour food, especially ice cream. (Genus *Pistacia vera*, family Anacardiaceae.)

pistil

general term for the female part of a flower, either referring to one single carpel or a group of several fused carpels.

pistol

any small firearm designed to be fired with one hand.

Pistols were in use from the early 15th century.

The problem of firing more than once without reloading was tackled by using many combinations of multiple barrels, both stationary and revolving. A breech-loading, multichambered revolver from 1650 still survives; the first practical solution, however, was Samuel Colt's six-gun, patented in 1835. It was mass-produced during the Mexican War (1846–48) when the US government ordered 1,000 guns. Behind a single barrel, a short six-chambered cylinder was rotated by cocking the hammer and a fresh round of ammunition brought into firing position. The automatic pistol, operated by gas or recoil, was introduced in Germany in the 1890s. Both revolvers and automatics remain in widespread military use.

piston

any disc or cylinder, circular in cross-section, used in reciprocating engines (steam, petrol, diesel oil) to harness power. Pistons are driven up and down in cylinders by expanding steam or hot gases. They pass on their motion via a connecting rod and crank to a crankshaft, which turns the driving wheels. In a pump or compressor, the role of the piston is reversed, being used to move gases and liquids. See also internal-combustion engine.

pit bull terrier

or American pit bull terrier

variety of dog that was developed in the USA solely as a fighting dog. It usually measures about 50 cm/20 in at the shoulder and weighs roughly 23 kg/50 lb, but there are no established criteria since it is not recognized as a breed by either the American or British Kennel Clubs. Selective breeding for physical strength and aggression has created a dog unsuitable for life in the modern community.

pitch

in chemistry, a black, sticky substance, hard when cold, but liquid when hot, used for waterproofing, roofing, and paving. It is made by the destructive distillation of wood or coal tar, and has been used since antiquity for caulking wooden ships.

pitch

in mechanics, the distance between the adjacent threads of a screw or bolt. When a screw is turned through one full turn it moves a distance equal to the pitch of its thread. A screw thread is a simple type of machine, acting like a rolled-up inclined plane, or ramp (as may be illustrated by rolling a long paper triangle around a pencil). A screw has a mechanical advantage greater than one.

pitchblende

or uraninite

brownish-black mineral, the major uranium ore, consisting mainly of uranium oxide (UO_2). It also contains some lead (the final, stable product of uranium decay) and variable amounts of most of the naturally occurring radioactive elements, which are products of either the decay or the fissioning of uranium isotopes.

The uranium yield is 50-80%; it is also a source of radium, polonium, and actinium. Pitchblende was first studied by Pierre and Marie Curie, who found radium and polonium in its residues in 1898.

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pitcher plant

any of various insectivorous plants, the leaves of which are shaped like a pitcher and filled with a fluid that traps and digests insects. (Genera especially *Nepenthes* and *Sarracenia*, family Sarraceniaceae.)

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pitot tube

instrument that measures fluid (gas or liquid) flow. It is used to measure the speed of aircraft, and works by sensing pressure differences in different directions in the airstream.

It was invented in the 1730s by the French scientist Henri Pitot (1695-1771).

Pitot Tube

Go to site

Contains a detailed description of Pitot tubes (speedometers in aeroplanes) and their uses, as well as a diagram to accompany the text.

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pitta

tropical bird of order Passeriformes, genus *Pitta*, forming the family Pittidae. Some 20 species are native to Southeast Asia, West Africa, and Australia. They have round bodies, big heads, are often brightly coloured, and are silent. They live on the ground and in low undergrowth, and can run from danger. They feed on insects.

A new species of antpitta was discovered in southern Ecuador in 1998. It measures 20 cm/7.9 in in length which means it is the largest bird to be discovered in the last 50 years.

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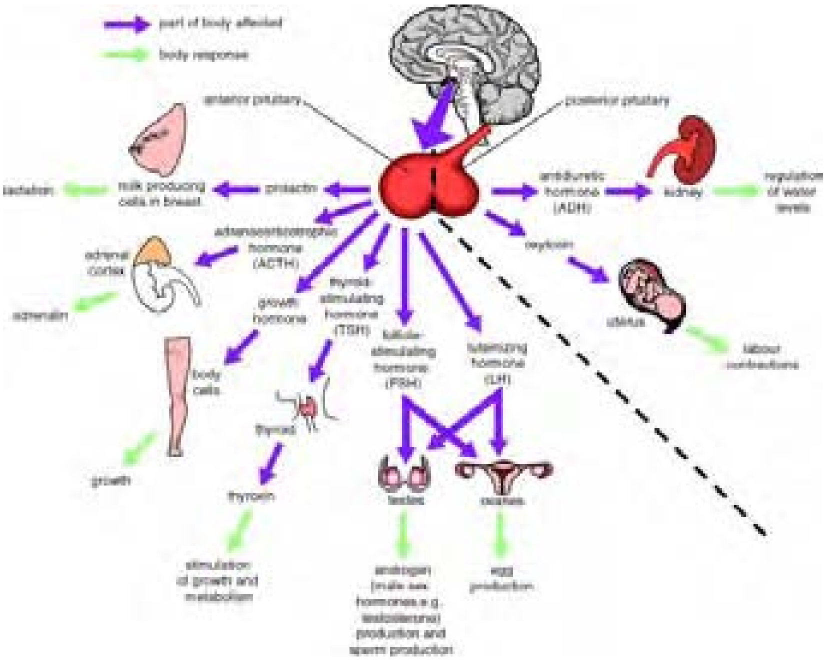
pituitary gland

major endocrine gland of vertebrates, situated in the centre of the brain. It is attached to the hypothalamus by a stalk. The pituitary consists of two lobes. The posterior lobe is an extension of the hypothalamus, and is in effect nervous tissue. It stores two hormones synthesized in the hypothalamus: ADH and oxytocin.
The anterior lobe secretes six hormones, some of which control the activities of other glands (thyroid, gonads, and adrenal cortex); others are direct-acting hormones affecting milk secretion and controlling growth.

pituitary gland


part of body affected
body response
anterior pituitary
posterior pituitary
lactation
milk producing cells in breast
prolactin
antidiuretic hormone (ADH)
kidney
regulation of water levels
adrenocorticotrophic hormone (ACTH)
adrenal cortex
adrenalin
oxytocin
uterus
labour contractions
growth hormone
thyroid-stimulating hormone (TSH)
follicle-stimulating hormone (FSH)
luteinizing hormone (LH)
body cells
growth
thyroid
thyroxin
stimulation of growth and metabolism
testes
ovaries
androgen (male sex hormones e.g. testosterone) production and sperm production
egg production

(Image © Research Machines plc)

The hormones secreted from the pituitary and the effects they have on the body. Two hormones (ADH and oxytocin) are secreted from the posterior pituitary and six (prolactin, ACTH, growth hormone, TSH, FSH, and LH) from the anterior pituitary.

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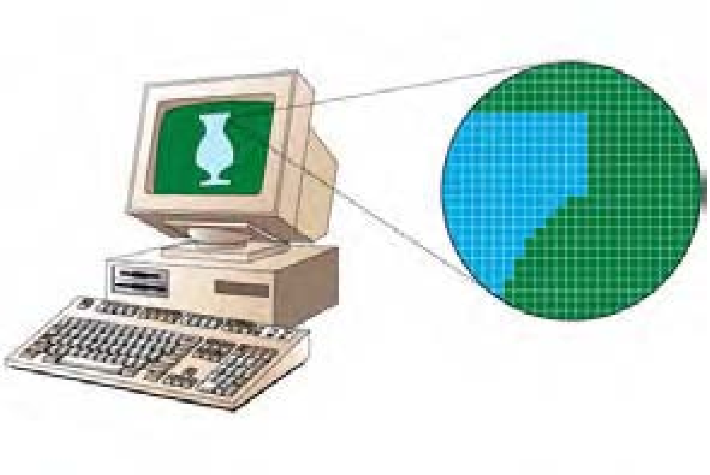
pixel

derived from picture element

single dot on a computer screen. All screen images are made up of a collection of pixels, with each pixel being either off (dark) or on (illuminated, possibly in colour). The number of pixels available determines the screen's resolution. Typical resolutions of microcomputer screens vary from 640 × 480 pixels to 1,024 × 768 pixels, but screens with 1,600 × 1,200 pixels or more are now common for high-quality graphic (pictorial) displays.

pixel



(Image © Research Machines plc)

Computer screen images are made of a number of pixels ('dots'). The greater the number of pixels the greater the resolution of the image; most computer screens are set at 640 × 480 pixels, although higher resolutions are available.

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placebo

(Latin 'I will please')

any harmless substance, often called a 'sugar pill', that has no active ingredient, but may nevertheless bring about improvement in the patient's condition.

The use of placebos in medicine is limited to drug trials, where a placebo is given alongside the substance being tested,to compare effects. The 'placebo effect', first named in 1945, demonstrates the control mind exerts over matter, bringing changes in blood pressure, perceived pain, and rates of healing. Recent research points to the release of certain neurotransmitters and endorphins in the production of the placebo effect.

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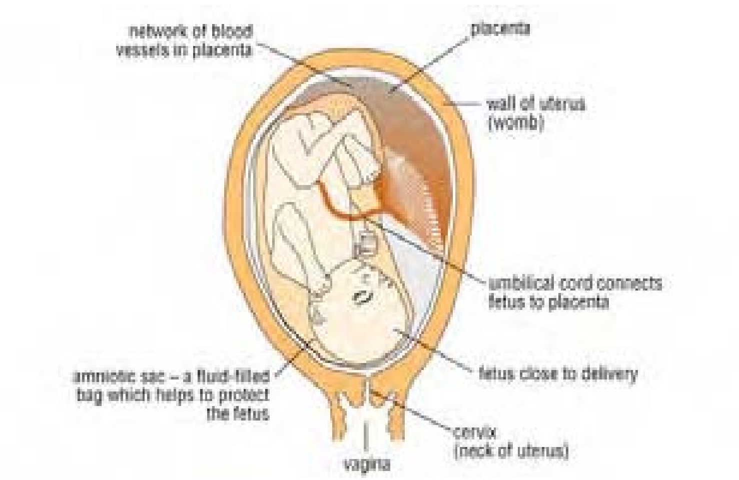
placenta

organ that attaches the developing embryo or fetus to the uterus (womb) in placental mammals (mammals other than marsupials, platypuses, and echidnas). Composed of maternal and embryonic tissue, it links the blood supply of the embryo to the blood supply of the mother, allowing the exchange of oxygen, nutrients, and waste products. The two blood systems are not in direct contact, but are separated by thin membranes, with materials diffusing across from one system to the other. The placenta also produces hormones that maintain and regulate pregnancy. It is shed as part of the afterbirth.

The placenta is an organ essential to the development of the fetus. In mammals, the fetus develops inside the body of the mother. The placenta is attached to the fetus by a cord containing blood vessels - the umbilical cord. The placenta is also firmly attached to the uterus of the mother. The role of the placenta is to bring the blood of the fetus close to the blood of the mother. This then allows oxygen and mineral salts to pass from the mother to the fetus, while carbon dioxide and other waste materials pass in the opposite direction. A variety of materials, including drugs and viruses, can pass across the placenta and enter the fetus. HIV, the virus that causes AIDS, can be transmitted in this way. However, the mother provides some protection against infection. There are chemicals that the mother makes to defend against disease that can cross into the fetus, such as some antibodies.

The tissue in plants that joins the ovary to the ovules is also called a placenta.

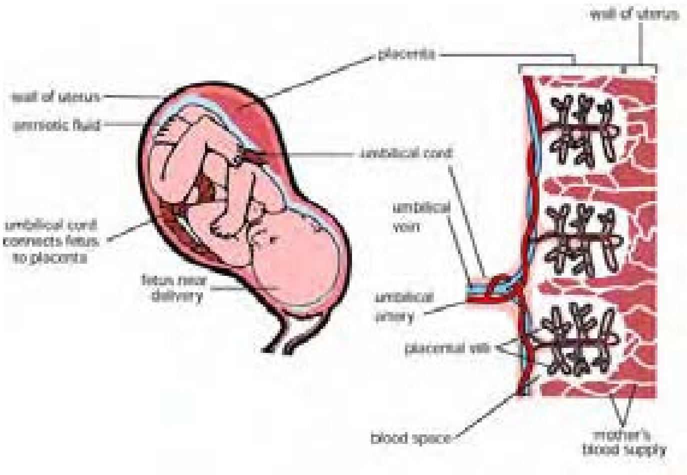
placenta


network of blood vessels in placenta
placenta
wall of uterus (womb)
umbilical cord connects fetus to placenta
fetus close to delivery
amniotic sac – a fluid-filled bag which helps to protect the fetus
cervix (neck of uterus)
vagina

(Image © Research Machines plc)

The human placenta is a disc-shaped organ about 25 cm/10 in in diameter and 3 cm/1 in thick. It is connected to the fetus by the umbilical cord.

placenta


wall of uterus
placenta
wall of uterus
amniotic fluid
umbilical cord
umbilical cord connects fetus to placenta
umbilical vein
fetus near delivery
umbilical artery
placental villi
blood space
mother's blood supply

(Image © Research Machines plc)

Structure of the human placenta. The fetal blood vessels attach to the placenta through the umbilical cord. The mother's blood supply runs through the placenta, which supplies the fetus with nutrients and removes waste products from the fetal blood.

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placer deposit

detrital concentration of an economically important mineral, such as gold, but also other minerals such as cassiterite, chromite, and platinum metals. The mineral grains become concentrated during transport by water or wind because they are more dense than other detrital minerals such as quartz, and (like quartz) they are relatively resistant to chemical breakdown. Examples are the Witwatersrand gold deposits of South Africa, which are gold- and uranium-bearing conglomerates laid down by ancient rivers, and the placer tin deposits of the Malay Peninsula.

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plage

in astronomy, bright patch in the chromosphere above a group of sunspots, occasionally seen on images of the Sun in hydrogen light.

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plague

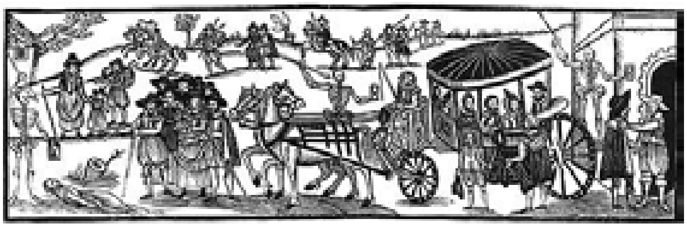
term applied to any epidemic disease with a high mortality rate, but it usually refers to bubonic plague. This is a disease transmitted by fleas (carried by the black rat), which infect the sufferer with the bacillus *Yersinia pestis*. An early symptom is swelling of lymph nodes, usually in the armpit and groin; such swellings are called 'buboes'. It causes virulent blood poisoning and the death rate is high.

Rarer but more virulent forms of plague are **septicaemic** and **pneumonic**; both still exert a formidable mortality. Outbreaks of plague still occur, mostly in poor countries, but never to the extent seen in the late Middle Ages. According to a World Health Organization report published in 1996, the incidence of plague is on the increase. It was reported in 13 states of the USA between 1984 and 1994, in comparison with just 3 states in the 1940s.

plague

In 1666, to help counter the spread of plague, the British Parliament decreed that all bodies had to be wrapped in a woollen shroud for burial. This decree provided wool-makers with a constant source of business for nearly 150 years.

plague



(Image © Billie Love)

A depiction of the flight of townspeople into the country to escape from the plague, in 1630. The European epidemics in the years from 1600 to 1750 were among the most devastating in human history. The new waves of the plague which struck northern Italy and Tuscany in 1630 were believed to have killed up to 70% of the population.

Plague and Public Health in Renaissance Europe

Go to site

Electronic text selection of government decrees, medical narratives, and religious writings about the plague epidemic that swept through Europe during the Renaissance.

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plaice

any of various flatfishes of the flounder group, especially the genera *Pleuronectes* and *Hippoglossoides*.

The American plaice *H. platessoides* grows to 2.5 ft/80 cm, and is valuable commercially.

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plain

or grassland

land, usually flat, upon which grass predominates. The plains cover large areas of the Earth's surface, especially between the deserts of the tropics and the rainforests of the Equator, and have rain in one season only. In such regions the climate belts move north and south during the year, bringing rainforest conditions at one time and desert conditions at another. Temperate plains include the North European Plain, the High Plains of the USA and Canada, and the Russian Plain (also known as the steppe).

Planck, Max Karl Ernst Ludwig (1858-1947)

German physicist who was awarded the Nobel Prize for Physics in 1918 for his formulation of the quantum theory in 1900. His research into the manner in which heated bodies radiate energy led him to report that energy is emitted only in indivisible amounts, called 'quanta', the magnitudes of which are proportional to the frequency of the radiation. His discovery ran counter to classical physics and is held to have marked the commencement of modern science.

Measurements of the frequency distribution of black-body radiation by Wilhelm Wien in 1893 showed the peak value of energy occurring at a higher frequency with greater temperature. This may be observed in the varying colour produced by a glowing object. At low temperatures, it glows red but as the temperature rises the peak energy is emitted at a greater frequency, and the colour become yellow and then white.

Wien attempted to derive a radiation law that would relate the energy to frequency and temperature but discovered a radiation law in 1896 that was valid only at high frequencies. Lord Rayleigh later found a similar equation that held for radiation emitted at low frequencies. Planck was able to combine these two radiation laws, arriving at a formula for the observed energy of the radiation at any given frequency and temperature. This entailed making the assumption that the energy consists of the sum of a finite number of discrete units of energy that he called quanta, and that the energy ε of each quantum is given by the equation: $\varepsilon = hv$, where v is the frequency of the radiation and h is a constant now recognized to be a fundamental constant of nature, called Planck's constant. By directly relating the energy of a radiation to its frequency, an explanation was found for the observation that radiation of greater energy has a higher frequency distribution.

Planck's idea that energy must consist of indivisible particles, not waves, was revolutionary because it totally contravened the accepted belief that radiation consisted of waves. It soon found rapid acceptance: Albert Einstein in 1905 used Planck's quantum theory as an explanation for photoelectricity and in 1913 Danish physicist Niels Bohr successfully applied the quantum theory to the atom. This was later developed into a full system of quantum mechanics in the 1920s, when it also became clear that energy and matter have both a particle and a wave nature.

Planck's constant, a fundamental constant (symbol *h*), is the energy of one quantum of electromagnetic radiation divided by the frequency of its radiation.

Planck, Max Karl Ernst Ludwig

Go to site

Biography of the eminent German physicist Max Planck. Planck is thought of by many to have been more influential than any other in the foundation of quantum physics, and partly as a consequence has a fundamental constant named after him. This Web site contains a description of his working relationships with his contemporaries, and also features a photograph of Planck. Several literature references for further reading on the works of Planck are also listed.

Planck's constant

symbol h

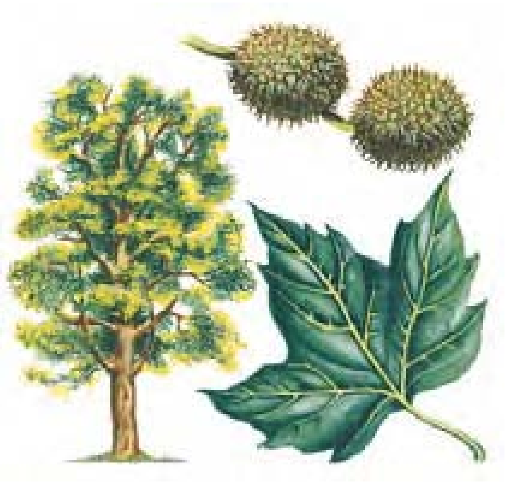
fundamental constant that relates the energy (E) of one quantum of electromagnetic radiation (a 'packet' of energy; see quantum theory) to the frequency (f) of its radiation by $E = hf$. Its value is 6.6262×10^{-34} joule seconds.

plane

in botany, any of several trees belonging to the plane family. Species include the oriental plane (*P. orientalis*), a favourite plantation tree of the Greeks and Romans, and the American plane or buttonwood (*P. occidentalis*). A hybrid of these two is the London plane (*P. x acerifolia*), with palmate, usually five-lobed leaves, which is widely planted in cities for its resistance to air pollution. (Genus *Platanus*, family Platanaceae.)

All species have hanging burlike fruits and can grow to 30 m/100 ft high.

plane



(Image © Research Machines plc)

The plane tree is very tolerant of pollution and is widely grown in towns. It has flaky bark and burrlike fruit resembling drumsticks.

planet

(Greek 'wanderer')

large celestial body in orbit around a star, composed of rock, metal, or gas. There are nine planets in the Solar System orbiting the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Neptune, Uranus, and Pluto (though the status of Pluto as a planet is questionable). The inner four, called the **terrestrial planets**, are small and rocky, and have few natural satellites. The outer planets, with the exception of Pluto, are called the **major planets**, and have denser atmospheres consisting mainly of hydrogen and helium gases, and many natural satellites. The largest planet in the Solar System is Jupiter (about 780 million km/490 million mi from the Sun) with a diameter of 140,000 km/87,500 mi, which contains a mass greater than all the other planets combined. The smallest (and furthest from the Sun at about 5,900 million km/3,600 million mi) is Pluto with a diameter of 2,300 km/1,400 mi.

As seen from the Earth, the five planets from Mercury to Saturn are conspicuous naked-eye objects moving in looped paths against the stellar background. The sizes of these loops, which are caused by the Earth's own motion around the Sun, are inversely proportional to the planet's distance from the Earth. Planets do not produce light, but reflect the light of their parent star.

recent discoveries

Scores of planets orbiting stars other than the Sun have been discovered. Confirmed detections were first made in the early 1990s. Since then planets have been discovered by a variety of methods. A large planet causes a 'wobble' in the parent starseverals motion. A planet circling a pulsar may affect the timing of the pulsarseverals radio signals. A planet may pass between us and the parent star and dim its light. A few objects have been directly imaged - though these are large, and may be brown dwarfs rather than planets. The objects discovered range in mass from brown-dwarf size (about 5-90 times the mass of Jupiter) to a few times the mass of the Earth.

In 2005 US astronomers announced the discovery of a candidate for the title of tenth planet in our Solar System. They observed an object approximately 3,000 km/1,800 mi wide orbiting the Sun three times as far away as the planet Pluto. It is larger than Pluto and is the largest object to be found in the Solar System since Neptune was discovered in 1846. The planet was given the temporary designation 2003 UB313 (it was originally observed in 2003 but only confirmed as a planet in January 2005).The astronomers used telescopes at the Palomar Observatory, California and Mauna Kea, Hawaii to make their discovery.

Space probes to planets include: Mariner 2 (launched in 1962 to Venus); Pioneer 10 (launched in 1972 to Jupiter); Mariner 10 (launched in 1973 to Venus and Mercury); Viking 1 and Viking 2 (launched in 1975 to Mars); Voyager 1 and Voyager 2 (launched in 1977) to Jupiter, Saturn, Uranus, and Neptune; Galileo (launched in 1989 to Jupiter); Cassini (launched in 1997 to Saturn); and numerous missions to Mars in the 1990s.

Discovery of the Major Planets

the first five

Other than the Earth, there are eight major planets in the solar system. Five of them - Mercury, Venus, Mars, Jupiter and Saturn - have been known since antiquity. Looking like bright stars, they reveal their true nature by moving slowly from night to night against the background of the constellations. Indeed, the word 'planet' comes from the ancient Greek for 'wanderer'.

Venus is unmistakable. Shining brilliant white, it is by far the brightest object in the sky after the Sun and Moon and is often visible in daylight. Every few months it is an arresting sight in the evening or morning sky. Jupiter, Mars and Saturn are also prominent, and Mercury may escape attention only because it is close to the Sun and never seen in darkness. These five, together with the Sun and Moon, were familiar sights in the heavens throughout recorded history and have been woven into religious and astrological myth since ancient times.

Uranus

The world was taken by surprise then, when a humble music teacher discovered a new member of the Sun's family of planets in 1781. William Herschel (1738-1822) was a committed amateur astronomer and a skilled telescope maker. He had built a series of superb telescopes at his home in Bath, England. On 13 March, while conducting a survey of the night sky, he came across a curious star that appeared as a disk rather than a point of light. A few nights later it had changed position and within months the astronomical world had confirmed that Herschel's object was a new planet far beyond the orbit of Saturn, then the outermost known member of the solar system.

Herschel wanted to call it George's Star, in honour of King George III, but the name Uranus, after the Greek sky god and father of Cronos (Saturn), was eventually accepted. The king was dazzled nonetheless, and Herschel, the first person ever to discover a new planet, became a favourite at the royal court and soon the most influential astronomer of his day.

Uranus, though faint, is actually visible to the naked eye under good conditions. It was later found that the planet had been recorded on at least 20 occasions as far back as 1690 and mistaken for a star each time. The earlier observers had not had the benefit of Herschel's powerful telescopes which were able to discern the greenish disc of the planet.

Neptune

Some years later astronomers were having problems with the orbit of Mercury, the planet closest to the Sun. Its movements could not be completely accounted for by Newton's laws of gravity. A French astronomer, Urbain Leverrier (1811-1877), proposed in 1845 that the discrepancy could be explained by the gravitational attraction of an undiscovered planet, which he called Vulcan, orbiting within the orbit of Mercury only 30 million km from the Sun. All attempts to find Vulcan failed, and the Mercury problem remained unsolved until 1915, when Albert Einstein (1879-1955) showed that the discrepancies in the orbit were a consequence of the general theory of relativity.

Leaving astronomers to search for Vulcan, Leverrier turned his attention to Uranus which was also deviating from its predicted path. Again, he attributed the perturbation to another planet, this time beyond the orbit of Uranus, and predicted where in the sky it would be found. Johann Galle (1812-1910) at the Berlin Observatory pointed a telescope at Leverrier's position on 23 September 1846 and almost at once discovered the new planet only one degree from the predicted location. It became known as Neptune, after the Roman god of the sea.

It turned out that a young Cornish mathematician, John Couch Adams (1819-1892) had predicted the position of Neptune a year earlier but had been unable to persuade the Astronomer Royal, George Airy (1801-1892) to take it seriously. When Airy finally asked James Challis (1803-1882) at Cambridge Observatory to search for the planet, Challis saw it on two occasions more than a month before Galle but failed to recognize it.

Pluto

Buoyed by this outstanding triumph of Newtonian mechanics, astronomers soon suspected that Neptune in turn was being affected by the pull of a still more distant planet. One of the scientists who attempted to calculate its position was US businessman and astronomer Percival Lowell (1855-1916). He built his own observatory in 1895 at Flagstaff in Arizona but failed to track down the mystery planet. It was not until 18 February 1930, 14 years after Lowell's death, that Clyde Tombaugh (1906-1997), an assistant at the observatory, finally stumbled across the planet. He had ignored the predictions of the mathematicians and had systematically worked his way through the zodiac, the band of sky in which the planets move, comparing pairs of photographs taken on different nights and looking for a 'star' that had moved.

The planet, which was named Pluto after the god of the underworld, was much fainter than expected and was later found on several photographs taken during earlier searches.

Though astronomers continue to discover asteroids, comets and other small bodies in the outer solar system, modern search techniques are so thorough that there is little chance of more major planets lying unseen beyond the orbit of Pluto.

planets

To remember the order of the planets, outwards from the Sun:

My **v**ery **e**ducated **m**other **j**ust **s**erved **u**s **n**ine **p**ies

Mercury, **V**enus, **E**arth, **M**ars, **J**upiter, **S**aturn, **U**ranus, **N**eptune, **P**luto

Planets

(- = not applicable.)

Planet	Main constituents	Atmosphere	Average distance from the Sun		Orbital period (Earth yrs)	Day length	Diameter		Density[1]
			km (millions)	mi (millions)			km (thousands)	mi (thousands)	
Mercury	rock, ferrous	-	58	36	0.241	58d 15h 30m	4.88	3.03	5.4
Venus	rock, ferrous	carbon dioxide	108	67	0.615	243d 0h 27m	12.10	7.51	5.2
Earth	rock, ferrous	nitrogen, oxygen	150	93	1.000	23h 56m	12.76	7.92	5.5
Mars	rock	carbon dioxide	228	141	1.880	24h 37m	6.78	4.21	3.9
Jupiter	liquid hydrogen, helium	-	778	483	11.860	9h 51m	142.80	88.73	1.3
Saturn	hydrogen, helium	-	1,427	886	29.460	10h 14m	120.00	74.56	0.7
Uranus	ice, hydrogen, helium	hydrogen, helium	2,870	1,783	84.000	17h 14m	50.80	31.56	1.3
Neptune	ice, hydrogen, helium	hydrogen, helium	4,497	2,794	164.800	16h 7m	48.60	30.20	1.6
Pluto	ice, rock	methane	5,900	3,666	248.50	6d 9h 17m	2.27	1.41	~2.0

[1] Relative density: 1 = density of water.

Planetary Sciences at the National Space Science Data Center

Go to site

NASA archive of planetary data and images. The site includes fact sheets and press releases, information on forthcoming missions, and a useful chronology of lunar and planetary exploration. There is also information about the impact of the comet Shoemaker-Levy 9 with Jupiter.

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planetarium

optical projection device by means of which the motions of stars and planets are reproduced on a domed ceiling representing the sky; or, more generally, any device that represents such motions, such as an orrery. Traditional projectors are being replaced by digital systems in which an image is created by computer, and then cast onto the dome by one or more projectors.

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planetary embryo

one of numerous massive bodies thought to have formed from the accretion of planetesimals during the formation of the Solar System. Embryos in the region of the Earth's orbit would have been about 10^{23} kg in mass, and about 10-100 of them would have coalesced to make the Earth.

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planetary nebula

shell of gas thrown off by a star at the end of its life. Planetary nebulae have nothing to do with planets. They were named by German-born English astronomer William Herschel, who thought their rounded shape resembled the disc of a planet. After a star such as the Sun has expanded to become a red giant, its outer layers are ejected into space to form a planetary nebula, leaving the core as a white dwarf at the centre.

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planimeter

simple integrating instrument for measuring the area of a regular or irregular plane surface. It consists of two hinged arms: one is kept fixed and the other is traced around the boundary of the area. This actuates a small graduated wheel; the area is calculated from the wheel's change in position.

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planisphere

in astronomy, graphical device for determining the aspect of the sky for any date and time in the year. It consists of two discs mounted concentrically so that the upper disc, which has an aperture corresponding to the horizon of the observer, can rotate over the lower disc, which is printed with a map of the sky centred on the north or south celestial pole. In use, the observer aligns the time of day marked around the edge of the upper disc with the date marked around the edge of the lower disc. The aperture then shows which stars are above the horizon.

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plankton

small, often microscopic, forms of plant and animal life that live in the upper layers of fresh and salt water, and are an important source of food for larger animals. Marine plankton is concentrated in areas where rising currents bring mineral salts to the surface.

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plant

organism that carries out photosynthesis, has cellulose cell walls and complex cells, and is immobile. A few parasitic plants have lost the ability to photosynthesize but are still considered to be plants.

Plants are autotrophs, that is, they make carbohydrates from water and carbon dioxide, and are the primary producers in all food chains, so that all animal life is dependent on them. They play a vital part in the carbon cycle, removing carbon dioxide from the atmosphere and generating oxygen. The study of plants is known as botany.

levels of complexity

The simplest plants consist of a body, or thallus, on which the organs of reproduction are borne. Simplest of all are the threadlike algae, for example *Spirogyra*, which consist of a chain of cells.

The seaweeds (algae) and mosses and liverworts (bryophytes) represent a further development, with simple, multicellular bodies that have specially modified areas in which the reproductive organs are carried. Higher in the morphological scale are the ferns, club mosses, and horsetails (pteridophytes). Ferns produce leaflike fronds bearing sporangia on their under surface in which the spores are carried. The spores are freed and germinate to produce small independent bodies carrying the sexual organs; thus the fern, like other pteridophytes and some seaweeds, has two quite separate generations in its life cycle (see alternation of generations).

The pteridophytes have special supportive water-conducting tissues, which identify them as vascular plants, a group which includes all seed plants, that is the gymnosperms (conifers, yews, cycads, and ginkgos) and the angiosperms (flowering plants).

seed plants

The seed plants are the largest group, and structurally the most complex. They are usually divided into three parts: root, stem, and leaves. Stems can grow above or below ground. Their cellular structure is designed to carry water and salts from the roots to the leaves in the xylem, and sugars from the leaves to the roots in the phloem. The leaves manufacture the food of the plant by means of photosynthesis, which occurs in the chloroplasts they contain. Flowers and cones are modified leaves arranged in groups, enclosing the reproductive organs from which the fruits and seeds result.

conservation status

The World Conservation Union published a world list of threatened plants in 1998. The list includes 33,798 species of vascular plants (flowering plants, ferns, cycads, and conifers); in other words, one in eight of the estimated 270,000 species of vascular plants are now endangered.

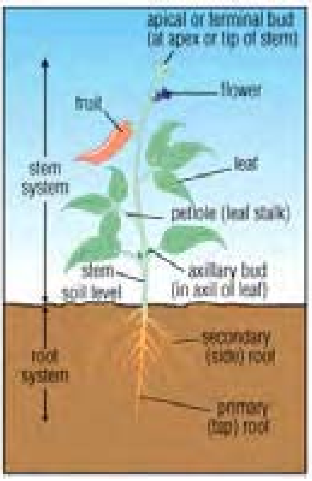
plants: communication

Plants can communicate with each other. A wounded plant may release a gaseous hormone that warns its neighbours to prepare their defences for insect attack, thus limiting potential damage.

plants: oldest

The oldest living plant is the Tasmanian king's holly *Loamtia tasmanica*, which has survived for 43,000 years.

plant



(Image © Research Machines plc)

The external anatomy of a typical flowering plant.

Major divisions in the plant kingdom

Phylum	Translation	Examples
Bryophyta	moss plant	mosses, liverworts, hornworts
Psilophyta	bare, smooth plant	whisk ferns
Lycophyta	wolf foot plant	club mosses
Sphenophyta	wedge plant	horsetails
Filicinophyta/Pteridophyta	fern plant	ferns
Cycadophyta	palm plant	cycads
Ginkgophyta	silver apricot plant[1]	*Ginkgo*
Coniferophyta	cone-bearing plant	cedar, cypress, juniper, pine, redwood
Gnetophyta	desert cone plant[2]	gnetum, welwitschia, ephedra
Angiospermophyta	little case seed plant	flowering plants[3]

[1] Japanese, not Latin, origin.

[2] Not literal translation.

[3] The Angiospermophyta, also called Angiosperms or Anthophyta, are the most successful land plants, found in almost every habitat. This phylum contains nearly every tree, shrub, grass, and plant that produces flowers and seeds. The phylum has two broad sub-divisions: Dicotyledons (Dicots) and Monocotyledons (Monocots). In the Dicots, the seedling emerges with a pair of seed leaves (cotyledons), whereas in Monocots, there is only the one.
The Monocots include the grasses, rushes, and sedges, as well as many other flowering plants with long leaves with the veins running along the length. The Dicots include the majority of flowering plants and trees.

Plants and their Structure

Go to site

Informative guide to the structure of plants. The page begins with a hypertext exploration of the general organization of plant species, then moves on to a discussion of plant cells and tissue types. Diagrams and microscopic images accompany the text.

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plantain

any of a group of northern temperate plants. The great plantain (*P. major*) is low-growing with large oval leaves close to the ground, grooved stalks, and spikes of green flowers with purple anthers (in which the pollen matures) followed by seeds, which are used in bird food. (Genus *Plantago*, family Plantaginaceae.)

The most common introduced species is the ribwort plantain (*P. lanceolata*), native to Europe and Asia and a widespread weed in Australia, Europe, and America. Many other species are troublesome weeds.

A type of banana is also known as plantain.

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plantation

large farm or estate where commercial production of one crop – such as rubber (in Malaysia), palm oil (in Nigeria), or tea (in Sri Lanka) – is carried out. Plantations are usually owned by large companies, often multinational corporations, and run by an estate manager. Many plantations were established in countries under colonial rule, using slave labour.

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plant cell

cell in a plant, which, like all cells, has a cell membrane, cytoplasm, and a nucleus, but which differs from an animal cell by having a cell wall outside the cell surface membrane and a large vacuole. They may also have chloroplasts in the cytoplasm.

The cell surface membrane keeps the cell together by being strong, although it is still very thin and flexible. This membrane controls what enters and leaves the cell - for example, nutrients must be allowed to enter and waste materials must be allowed to leave. The cell has some cytoplasm, but most of the space inside the cell is generally filled with a large vacuole. The cytoplasm contains the nucleus, which controls the activities of the cell, and often contains many chloroplasts, which capture sunlight and make food for the plant through photosynthesis. Chloroplasts are green - this explains why most plants look green.

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plant classification

taxonomy or classification of plants. Originally the plant kingdom included bacteria, diatoms, dinoflagellates, fungi, and slime moulds, but these are not now thought of as plants. The groups that are always classified as plants are the bryophytes (mosses and liverworts), pteridophytes (ferns, horsetails, and club mosses), gymnosperms (conifers, yews, cycads, and ginkgos), and angiosperms (flowering plants). The angiosperms are split into monocotyledons (for example, orchids, grasses, lilies) and dicotyledons (for example, oak, buttercup, geranium, and daisy).

The basis of plant classification was established by the Swedish naturalist Carolus Linnaeus. Among the angiosperms, it is largely based on the number and arrangement of the flower parts.

The unicellular algae, such as *Chlamydomonas*, are often now put with the protists (single-celled organisms) instead of the plants. Some classification schemes even classify the multicellular algae (seaweeds and freshwater weeds) in a new kingdom, the Protoctista, along with the protists.

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plant hormone

substance produced by a plant that has a marked effect on its growth, flowering, leaf fall, fruit ripening, or some other process. Examples include auxin, gibberellin, ethene, and cytokinin.

Unlike animal hormones, these substances are not produced by a particular area of the plant body, and they may be less specific in their effects. It has therefore been suggested that they should not be described as hormones at all.

Plants lack a nervous system and so, for the most part, are unable to respond quickly to stimuli in the way animals can. The two important stimuli for plants are light and gravity, and plants respond by growing either towards or away from the stimulus (this is termed tropism). For example, the shoot of a plant grows toward light (phototropism), while root growth is governed by the pull of gravity (geotropism). Tropism plays a very important part in plant development and survival. Shoots need to grow upwards toward the light so that the leaves can photosynthesize, and flowers can be pollinated; whereas roots need to grow downwards into the soil in order to anchor the plant and absorb water and minerals. The response to stimuli is controlled by plant hormones. Plant hormones are organic chemicals, and are usually referred to as 'growth substances'. These are synthesized by plants, and the five major types are abscisic acid, auxin, cytokinin, ethylene (ethene), and gibberellin. These substances regulate growth and development, and are usually produced in a particular part of the plant, such as the shoot tip, and transported to other parts where they take effect.

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plant propagation

production of plants. Botanists and horticulturalists can use a wide variety of means for propagating plants. There are the natural techniques of vegetative reproduction, together with cuttings, grafting, and micropropagation. The range is wide because most plant tissue, unlike animal tissue, can give rise to the complete range of tissue types within a particular species.

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plaque

any abnormal deposit on a body surface, especially the thin, transparent film of sticky protein (called mucin) and bacteria on tooth surfaces. If not removed, this film forms tartar (calculus), promotes tooth decay, and leads to gum disease. Another form of plaque is a deposit of fatty or fibrous material in the walls of blood vessels causing atheroma.

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plasma

in biology, the liquid component of the blood. It is a straw-coloured fluid, largely composed of water (around 90%), in which a number of substances are dissolved. These include a variety of proteins (around 7%) such as fibrinogen (important in blood clotting), inorganic mineral salts such as sodium and calcium, waste products such as urea, traces of hormones, and antibodies to defend against infection.

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plasma

in physics, ionized gas produced at extremely high temperatures, as in the Sun and other stars. It contains positive and negative charges in equal numbers. It is a good electrical conductor. In thermonuclear reactions the plasma produced is confined through the use of magnetic fields.

Perspectives on Plasmas

Go to site

Impressive guide to plasmas. The site has lots of good articles on plasma basics, plasma technology, and the applications of plasma science. The pages contain lots of photographs and there is a gallery of colourful and interesting plasma pictures.

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plasmapheresis

technique for acquiring plasma from blood. Blood is withdrawn from the patient and separated into its components (plasma and blood cells) by centrifugal force in a continuous-flow cell separator. Once separated, the plasma is available for specific treatments. The blood cells are transfused back into the patient.

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plasmid

small, mobile piece of DNA found in bacteria that, for example, confers antibiotic resistance, used in genetic engineering. Plasmids are separate from the bacterial chromosome but still multiply during cell growth. Their size ranges from 3% to 20% of the size of the chromosome. Some plasmids carry 'fertility genes' that enable them to move from one bacterium to another and transfer genetic information between strains. Plasmid genes determine a wide variety of bacterial properties including resistance to antibiotics and the ability to produce toxins.

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plaster of Paris

form of calcium sulphate $CaCo_3.1/2H_2O$, obtained from gypsum; it is mixed with water for making casts and moulds.

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plastic

any of the stable synthetic materials that are fluid at some stage in their manufacture, when they can be shaped, and that later set to rigid or semi-rigid solids. Plastics today are chiefly derived from petroleum. Most are polymers, made up of long chains of identical molecules.

environmental influence

Since plastics have afforded an economical replacement for ivory in the manufacture of piano keys and billiard balls, the industrial chemist may well have been responsible for the survival of the elephant.

Most plastics cannot be broken down by micro-organisms, so cannot easily be disposed of. Incineration leads to the release of toxic fumes, unless carried out at very high temperatures.

Plastic: Different Types

types of plastic

Plastics are any of the stable synthetic materials that are fluid at some stage in their manufacture, when they can be shaped, and that later set to rigid or semi-rigid solids. Plastics today are chiefly derived from petroleum. Most are polymers, made up of long chains of molecules.

Processed by extrusion, injection-moulding, vacuum-forming and compression, plastics emerge in consistencies ranging from hard and inflexible to soft and rubbery. They replace an increasing number of natural substances, being lightweight, easy to clean, durable, and capable of being rendered very strong - for example, by the addition of carbon fibres - for building aircraft and other engineering projects.

thermoplastics

Thermoplastics soften when warmed, then re-harden as they cool. Examples of thermoplastics include polystyrene, a clear plastic used in kitchen utensils or (when expanded into a 'foam' by gas injection) in insulation and ceiling tiles; polyethylene or polythene, used for containers and wrapping; and polyvinyl chloride (PVC), used for drainpipes, floor tiles, audio discs, shoes, and handbags.

thermosets

Thermosets remain rigid once set, and do not soften when warmed. They include bakelite, used in electrical insulation and telephone receivers; epoxy resins, used in paints and varnishes, to laminate wood, and as adhesives; polyesters, used in synthetic textile fibres and, with fibreglass reinforcement, in car bodies and boat hulls; and polyurethane, prepared in liquid form as a paint or varnish, and in foam form for upholstery and in lining materials (where it may be a fire hazard).

silicones

One group of plastics, the silicones, are chemically inert, have good electrical properties, and repel water. Silicones find use in silicone rubber, paints, electrical insulation materials, laminates, waterproofing for walls, stain-resistant textiles, and cosmetics.

plastics with a memory

Shape-memory polymers are plastics that can be crumpled or flattened and will resume their original shape when heated. They include transpolyisoprene and polynorbornene. The initial shape is determined by heating the polymer to over 35°C and pouring it into a metal mould. The shape can be altered with boiling water and the substance solidifies again when its temperature falls below 35°C.

environmentally friendly plastics

Biodegradable plastics are increasingly in demand: Biopol was developed in 1990. Soil micro-organisms are used to build the plastic in their cells from carbon dioxide and water (it constitutes 80% of their cell tissue). The unused parts of the micro-organism are dissolved away by heating in water. The discarded plastic can be placed in landfill sites where it breaks back down into carbon dioxide and water. It costs three to five times as much as ordinary plastics to produce.

The History of Plastics

introduction

The development of humankind from prehistoric times up to the modern age has been closely associated with the materials used to fabricate tools and artefacts. The earliest materials were wood and stone, which were replaced by copper and iron when it was discovered how metals could be obtained from mineral ores. Advances in metallurgy led to the development of metallic alloys, such as bronze and steel, which soon replaced pure metals for making tools. However, it was to take until the middle of the 19th century before the development of the first truly synthetic material, plastic. The word 'plastic' is derived from the Greek word *plastikos*, which means 'able to be moulded'. The strict definition of a plastic is a synthetic non-metal material that can be shaped into almost any form.

cellulose-based plastics

The first synthetic plastics were produced from cellulose, a natural material present in the cell walls of plants. In 1855 British chemist Alexander Parkes discovered that dissolving partially nitrated cellulose in a mixture of ether, alcohol, and camphor resulted in a hard solid that could be shaped when hot, but retained its final form when cold. Parkes presented his material at the Great International Exhibition of 1862 in London and it became known as 'Parkesine'. He suggested that it could be used as a substitute for natural materials such as ivory and tortoiseshell, which were becoming increasingly scarce. In 1866 he founded the Parkesine Company to exploit his discovery commercially, but the high cost of raw materials led to the company failing a few years later.

A rise in the popularity of the game of billiards in the USA, using ivory balls, led to a crisis in the ivory trade. The demand was so high that hundreds of elephants were killed each day in an attempt to supply enough material to make the required amount of billiard balls. A prize of $10,000 was offered to anyone who could produce a cheap alternative to ivory. In 1866 US inventor John Hyatt accidentally spilt a bottle of collodian, a solution of nitrocellulose similar to that used by Parkes, and noticed that it congealed to form a tough film. His initial efforts to make billiard balls were hampered by the fact that the material was unstable and the balls were prone to explode on impact. However, he discovered that the addition of camphor stabilized the material, which he called 'celluloid'. He won the prize and patented the material in 1869. Celluloid could be produced cheaply in a variety of colours and was used in the manufacture of combs, toys, and false teeth. It was later used in the production of photographic films.

the first synthetic fibres

It was not long before the knowledge of plastics was applied to find a replacement for natural fibres such as silk and cotton. The first synthetic fibres were made from cellulose derivatives and were collectively known as rayon, from the French meaning 'ray of light'.

French chemist Louis Marie Hilaire Bernigaud, comte de Chardonnet had noticed that silkworms produced a liquid that rapidly hardened on contact with air to form silk fibres, and he reasoned that forcing a plastic material through a series of small holes would similarly produce fibres. Chardonnet perfected a technique of forcing a nitrocellulose solution through a series of thin glass tubes to produce the first synthetic fibres. The material closely resembled natural silk in appearance and consequently became known as 'Chardonnet silk'. He presented the material at the Paris Exposition of 1889 and produced it commercially from a factory in Besançon, France, in 1891. Unfortunately the material was highly flammable, which led to it being withdrawn.

viscose and cellophane

In 1892 English chemists Charles Cross and Edward Bevan discovered an alternative method for producing artificial silk that was significantly less flammable than Chardonnet silk. Cellulose again formed the basis of the material and a solution based on caustic soda was used to produce a viscous yellow liquid, which they called 'viscose'. This was injected into a neutralizing acid bath through a series of small holes to produce synthetic fibres.

However, French chemist Jacques Brandenberger discovered the most important use for viscose in 1908. He was searching for a plastic that could be applied to cloth to protect it from liquid spillages and developed a process for forcing viscose through narrow slots to produce plastic sheets. He perfected the process to allow the mass production of a transparent, flexible plastic film, which he called 'cellophane'. This became widely used as a waterproof wrapping material and marked the beginning of the popularization of plastic materials.

plastic resins

Cellulose-based plastics lose their shape when heated, but in 1909 US chemist Leo Baekeland developed a material that retained its shape once hardened, even if heat was reapplied. He called this material 'Bakelite' and it was the first plastic to be made without using cellulose. Bakelite was resistant to almost all acids and solvents and could be added to materials, such as softwoods, to make them more durable. It was widely used in World War II in the manufacture of lightweight components for weapons and equipment, and is still used as an electrical insulator in many household applications today.

The discovery of the non-stick plastic resin Teflon in 1938 was the result of the cooling under pressure of the then recently developed refrigerant gas Freon. US chemist Roy Plunkett had accidentally left a sample overnight and discovered the next day that the gas had formed a chemically inert plastic to which fats could not stick. Teflon became the world's most widely used non-stick coating.

the scientific approach to plastics

The development of plastics owed a great deal to the persistence of German chemist Hermann Staudinger. Plastics belong to a class of compounds known as polymers, which were thought to be composed of disorderly conglomerates of small molecules. Staudinger was virtually the only person who thought that polymer molecules were composed of tens of thousands of atoms held together with ordinary chemical bonds. In 1922 he coined the word 'macromolecule' to describe the huge molecular chains that make up natural rubber and proposed a method for producing a polymer molecule by the reaction of hundreds of smaller molecules called 'monomers'. His ideas were universally rejected until Swedish chemist Theodore Svedberg developed the ultracentrifuge in 1924 and conclusively proved the existence of macromolecules. The acceptance of Staudinger's theories led to methods of synthesizing polymers without requiring the use of natural materials such as cellulose and can be considered as the foundation of the modern plastics industry.

modern plastics

The discovery of how polymer molecules are constructed led to the rapid development of many new plastics. The Naugatuck Chemical Company in Canada was the first to produce polystyrene commercially in 1925. US chemist Waldo Semon developed the manufacture of polyvinyl chloride, PVC, in 1926 to produce the rubber-like plastic Koroseal.

British chemist Michael Perrin discovered one of the most important new plastic materials in 1935 when he successfully synthesized polyethylene. His method required pressures of over 30,000 atmospheres and it took until 1939 before full-scale production began. However, it became one of the key materials of World War II, and was used as a lightweight insulating material for communication cables and portable radars. The use of polyethylene allowed radar equipment to be made light enough to be fitted into aircraft.

In 1953 German chemist Karl Ziegler developed a catalyst that allowed polyethylene to be produced at atmospheric pressure. This form of the plastic was considerably cheaper to produce and led to the material becoming the most used plastic by volume in the world today.

modern synthetic fibres

The first totally synthetic fibre, nylon, was produced by US company Dupont in 1938. This was the culmination of years of research by US chemist Wallace Carothers. The material was lightweight and strong and was initially used to replace animal hair in toothbrushes and silk in the manufacture of stockings, and was later used to make parachutes.

This discovery led the way to further developments. In 1941 British chemists J R Whinfield and J T Dickson produced the first polyester-based synthetic fibre, Terylene, which was independently developed in the USA as Dacron. Blends of this material with natural fibres proved to be more popular than the pure material and are still widely used in clothing manufacture.

The adaptability of the plastic industry to changing clothing trends was reflected by the development of the elastic polymer Lycra in 1958. This fibre retains its shape after stretching and is used, for example, in the production of sportswear.

the next generation of plastics

Research is continuing on the development of plastics with useful properties. In 1977 Japanese researcher Hideki Shirakawa and US researchers Alan McDiarmid and Alan Heeger made the first electrically conducting plastic. This led to the development of the first plastic battery in 1981. Their discovery also allowed the development of semiconducting plastics and the production of the first light-emitting polymers in 1993. These are more energy efficient than conventional light-emitting diodes and give off less heat.

In an increasingly environmentally aware society, the plastics industry is developing biodegradable materials. The first practical example of this was the development of Biopal in 1990. This plastic is degraded by exposure to sunlight.

Hands on Plastics - Introduction to Plastics

Go to site

Detailed insight into the processes behind creating plastics, and the properties that arise from their characteristics. Diagrams of the structure of different types of plastic are included, as well as a list of the applications of plastics in industry. This is useful for gathering information on the suitability of different types of materials.

Plastics

Go to site

Datasheets on 49 generic plastic materials, showing their comparative chemical and physical properties.

Plastics

Go to site

Good introduction to the nature of plastics from a US plastics distributor. It gives a brief history of the plastics industry, followed by a description of the nature of polymers (the building blocks of plastics) and the properties of different kinds of plastic.

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plastic surgery

surgical speciality concerned with the repair of congenital defects and the reconstruction of tissues damaged by disease or injury, including burns. If a procedure is undertaken solely for reasons of appearance, for example, the removal of bags under the eyes or a double chin, it is called **cosmetic surgery**.

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plastid

general name for a cell organelle of plants that is enclosed by a double membrane and contains a series of internal membranes and vesicles. Plastids contain DNA and are produced by division of existing plastids. They can be classified into two main groups: the **chromoplasts**, which contain pigments such as carotenes and chlorophyll, and the **leucoplasts**, which are colourless; however, the distinction between the two is not always clear-cut.

Chloroplasts are the major type of chromoplast. They contain chlorophyll, are responsible for the green coloration of most plants, and perform photosynthesis. Other chromoplasts give flower petals and fruits their distinctive colour. Leucoplasts are food-storage bodies and include amyloplasts, found in the roots of many plants, which store large amounts of starch.

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plate

or tectonic plate or lithospheric plate

one of several relatively distinct sections of the lithosphere, approximately 100 km/60 mi thick, which together comprise the outermost layer of the Earth (like the pieces of the cracked shell of a hard-boiled egg).

The plates are made up of two types of crustal material: oceanic crust (sima) and continental crust (sial), both of which are underlain by a solid layer of mantle. Dense **oceanic crust** lies beneath Earth's oceans and consists largely of basalt.
Continental crust, which underlies the continents and the continental shelves, is thicker, less dense, and consists of rocks that are rich in silica and aluminium.

Due to convection in the Earth's mantle (see plate tectonics) these pieces of lithosphere are in motion, riding on a more plastic layer of the mantle, called the asthenosphere. Mountains, volcanoes, earthquakes, and other geological features and events all come about as a result of interaction between these plates.

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plateau

elevated area of fairly flat land, or a mountainous region in which the peaks are at the same height. An **intermontane plateau** is one surrounded by mountains. A **piedmont plateau** is one that lies between the mountains and low-lying land. A **continental plateau** rises abruptly from low-lying lands or the sea. Examples are the Tibetan Plateau and the Massif Central in France.

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platelet

tiny disc-shaped structure found in the blood, which helps it to clot. Platelets are not true cells, but membrane-bound cell fragments without nuclei that bud off from large cells in the bone marrow.

They play a vital role in blood clotting as they release blood clotting factors at the site of a cut. Over twelve clotting factors have been discovered and they produce a complex series of reactions which ultimately leads to fibrinogen, the inactive blood sealant always found in the plasma, being converted into fibrin. Fibrin aggregates into threads which form the fabric of a blood clot.

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plate tectonics

theory formulated in the 1960s to explain the phenomena of continental drift and sea-floor spreading, and the formation of the major physical features of the Earth's surface. The Earth's outermost layer, the lithosphere, is seen as a jigsaw puzzle of rigid major and minor plates that move relative to each other, probably under the influence of convection currents in the mantle beneath. At the margins of the plates, where they collide or move apart or slide past one another, major landforms such as mountains, rift valleys, volcanoes, ocean trenches, and **mid-ocean ridges** are created. The rate of plate movement is on average 2-3 cm/1 in per year and at most 15 cm/6 in per year.

The concept of plate tectonics brings together under one unifying theory many phenomena observed in the Earth's crust that were previously thought to be unrelated. The size of the crust plates is variable, as they are constantly changing, but six or seven large plates now cover much of the Earth's surface, the remainder being occupied by a number of smaller plates. Each large plate may include both continental and ocean lithosphere. As a result of seismic studies it is known that the lithosphere is a rigid layer extending to depths of about 50-100 km/30-60 mi, overlying the upper part of the mantle (the asthenosphere), which is composed of rocks very close to melting point. This zone of mechanical weakness allows the movement of the overlying plates. The margins of the plates are defined by major earthquake zones and belts of volcanic and tectonic activity. Almost all earthquake, volcanic, and tectonic activity is confined to the margins of plates, and shows that the plates are in constant motion.

plate tectonics

(Image © Garret Nagle)

Rocks at Thingvellir, in Iceland, are disrupted by earth movements as two plates of the Earth's crust move apart, as well as broken down by repeated freeze-thaw action.

plate tectonics

(Image © Garret Nagle)

Fractured rock at Thingvellir, Iceland. Rock weaknesses may be caused, as here, by tectonic movement. In this location, the North American plate moves away from the European plate. Iceland is growing wider by an average of 2 cm/0.8 in per year.

plate tectonics

(Image © Garret Nagle)

The steep inclines on these massive slabs of rock at Thingvellir, Iceland, testify to the tectonic forces at work here. This is the site of part of the Mid-Atlantic Ridge, where the North American plate is pulling away from the European plate. This is a constructive plate boundary, where new material is formed by the cooling of lava, but it also leads to the subsidence of some of the Earth's crust.

Ground Beneath

Go to site

ThinkQuest project, particularly aimed at young people. This well-organized site is a guide to 'What's beneath the Earth's crust and all about plate tectonics'.

Paleomap Project

Go to site

The goal of the Paleomap Project is to illustrate the plate tectonic development of the ocean basins and continents, as well as the changing distribution of land and sea during the past 1,100 million years.

Plate Tectonics

Go to site

Well-illustrated site on this geological phenomenon. As well as plentiful illustrations, this site also has a good, clear manner of explaining the way the plates of the Earth's crust interact to produce seismic activity.

Plate Tectonics

Go to site

US-based site providing a thorough introduction to plate tectonics. Although navigation is rather basic, useful illustrated descriptions of topics such as 'The layers of the Earth', 'Types of plate motion', 'Location of plate boundaries', and 'Continental drift' can be found by clicking on the arrow at the bottom of the initial page.

This Dynamic Earth: The Story of Plate Tectonics

Go to site

Electronic version of a book published by the US Geological Survey.

This Dynamic Planet

Go to site

Online publication about plate tectonics, its history and theory, with a map that shows the Earth's physiographic features, the current movements of its major tectonic plates, and the locations of its volcanoes, earthquakes, and impact craters. The use of colour and shaded relief helps the reader to identify significant features of the land surface and the ocean floor. Over 1,500 volcanoes active during the past 10,000 years are plotted on the map in four age categories.

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platinum

chemical symbol Pt

(Spanish platina 'little silver')

heavy, soft, silver-white, malleable and ductile, metallic element, atomic number 78, relative atomic mass 195.09. It is the first of a group of six metallic elements (platinum, osmium, iridium, rhodium, ruthenium, and palladium) that possess similar properties, such as resistance to tarnish, corrosion, and attack by acid, and that often occur as free metals (native metals). They often occur in natural alloys with each other, the commonest of which is osmiridium. Both pure and as an alloy, platinum is used in dentistry, jewellery, and as a catalyst.

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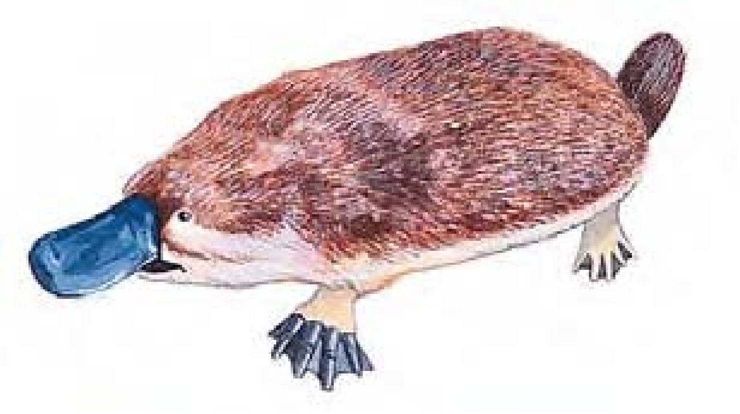
platypus

monotreme, or egg-laying, mammal *Ornithorhynchus anatinus*, found in Tasmania and eastern Australia. Semiaquatic, it has small eyes and no external ears, and jaws resembling a duck's beak. It lives in long burrows along river banks, where it lays two eggs in a rough nest. It feeds on water worms and insects, and when full-grown is 60 cm/2 ft long.

Platypuses locate their prey by detecting the small electric fields produced by their nerve and muscle activity. Males have sharp venomous spurs on their hind legs that they use for defence. The spurs administer (by way of a kick) a cocktail of at least four different toxins that cause intense pain that may last for several weeks.

platypus



(Image © Research Machines plc)

When the platypus was discovered 200 years ago, scientists thought the first specimens were fakes. It has some birdlike features, such as the duck's beak and webbed feet; it also lays eggs. The body has some reptilian characteristics, but is covered with hair like a mammal. Like a mammal, the platypus feeds its young with milk.

Platypus World

Go to site

Comprehensive information on this shy monotreme. Findings of latest research into platypuses is presented, together with recommendations to help preserve the species, and games and activities.

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playa

temporary lake in a region of interior drainage (it has no outlet to the sea). Such lakes are common features in arid desert basins that are fed by intermittent streams. The streams bring dissolved salts to the playa, and when it shrinks during dry spells, the salts precipitate as evaporite deposits.

Pleiades

in astronomy, an open star cluster about 400 light years away from Earth in the constellation Taurus, represented as the Seven Sisters of Greek mythology. Its brightest stars (highly luminous, blue-white giants only a few million years old) are visible to the naked eye, but there are many fainter ones.

It is a young cluster, and the stars of the Pleiades are still surrounded by traces of the reflection nebula from which they formed, visible on long-exposure photographs.

Pleistocene epoch

first part of the Quaternary period of geological time, beginning 1.64 million years ago and ending 10,000 years ago. The polar ice caps were extensive and glaciers were abundant during the ice age of this period, and humans evolved into modern *Homo sapiens sapiens* about 100,000 years ago.

Late Pleistocene Extinctions

Go to site

Exploration of possible causes of the Late Pleistocene extinction of most large mammals in North America. Different theories are discussed. There is also information on the prehistoric inhabitants of North America.

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plesiosaur

prehistoric carnivorous marine reptile of the Jurassic and Cretaceous periods, which reached a length of 12 m/36 ft, and had a long neck and paddlelike limbs. The pliosaurs evolved from the plesiosaurs.

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pleurisy

inflammation of the pleura, the thin, secretory membrane that covers the lungs and lines the space in which they rest. Pleurisy is nearly always due to bacterial or viral infection, but may also be a complication of other diseases.

Normally the two lung surfaces move easily on one another, lubricated by small quantities of fluid. When the pleura is inflamed, the surfaces may dry up or stick together, making breathing difficult and painful. Alternatively, a large volume of fluid may collect in the pleural cavity, the space between the two surfaces, and pus may accumulate.

Plexiglas

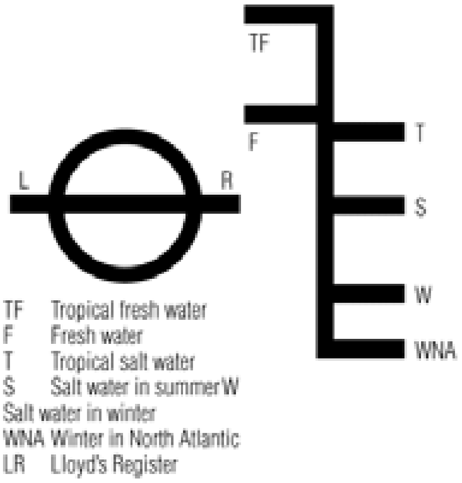
trademark for a clear, lightweight, tough plastic first produced in the USA in 1930. It is widely used for watch glasses, advertising signs, domestic baths, motorboat windshields, aircraft canopies, and protective shields. Its chemical name is polymethylmethacrylate (PMMA). It is manufactured under other names: Lucite, Acrylite, and Rhoplex (in the USA), and Perspex and Oroglas (in Europe).

During World War II, the British surgeon Harold Ridley operated on fighter pilots who had splinters of PMMA from broken cockpit windows in their eyes. He noticed that the eye tolerates this material surprisingly well. Based on this discovery, he developed the first artificial eye lens which he implanted in 1949. Today millions of cataract patients receive this treatment every year.

Plimsoll line

loading mark painted on the hull of merchant ships, first suggested by the 19th-century English politician Samuel Plimsoll. It shows the depth to which a vessel may be safely (and legally) loaded.

Plimsoll line



(Image © Research Machines plc)

The Plimsoll line on the hull of a ship indicates the maximum safe loading levels for sea or fresh water, winter or summer, in tropical or temperate waters.

Pliocene Epoch

('almost recent')

fifth and last epoch of the Tertiary period of geological time, 5.2-1.64 million years ago. The earliest hominid, the humanlike ape *Australopithecines*, evolved in Africa.

pliosaur

prehistoric carnivorous marine reptile, descended from the plesiosaurs, but with a shorter neck, and longer head and jaws. It was approximately 5 m/15 ft long. In 1989 the skeleton of one of a previously unknown species was discovered in northern Queensland, Australia. A hundred million years ago, it lived in the sea that once covered the Great Artesian Basin.

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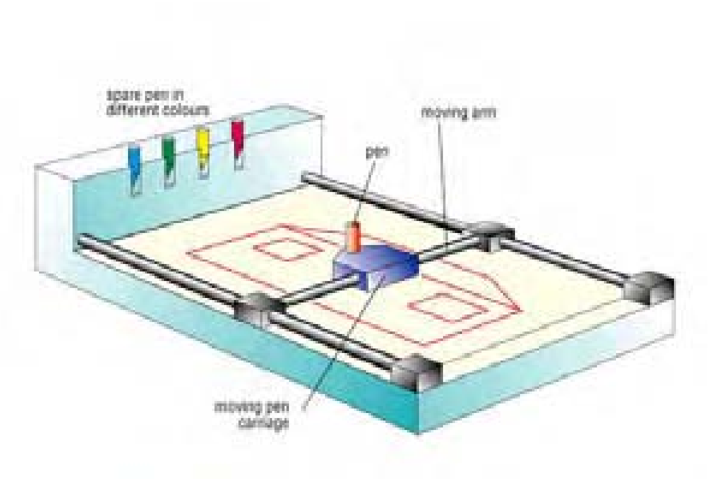
plotter

or graph plotter

device that draws pictures or diagrams under computer control.

Plotters are often used for producing business charts, architectural plans, and engineering drawings. **Flatbed plotters** move a pen up and down across a flat drawing surface, whereas **roller plotters** roll the drawing paper past the pen as it moves from side to side.

plotter



(Image © Research Machines plc)

A flatbed plotter, which may be used to produce plans, graphs, and other drawings. The moving arm, holding a pen of the appropriate colour, travels over the surface of the paper.

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plough

agricultural implement used for tilling the soil. The plough dates from about 3500 BC, when oxen were used to pull a simple wooden blade, or ard. In about 500 BC the iron ploughshare came into use. By about AD 1000 horses as well as oxen were being used to pull wheeled ploughs, equipped with a ploughshare for cutting a furrow, a blade for forming the walls of the furrow (called a coulter), and a mouldboard to turn the furrow.

Steam ploughs came into use in some areas in the 1860s, superseded half a century later by tractor-drawn ploughs. The modern plough consists of many 'bottoms', each comprising a curved ploughshare and angled mouldboard. The bottom is designed so that it slices into the ground and turns the soil over.

plough

(Image © Research Machines plc)

Over four thousand years ago, the invention of the plough marked a huge advance in human civilization. Though the principle of ploughing has remained unchanged, the history of the plough has been one of increasing technological sophistication. Even in the past thirty years, the advent of reversible ploughing and far more powerful four-wheel-drive tractors have greatly improved efficiency.

plover

any shore bird of the family Charadriidae, found worldwide. Plovers are usually black or brown above, and white below, and have short bills. The largest of the ringed plovers is the killdeer *Charadrius vociferus*, called because of its cry.

The semipalmated plover *C. semipalmatus* reaches 7 in/18 cm, has a black neck ring, and is common on beaches and lakeshores.

plucking

in earth science, a process of glacial erosion. Water beneath a glacier will freeze fragments of loose rock to the base of the ice. When the ice moves, the rock fragment is 'plucked' away (literally ripped) from the underlying bedrock. Plucking is thought to be responsible for the formation of steep, jagged slopes such as the backwall of the corrie and the downslope-side of the roche moutonnée.

plum

smooth-skinned, oval, reddish-purple or green edible fruit of the plum tree. There are many varieties, including the Victoria, czar, egg-plum, greengage, and damson; the wild sloe (*P. spinosa*), which is the fruit of the blackthorn, is closely related. Dried plums are known as prunes. (Genus *Prunus domestica*, family Rosaceae.)

plumbago

alternative name for the mineral graphite.

plumule

part of a seed embryo that develops into the shoot, bearing the first true leaves of a plant. In most seeds, for example the sunflower, the plumule is a small conical structure without any leaf structure. Growth of the plumule does not occur until the cotyledons have grown above ground. This is epigeal germination. However, in seeds such as the broad bean, a leaf structure is visible on the plumule in the seed. These seeds develop by the plumule growing up through the soil with the cotyledons remaining below the surface. This is known as hypogeal germination.

Pluto

smallest and, usually, outermost planet of the Solar System. The existence of Pluto was predicted by calculation by US astronomer Percival Lowell and the planet was located by US astronomer Clyde Tombaugh in 1930. Its highly elliptical orbit occasionally takes it within the orbit of Neptune, as in 1979–99. Pluto has a mass about 0.002 of that of Earth.

mean distance from the Sun

5.8 billion km/3.6 billion mi

equatorial diameter

2,300 km/1,438 mi

rotation period

6.39 Earth days

year

248.5 Earth years

atmosphere

thin atmosphere with small amounts of methane gas

surface

low density, composed of rock and ice, primarily frozen methane; there is an ice cap at Pluto's north pole

satellites

one moon, Charon

Pluto

Go to site

Detailed description of the planet Pluto. It includes a chronology of the exploration of the planet, along with statistics and information on its rings, moons, and satellites. There is also a good selection of images.

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plutonic rock

igneous rock derived from magma that has cooled and solidified deep in the crust of the Earth; granites and gabbros are examples of plutonic rocks.

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plutonium

chemical symbol Pu

silvery-white, radioactive, metallic element of the actinide series, atomic number 94, relative atomic mass 239.13. It occurs in nature in minute quantities in pitchblende and other ores, but is produced in quantity only synthetically. It has six allotropic forms (see allotropy) and is one of the fissile elements (elements capable of splitting into other elements - others include thorium and uranium). Plutonium dioxide, PuO_2, a yellow crystalline solid, is the compound most widely used in the nuclear industry. It was believed to be inert until US researchers discovered in 1999 that it reacts very slowly with oxygen and water to form a previously unknown green crystalline compound that is soluble in water.

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plywood

manufactured panel of wood widely used in building. It consists of several thin sheets, or plies, of wood, glued together with the grain (direction of the wood fibres) of one sheet at right angles to the grain of the adjacent plies. This construction gives plywood equal strength in every direction.

plywood

Many people know that Alfred Nobel, founder of the prizes that bear his name, was the inventor of dynamite. However, it is less well known that his father, Immanuel Nobel, was the inventor of plywood.

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pneumatic drill

drill operated by compressed air, used in mining and tunnelling, for drilling shot holes (for explosives), and in road repairs for breaking up pavements. It contains an air-operated piston that delivers hammer blows to the drill bit many times a second. The French engineer Germain Sommeiller (1815-1871) developed the pneumatic drill in 1861 for tunnelling in the Alps.

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pneumatophore

erect root that rises up above the soil or water and promotes gas exchange. Pneumatophores, or breathing roots, are formed by certain swamp-dwelling trees, such as mangroves, since there is little oxygen available to the roots in waterlogged conditions. They have numerous pores or lenticels over their surface, allowing gas exchange.

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pneumoconiosis

disease of the lungs caused by an accumulation of dust, especially from coal, asbestos, or silica. Inhaled particles make the lungs gradually fibrous and the victim has difficulty breathing. Over many years the condition causes severe disability.

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pneumonectomy

surgical removal of all or part of a lung.

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pneumonia

inflammation of the lungs, generally due to bacterial or viral infection but also to particulate matter or gases. It is characterized by a build-up of fluid in the alveoli, the clustered air sacs (at the ends of the air passages) where oxygen exchange takes place.

Symptoms include fever and pain in the chest. With widespread availability of antibiotics, infectious pneumonia is much less common than it was. However, it remains a dire threat to patients whose immune systems are suppressed (including transplant recipients and AIDS and cancer victims) and to those who are critically ill or injured. Pneumocystis pneumonia is a leading cause of death in AIDS. A vaccine against bacterial pneumonia is recommended for people over 65 and other high-risk groups.

Antibiotic Resistance: A Rising Toll

introduction

When, in 1969, the US Surgeon-General announced that we could soon 'close the book' on infectious diseases, he was speaking prematurely. For already, two years earlier, first reports had surfaced of penicillin resistance developing in *Pneumococcus*, a bacterium which causes a number of potentially fatal diseases, including pneumonia and meningitis. Within little more than a decade, epidemics of pneumococcal disease were breaking out in many countries. In 1995, when workers from the Centers for Disease Control in Atlanta looked at samples taken from patients with severe pneumonia, they found that a quarter had been hit by pneumococcal (*Staphylococcus pneumoniae*) strains resistant to penicillin; some 15 % were also resistant to erythromycin. Today, growing resistance of this and other organisms to antibiotics is a global public health problem.

rise of the superbugs

Bacteria vary greatly in their sensitivity to antibiotics, and there is no such thing as a 'magic bullet' with blanket activity against all pathogens. The trouble is that, after more than half a century of antibiotic use, bacteria are mutating faster than new drugs can be found. The growth of super-resistance is being hastened by the indiscriminate use of antibiotics, including over-prescribing. In the developed world, the danger is greatest in hospitals, where people are already very sick. Currently thousands of Britons are dying each year from hospital-acquired infections caused by resistant bacteria. Most at risk are people whose immune systems are in some way impaired, including the very young or the frail elderly, AIDS patients, organ transplant recipients, and patients receiving chemotherapy for cancer. Most notorious of the so-called 'superbugs' staljing hospital floors is methicillin-resistant *Staphylococcus aureus* (MRSA), a pathogen with an awesome talent for acquiring resistance traits from its microscopic neighbours. So far outbreaks of MRSA, which can cause temporary closure of operating rooms and intensive care units, have been met with vancomycin, a 'last resort' antibiotic normally reserved for life-threatening infections. But in spring of 1997, the Japanese reported the most convincing evidence yet of the appearance of vancomycin-resistant strains. The Japanese report brings one step closer the spectre of the unstoppable 'superbug' overrunning hospitals. In fact, microbiologists have been predicting just this scenario, not least because strains of the intestinal bacterium *Enterococcus* have for some time been defying all existing antibiotics, including vancomycin and the closely related teicoplanin. In the laboratory, it has been shown that genes for resistance can pass from *Enterococcus* to the more deadly *S. aureus* by plasmid transfer. It was fear of an epidemic of untreatable infections that prompted the recent European ban on avoparcin, a drug administered to farm animals to promote growth. The rationale for antibiotic use in this context is that it improves feeding efficiency. However, avoparcin is close in chemical structure to vancomycin, and many scientists argue that its use as a growth promoter in livestock creates a potential reservoir of vancomycin-resistant bacteria that would be transmissible to human beings.

return of old-time diseases

The phenomenon of super-resistance means also that many one-time killer diseases, including tuberculosis (TB), typhoid, cholera, and diphtheria, are returning in force. TB, always a major problem in the developing world, is the biggest threat, since now it is making a comeback in countries where previously it had been brought under control. Moreover, some strains of the bacterium have become resistant. Parts of the country worst affected are deprived inner-city areas where resistance is widespread. A big factor in the spread of multi-drug-resistant tuberculosis (MDRTB) has been the failure of control programs in the industrialized countries. This has meant that many patients starting out on medication lapse before the six-month course is completed. If a patient carrying a resistant strain takes only one drug instead of the prescribed combination, or fails to complete the course, the effect is to promote resistant strains.

fresh strategies

Bacteria developing the ability to foil an antibiotic can become permanently resistant, according to researchers at Emory University in Atlanta. They demonstrated this in another rising superbug, *Escherichia coli*, which causes gastrointestinal infections. This finding implies that, contrary to what many doctors previously believed, reducing antibiotic use will not eliminate resistant strains. While the quest for new drugs to fight infection is now paramount, many researchers are developing fresh strategies. These include: tinkering with the structure of antibiotics to add in helper molecules; seeking to disable genes for resistance; and developing laser-activated chemical compounds to blitz the superbugs. Some teams, too, are reviving the old idea of turning bacteriophages (bacteria-eating viruses) loose on resistant bacteria. All these strategies and more may be needed to overcome the rising toll exacted by antibiotic resistance. Certainly, with infectious diseases claiming more than 17 million lives a year worldwide, we are still no nearer to 'closing the book'.

mechanisms of resistance

Bacteria may be naturally resistant to some antibiotics, or resistance may be acquired, mostly by the phenomenon of plasmid transfer. A plasmid is a free-floating fragment of DNA adrift in the cell cytoplasm. It carries some genetic material, including data governing the cell's resistance to antibiotics. Plasmids can be transmitted from one bacterium to another. Occasionally resistance may be due to spontaneous mutation, which is the result of an error in replication of the cell's nuclear material during reproduction. Further reproduction causes the development of a resistant strain. Bacteria demonstrate resistance in two ways. One way is by producing enzymes that disable drugs. A drug-defying enzyme is not always expressed by the organism targeted by therapy. The normally innocuous *Staphylococcus epidermidis* produces an enzyme that disables penicillin before it can act against harmful staphylococcal species; or some bacteria can contrive metabolic changes that foil the action of drugs. Sulphonamides - antibacterials introduced before the discovery of antibiotics - are often defeated by these metabolic readjustments on the part of bacteria.

Childhood Infections - Pneumonia

Go to site

Useful information about pneumonia. There is a detailed, illustrated description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

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pneumothorax

presence of air in the pleural cavity, between a lung and the chest wall. It may be due to a penetrating injury of the lung or to lung disease, or it may occur without apparent cause (spontaneous pneumothorax) in an otherwise healthy person. Prevented from expanding normally, the lung is liable to collapse.

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p-n junction diode

in electronics, another name for semiconductor diode.

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pochard

any of various diving ducks found in Europe and North America, especially the genus *Aythya*. They feed largely on water plants. Their nest is made in long grass on the borders of lakes and pools.

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pod

in botany, a type of fruit that is characteristic of legumes (plants belonging to the Leguminosae family), such as peas and beans. It develops from a single carpel and splits down both sides when ripe to release the seeds.

In certain species the seeds may be ejected explosively due to uneven drying of the fruit wall, which sets up tensions within the fruit.

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podiatry

or chiropody

the medical profession that deals with the specialized care of feet. Some podiatric treatments involve the use of orthopedic devices to correct fallen arches or improve improper positioning of feet during walking.

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podzol

or podsol

type of light-coloured soil found predominantly under coniferous forests and on moorlands in cool regions where rainfall exceeds evaporation. The constant downward movement of water leaches nutrients from the upper layers, making podzols poor agricultural soils. Podzols are very acidic soils.

The leaching of minerals such as iron and alumina leads to the formation of a bleached zone, which is often also depleted of clay.

These minerals can accumulate lower down the soil profile to form a hard, impermeable layer which restricts the drainage of water through the soil.

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poikilothermy

condition in which an animal's body temperature is largely dependent on the temperature of the air or water in which it lives. It is characteristic of all animals except birds and mammals, which maintain their body temperatures by homeothermy (they are 'warm-blooded').

Poikilotherms have behavioural means of temperature control; they can warm themselves up by basking in the sun, or shivering, and can cool themselves down by sheltering from the Sun under a rock or by bathing in water.

Poikilotherms are often referred to as 'cold-blooded animals', but this is not correct: their internal temperatures, regulated by behavioural means, are often as high as those of birds and mammals during the times they need to be active for feeding and reproductive purposes, and may be higher, for example in very hot climates. The main difference is that their body temperatures fluctuate more than those of homeotherms.

Poincaré, (Jules) Henri (1854-1912)

French mathematician who developed the theory of differential equations and was a pioneer in relativity theory. He suggested that Isaac Newton's laws for the behaviour of the universe could be the exception rather than the rule. However, the calculation was so complex and time-consuming that he never managed to realize its full implication.

Poincaré wrote on the philosophy of science. He believed that some mathematical ideas precede logic, and stressed the role played by convention in scientific method.

He also published the first paper devoted entirely to topology (the branch of geometry that deals with the unchanged properties of figures).

Poincaré, Jules Henry

Go to site

Biography of the French mathematician. The site contains a description of his working relationships with his contemporaries, and also features a photograph of Poincaré. Several literature references for further reading on the works of Poincaré are also listed.

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poinsettia

or Christmas flower

winter-flowering shrub with large red leaves encircling small greenish-yellow flowers. It is native to Mexico and tropical America and is a popular houseplant in North America and Europe. (Genus *Euphorbia pulcherrima*, family Euphorbiaceae.)

poinsettia

(Image © Corel)

The decorative poinsettia, native to Mexico and South America, was named after its discoverer J.R. Poinsett (1779–1853), a US politician. Its bracts are more commonly scarlet in colour, but there are also pink, cream, and bi-coloured varieties.

point

in geometry, a basic element, whose position in the Cartesian system may be determined by its coordinates.

Mathematicians have had great difficulty in defining the point, as it has no size, and is only the place where two lines meet. According to the Greek mathematician Euclid, (i) a point is that which has no part; (ii) the straight line is the shortest distance between two points.

pointer

any of several breeds of gun dog, bred especially to scent the position of game and indicate it by standing, nose pointed towards it, often with one forefoot raised, in silence. English pointers have smooth coats, mainly white mixed with black, tan, or dark brown. They stand about 60 cm/24 in tall and weigh 28 kg/62 lb.

A very similar breed, the German short-haired pointer, was developed in the 19th century to point and also to pursue game.

The Weimeraner is another pointing breed.

point of sale

POS

in business premises, place at which a sale is made. This could be at a retail store (such as a supermarket checkout), at home (door-to-door sales), or on the phone (phone selling). At the point of sale there will often be promotional materials and other inducements to purchase, such as notices of special offers. In conjunction with electronic funds transfer, point of sale is part of the terminology of 'cashless shopping', enabling buyers to transfer funds directly from their bank accounts to the shop's.

point-of-sale terminal

or POS terminal

computer terminal used in shops to input and output data at the point where a sale is transacted; for example, at a supermarket checkout. The POS terminal inputs information about the identity of each item sold, retrieves the price and other details from a central computer, and prints out a fully itemized receipt for the customer. It may also input sales data for the shop's computerized stock-control system.

A POS terminal typically has all the facilities of a normal till, including a cash drawer and a sales register, plus facilities for the direct capture of sales information – commonly, a laser scanner for reading bar codes. It may also be equipped with a device to read customers' bank cards, so that payment can be transferred electronically from the customers' bank accounts to the shop's (see EFTPOS).

poise

symbol P

c.g.s. unit of dynamic viscosity (the property of liquids that determines how readily they flow). It is equal to one dyne-second per square centimetre. For most liquids the centipoise (one hundredth of a poise) is used. Water at 20°C/68°F has a viscosity of 1.002 centipoise.

poison

any substance that causes injury, illness, or death, especially by chemical means. In biology, the word poison is reserved for substances that are most likely to enter the body via the mouth or airways. Poisonous substances injected by biting or stinging animals are called venom, while those released by bacteria in an infection are known as toxins. The liver removes some poisons from the blood. The majority of poisons may be divided into **corrosives**, such as sulphuric, nitric, and hydrochloric acids; **irritants**, including arsenic and copper sulphate; **narcotics**, such as opium and carbon monoxide; and **narcotico-irritants**, from any substances of plant origin including phenol acid and tobacco.

how poisons work

Corrosives all burn and destroy the parts of the body with which they come into contact; irritants have an irritating effect on the stomach and bowels; narcotics affect the brainstem and spinal cord, inducing a stupor; and narcotico-irritants can cause intense irritations and finally act as narcotics.

At the molecular level, many poisons address one specific biochemical receptor, transporter, or channel. For instance, both carbon monoxide and cyanide ions bind irreversibly to the oxygen transporter haemoglobin, and thereby lead to internal suffocation.

Poisson, Siméon-Denis (1781-1840)

French applied mathematician and physicist. In probability theory he formulated the **Poisson distribution**. **Poisson's ratio** in elasticity is the ratio of the lateral contraction of a body to its longitudinal extension. The ratio is constant for a given material.

Much of Poisson's work involved applying mathematical principles in theoretical terms to contemporary and prior experiments in physics, particularly with reference to electricity, magnetism, heat, and sound. Poisson was also responsible for a formulation of the 'law of large numbers', which he introduced in his work on probability theory, *Recherches sur la probabilité des jugements/Researches on the Probability of Opinions* (1837).

Poisson, Siméon Denis

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of Siméon Poisson. In addition to biographical information, you will find a list of references about Poisson and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Poisson. There is also an image of him, which can be enlarged, and a map of his birthplace.

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polar bear

large white-coated bear that lives in the Arctic. Polar bears are normally solitary, except for females when rearing cubs. They feed mainly on seals but will eat berries and scavenge when food is scarce. Males weigh 400–800 kg/880–1,760 lb and are up to 2.5 m/8.25 ft in length (twice as large as females, 200–400 kg). The estimated world population in 1997 was 20,000–30,000 bears.

Polar bears mate in spring, but egg implantation is delayed until autumn to ensure that when the cubs emerge from the den in the following March, the weather is milder and food more plentiful. Two or sometimes three cubs are born after a short gestation, weighing only 500 g/17.6 oz each. Cubs remain with their mother for 2.5 years.

classification

Polar bears constitute a single species *Thalarctos maritimus*, in the bear family Ursidae, order Carnivora.

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polar coordinates

in mathematics, a way of defining the position of a point in terms of its distance r from a fixed point (the origin) and its angle θ to a fixed line or axis. The coordinates of the point are (r,θ).

Often the angle is measured in radians, rather than degrees. The system is useful for defining positions on a plane in programming the operations of, for example, computer-controlled cloth- and metal-cutting machines.

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polarimetry

in astronomy, any technique for measuring the degree of polarization of radiation from stars, galaxies, and other objects.

Polaris

or Pole Star or North Star

bright star closest to the north celestial pole, and the brightest star in the constellation Ursa Minor. Its position is indicated by the 'pointers' in Ursa Major. Polaris is a yellow supergiant about 500 light years away from the Sun. It is also known as **Alpha Ursae Minoris**.

It currently lies within 1° of the north celestial pole; precession (Earth's axial wobble) will bring Polaris closest to the celestial pole (less than 0.5° away) in about AD 2100. Then its distance will start to increase, reaching 1° in 2205 and 47° in 28000. Other bright stars that have been, or will be close to the north celestial pole are Alpha Draconis (2800 BC), Gamma Cephei (AD 4000), Alpha Cephei (AD 7000), and Vega (AD 14000).

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polarized light

light in which the electromagnetic vibrations take place in one particular plane. In ordinary (unpolarized) light, the electric fields vibrate in all planes perpendicular to the direction of propagation. After reflection from a polished surface or transmission through certain materials (such as Polaroid), the electric fields are confined to one direction, and the light is said to be **linearly polarized**. In **circularly polarized** and **elliptically polarized** light, the electric fields are confined to one direction, but the direction rotates as the light propagates. Polarized light is used to test the strength of sugar solutions and to measure stresses in transparent materials.

polarography

electrochemical technique for the analysis of oxidizable and reducible compounds in solution. It involves the diffusion of the substance to be analysed onto the surface of a small electrode, usually a bead of mercury, where oxidation or reduction occurs at an electric potential characteristic of that substance.

Polaroid camera

instant-picture camera, invented by Edwin Land in the USA in 1947. The original camera produced black-and-white prints in about one minute. Modern cameras can produce black-and-white prints in a few seconds, and colour prints in less than a minute. An advanced model has automatic focusing and exposure.

It ejects a piece of film on paper immediately after the picture has been taken.

The film consists of layers of emulsion and colour dyes together with a pod of chemical developer. When the film is ejected the pod bursts and processing occurs in the light, producing a paper-backed print.

The Polaroid company filed for bankruptcy protection in October 2001. It amassed debts of US$1 billion as digital cameras took over much of the market. However, its business is being continued by a holding company.

polar reversal

or magnetic reversal

change in polarity of Earth's magnetic field. Like all magnets, Earth's magnetic field has two opposing regions, or poles, positioned approximately near geographical North and South Poles. During a period of normal polarity the region of attraction corresponds with the North Pole. Today, a compass needle, like other magnetic materials, aligns itself parallel to the magnetizing force and points to the North Pole. During a period of reversed polarity, the region of attraction would change to the South Pole and the needle of a compass would point south.

Studies of the magnetism retained in rocks at the time of their formation (like small compasses frozen in time) have shown that the polarity of the magnetic field has reversed repeatedly throughout geological time.

The reason for polar reversals is not known. Although the average time between reversals over the last 10 million years has been 250,000 years, the rate of reversal has changed continuously over geological time. The most recent reversal was 780,000 years ago; scientists have no way of predicting when the next reversal will occur. The reversal process probably takes a few thousand years. Dating rocks using distinctive sequences of magnetic reversals is called magnetic stratigraphy.

polder

area of flat reclaimed land that used to be covered by a river, lake, or the sea. Polders have been artificially drained and protected from flooding by building dykes. They are common in the Netherlands, where the total land area has been increased by nearly one-fifth since AD 1200. Such schemes as the Zuider Zee project have provided some of the best agricultural land in the country.

pole

either of the geographic north and south points of the axis about which the Earth rotates. The geographic poles differ from the magnetic poles, which are the points towards which a freely suspended magnetic needle will point.

In 1985 the magnetic north pole was some 350 km/218 mi northwest of Resolute Bay, Northwest Territories, Canada. It moves northwards about 10 km/6 mi each year, although it can vary in a day about 80 km/50 mi from its average position. It is relocated every decade in order to update navigational charts.

It is thought that periodic changes in the Earth's core cause a reversal of the magnetic poles (see polar reversal, magnetic field). Many animals, including migrating birds and fish, are believed to orient themselves partly using the Earth's magnetic field. A permanent scientific base collects data at the South Pole.

polecat

Old World weasel *Mustela putorius* with a brown back and dark belly and two yellow face patches. The body is about 50 cm/20 in long and it has a strong smell from anal gland secretions. It is native to Asia, Europe, and North Africa. In North America, skunks are sometimes called polecats. A ferret is a domesticated polecat.

Pole Star

another name for Polaris, the northern pole star. There is no bright star near the southern celestial pole.

poliomyelitis

or polio

acute viral infection of the central nervous system affecting nerves that activate muscles. The disease used to be known as infantile paralysis since children were most often affected. The poliomyelitis virus is a common one, and mostly its effects are confined to the throat and intestine, as with influenza or a mild digestive upset. There may also be muscle stiffness in the neck and back. Paralysis is seen in about 1% of cases, and the disease is life-threatening only if the muscles of the throat and chest are affected. Cases of this kind, once entombed in an 'iron lung', are today maintained on a respirator. Two kinds of vaccine are available, one injected (see Salk) and one given by mouth.

The Americas were declared to be poliomyelitis-free by the Pan American Health Organization in October 1994. In 1997 the World Health Organization (WHO) reported that causes of poliomyelitis had dropped by nearly 90% since 1988 when the organization began its program to eradicate the disease. In October 2000, the Western Pacific Region was certified polio-free.Most remaining cases are in Africa and southeast Asia (in 1998 India accounted for over 30% of the world's poliomyelitis cases).

Politzer, Hugh David (1949-)

US physicist. With the US physicists David Gross and Frank Wilczek he shared the Nobel Prize for Physics in 2004 for his contributions to the development of a theory to explain how quark subatomic particles are held together by the strong nuclear force.

Politzer worked independently of his fellow Nobel prizewinners, Gross and Wilczek, to calculate how the strong force acts between subatomic particles known as quarks. Quarks are the building blocks for protons and neutrons in the nucleus of an atom. The standard model of particle physics, that was used to explain how subatomic particle behave, could not account for the observation that quarks could only be made to act as individual particles at very high energies. Politzer discovered that the strong force, also called the colour interaction, acts on quarks to make the attraction between them increase with distance. This has the effect of holding quarks within the nucleus as the forces of attraction increase the further away quarks move from each other. The discovery was published in two scientific papers in 1971 and formed the basis of the theory of colour interaction known as quantum chromodynamics (QCD). This work allowed the standard model of particle physics to be completed.

pollack

marine fish *Pollachius virens* of the cod family, growing to 75 cm/2.5 ft, and found close to the shore on both sides of the North Atlantic.

pollack

(Image © Research Machines plc)

Pollack, *Pollachius pollachius*, are members of the cod family. Widely distributed in waters from the northern Mediterranean to the Atlantic as far north as Iceland, they are still plentiful in the English Channel off the coasts of Devon and Cornwall, where the traditional method of handline fishing is often used to catch them.

pollarding

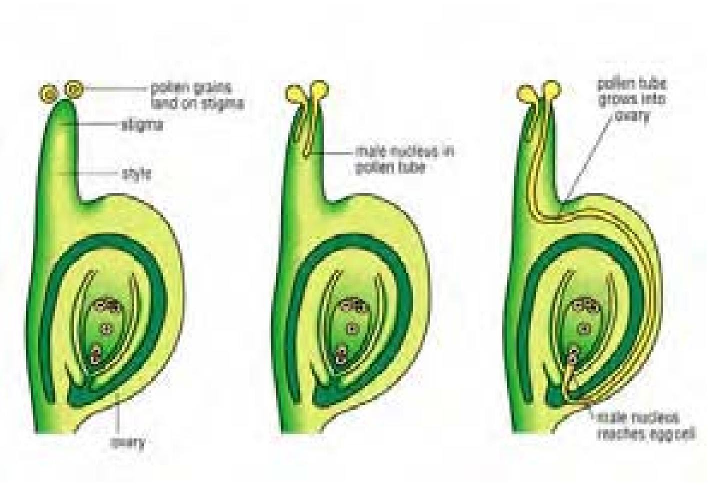
type of pruning whereby the young branches of a tree are severely cut back, about 2-4 m/6-12 ft above the ground, to produce a stumplike trunk with a rounded, bushy head of thin new branches. It is similar to coppicing.

pollen

grains of seed plants that contain the male gametes. In angiosperms (flowering plants) pollen is produced within anthers; in most gymnosperms (cone-bearing plants) it is produced in male cones. A pollen grain is typically yellow and, when mature, has a hard outer wall. Pollen of insect-pollinated plants (see pollination) is often sticky and spiny and larger than the smooth, light grains produced by wind-pollinated species.

The outer wall of pollen grains from both insect-pollinated and wind-pollinated plants is often elaborately sculptured with ridges or spines so distinctive that individual species or genera of plants can be recognized from their pollen. Since pollen is extremely resistant to decay, useful information on the vegetation of earlier times can be gained from the study of fossil pollen. The study of pollen grains is known as palynology.

pollen


pollen grains land on stigma
stigma
style
ovary
male nucleus in pollen tube
pollen tube grows into ovary
male nucleus reaches egg cell

(Image © Research Machines plc)

Pollination, the process by which pollen grains transfer their male nuclei (gametes) to the ovary of a flower. The pollen grains land on the stigma and form a pollen tube that grows down into the ovary. The male nuclei travel along the pollen tube.

pollen tube

outgrowth from a pollen grain that grows towards the ovule, following germination of the grain on the stigma. In angiosperms (flowering plants) the pollen tube reaches the ovule by growing down through the style, carrying the male gametes inside. The gametes are discharged into the ovule and one fertilizes the egg cell.

pollination

process by which pollen is transferred from one plant to another. The male gametes are contained in pollen grains, which must be transferred from the anther to the stigma in angiosperms (flowering plants), and from the male cone to the female cone in gymnosperms (cone-bearing plants). Fertilization (not the same as pollination) occurs after the growth of the pollen tube to the ovary. Self-pollination occurs when pollen is transferred to a stigma of the same flower, or to another flower on the same plant; cross-pollination occurs when pollen is transferred to another plant. This involves external pollen-carrying agents, such as wind (see anemophily), water (see hydrophily), insects, birds (see ornithophily), bats, and other small mammals.

Animal pollinators carry the pollen on their bodies and are attracted to the flower by scent, or by the sight of the petals. Most flowers are adapted for pollination by one particular agent only. Bat-pollinated flowers tend to smell of garlic, rotting vegetation, or fungus. Those that rely on animals generally produce nectar, a sugary liquid, or surplus pollen, or both, on which the pollinator feeds. Thus the relationship between pollinator and plant is an example of mutualism, in which both benefit. However, in some plants the pollinator receives no benefit (as in pseudocopulation), while in others, nectar may be removed by animals that do not effect pollination.

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pollution

harmful effect on the environment of by-products of human activity, principally industrial and agricultural processes – for example, noise, smoke, car emissions, pesticides, radiation, sewage disposal, household waste, and chemical and radioactive effluents in air, seas, and rivers. Air pollution contributes to the greenhouse effect.

Pollution control involves higher production costs for the industries concerned, but failure to implement adequate controls may result in irreversible environmental damage and an increase in the incidence of diseases such as cancer. For example, in agriculture the mismanagement of fertilizers may result in eutrophication, an excessive enrichment of lakes and rivers caused by nitrate pollution; the subsequent rapid growth of algae darkens the water and eventually depletes its oxygen, causing plants and animals to die. Nitrate pollution has also been linked to stomach cancer, although this is unproven. Radioactive pollution results from inadequate nuclear safety.

Transboundary pollution is when the pollution generated in one country affects another, for example as occurs with acid rain. Natural disasters may also cause pollution; volcanic eruptions, for example, cause ash to be ejected into the atmosphere and deposited on land surfaces.

Pollution and Eastern Europe

signs of hope, signs of stress

One of the many factors contributing to the collapse of Soviet-style communism in Eastern Europe was growing public discontent about the state of the environment. The Polish Ecology Club was the first legally independent organization to be established in Poland after the rise of Solidarity. Environmental issues were rallying calls to the former opposition in Czechoslovakia and Hungary, and Hungarian opposition to a dam on the Danube drew international attention. Yet now that the countries of central and Eastern Europe have opened up for the first time in decades, the overall state of the environment is by no means clear, as was once assumed by people in the West.

pollution problems

The best-known environmental problems in the central European countries are connected with various forms of pollution. Inefficient industrial processes, lax environmental standards, and the intrinsically higher pollution levels from the sulphur-rich lignite coal found in some of the former communist countries have combined to cause extremely high air-pollution levels in places.

For example, in the mid-1980s Poland had annual emissions of sulphur and nitrogen oxides almost identical to those coming from the UK but with a population not much more than half the size of Britain's, meaning that there was roughly twice as much acidic pollution per person. East Germany emitted more air pollution than West Germany, despite having not much more than a quarter of the population. Yet Britain and Germany had at that time some of the highest air-pollution emissions of Western European countries.

the effects

The results for the east include severely damaged forests, crumbling historical buildings, as in the heavily polluted Polish city of Kraków, and evidence that human cancer levels have increased in areas of high pollution. Children are kept home from school on 'bad days' in the most polluted areas of the Czech and Slovak Republics.

further pollution problems

There are other serious pollution problems. Freshwater pollution is reaching crisis levels in some areas. The Volga-Caspian basin, source of most of the world's caviar, contains 700 times the legal levels of petroleum products and 113 times the permitted levels of surface pollution from synthetic products. This has led to fears of an 'ecological disaster', according to Professor Vladimir Lukyanenko, a top Russian biologist.

Large areas of the Siberian taiga are said to be polluted by oil from spillage during drilling. Children in the Bulgarian town of Kuklen have blood lead levels so high that they would be sent for detoxification in the USA. Infant mortality rates in Czechoslovakia are 60% higher than in the West.

vital ecosystems in danger

Yet in other ways ecological conditions in Eastern Europe are superior to those found in the West. The largest remaining areas of natural or ancient forest in Europe are found in the east, where they serve as a vital reservoir of biodiversity. There are large populations of rare animals, such as bear and wolf.

Unfortunately, these irreplaceable forests are being slated for logging, often by western companies moving into rich new markets in the east. Russia has some 40% of the world's temperate timber, mainly in Siberia, where plans to log huge areas of this are rapidly gaining pace. Latvia is already developing forestry in areas that would be classed as internationally important nature reserves in most other European countries.

intervention by the West

The West is playing a role in the increasing damage from agrochemical pollution as well. Although some parts of Eastern Europe have long been run with extremely intensive agricultural systems, other areas are effectively still practising peasant farming. These places have a chance to develop organic and low-input farming systems with produce that would find a ready market in the West. However, western aid funding and the agrochemical companies are pushing the development of the type of intensive agriculture that is gradually being abandoned, or at least severely modified, in the rest of Europe.

Eastern Europe is an ecological disaster area in some respects. However, in other ways it has the potential to provide a reservoir of biodiversity that has long been destroyed in most Western European countries. It is therefore important that the 'help' coming from the West does not destroy the good while trying to correct things that are wrong.

Pollution: key dates

13th century	In York 58% of the population suffers from sinusitis as a result of the smoke and fumes.
1709	English industrialist Abraham Darby first smelts iron ore with coke, massively increasing industry's use of fossil fuels thereafter.
1852	Scottish chemist Robert Angus Smith first records unusually acidic rainfall in Manchester.
1856	The 'Year of the Great Stink' in London; the River Thames smells so bad that Parliament is evacuated.
1952	London is afflicted by severe smogs ('pea-soupers') which kill 4,000.
1962	US natural scientist Rachel Carson publishes *Silent Spring*, a treatise against the ecological dangers of pesticides.
1971	First international pollution compensation fund, the International Maritime Organization Oil Pollution Fund, established.
1984	A leak from a US-owned pesticide plant in Bhopal, India, kills 3,000, with another 30,000 seriously injured.
1985	A 'hole' in the stratospheric ozone layer over the Antarctic is first reported.
1986	Accident in the nuclear power plant at Chernobyl, Ukraine, contaminates a large area of the USSR. Fire at a chemical plant in Basel, Switzerland, releases chemicals into the River Rhine, killing almost all living organisms in a 320-km/200-mi stretch between Basel and Mainz.
1989	The tanker *Exxon Valdez* is wrecked off Alaska and discharges 37,000 tonnes of crude oil, causing substantial damage to bird and aquatic life.
1991	Iraqi military forces discharge 7-8 million barrels of oil in Kuwait, nearly twice the size of the previous largest oil spill.
1992	UN Convention on Climate Change opens for signing.
1993	Wrecked tanker *Braer* discharges 85,000 tonnes of oil to the Scottish coast.
1994	First international deal in which states agree to reduce pollutants by differing degrees according to the amount of damage they cause is signed.
1995	US researchers studying voles around the devastated Chernobyl reactor find mutation rates at much higher levels than in voles from outside the 'hot zone'. The Berlin Mandate, agreed unanimously at the climate conference in April, commits industrial nations to the continuing reduction of greenhouse gas emissions after 2000, when the existing pact to stabilize emissions runs out.
1996	In February, the supertanker *Sea Empress* runs aground off the southwest coast of Wales, spilling 72,000 tonnes of oil.
1997	Following forest clearance fires, smoke pollution in the city of Palangkaraya, Indonesia, reaches levels of 7.5 mg per cu m (nearly 3 mg more than the London smog of 1952).
2001	Ecuador declares a state of emergency after an oil spill in the Galapagos Islands.
2002	17,000 tonnes of oil are spilt after a tanker sinks near Spain.
2004	150,000 people are evacuated after a series of explosions hit a chemical plant in Chongqing, China.
2005	The water supply in Harbin, China is cut off after 100 tonnes of toxic waste leaks out after an explosion at a chemical plant.

Critical Mess

Go to site

Impassioned article from Greenpeace on the effects of nuclear waste and the need to stop producing it. Part of the large and sophisticated Greenpeace Digital Web site, this page is linked to suggestions for safer storage of nuclear waste, and and alternative energy sources.

Noise Pollution Clearinghouse

Go to site

Wide-ranging Internet resource for everyone interested in reducing noise pollution. This site defines the problem and provides information and tools for noise pollution activists, such as a library of information on hearing loss and occupational noise, as well as acting as an online hub for community concern.

US EPA History Office

Go to site

Extensive collection of documents and articles relating to the US Environmental Protection Agency (EPA). There are pages dedicated to a range of environmental issues, hazards, and emergencies including Three Mile Island, the *Exxon Valdez* oil spill, and Times Beach pollution.

Pollux

or Beta Geminorum

brightest star in the constellation Gemini, the Twins, and the 17th-brightest star in the night sky. Pollux is a yellow star with a true luminosity 45 times that of the Sun. It is 36 light years away from the Sun.

The first-magnitude Pollux and the second-magnitude Castor (Alpha Geminorum) mark the heads of the twins. It is thought that the two stars may have changed their relative brightness since Bayer named them, as Alpha is usually assigned to the brightest star in a constellation.

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polonium

chemical symbol Po

radioactive, metallic element, atomic number 84, relative atomic mass 210. Polonium occurs in nature in small amounts and was isolated from pitchblende. It is the element having the largest number of isotopes (27) and is 5,000 times as radioactive as radium, liberating considerable amounts of heat. It was the first element to have its radioactive properties recognized and investigated.

Polonium was isolated in 1898 from the pitchblende residues analysed by French scientists Pierre and Marie Curie, and named after Marie Curie's native Poland.

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polyanthus

cultivated variety of primrose, with several flowers on one stalk, bred in a variety of colours. (Family Primulaceae, *Primula* × *polyantha*.)

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polychlorinated biphenyl

PCB

any of a group of chlorinated isomers of biphenyl $(C_6H_5)_2$. They are dangerous industrial chemicals, valuable for their fire-resistant qualities. They constitute an environmental hazard because of their persistent toxicity. Since 1973 their use had been limited by international agreement. In December 2000, 122 nations agreed a treaty to ban the toxic chemicals known as persistent organic polluters (POPs), which include PCBs, although they are unlikely to be totally eliminated until about 2025.

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polyester

synthetic resin formed by the condensation of polyhydric alcohols (alcohols containing more than one hydroxyl group) with dibasic acids (acids containing two replaceable hydrogen atoms). Polyesters are thermosetting plastics, used for constructional plastics and, with glass fibre added as reinforcement, they are used in car bodies and boat hulls. Polyester is also a major synthetic fibre used for knitting or weaving fabrics which are strong but lightweight, and resist creasing but can be heat-set into pleats. Polyester is often mixed with other fibres and can be found in a wide range of different textiles.

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polyethylene

alternative term for polythene.

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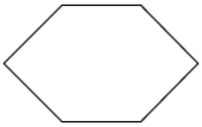
polygon

in geometry, a plane (two-dimensional) figure with three or more straight-line sides. **Regular polygons** have sides of the same length, and all the exterior angles are equal. Common polygons have names that define the number of sides (for example, **triangle** (3), **quadrilateral** (4), **pentagon** (5), **hexagon** (6), **heptagon** (7), **octagon** (8), and so on). These are all convex polygons, having no interior angle greater than 180°.

sum of internal angles

The sum of the internal angles of a polygon having n sides is given by the formula $180° \times (n - 2)$. For example:

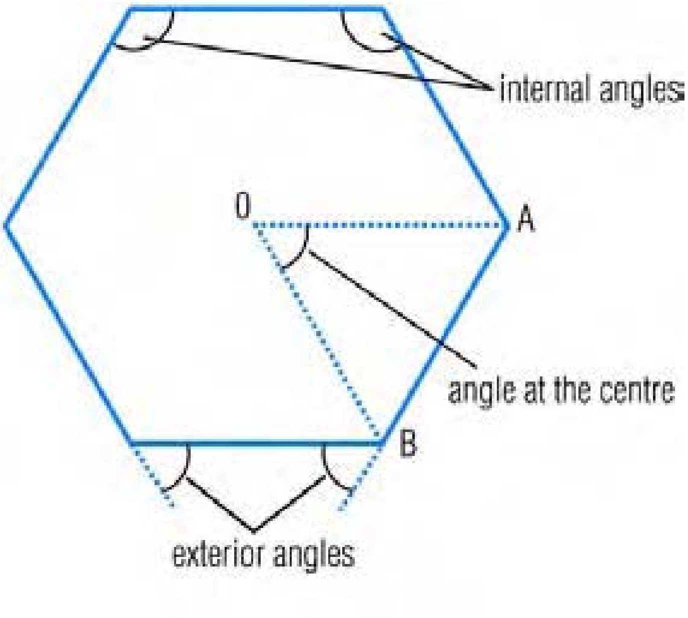


In this case (a hexagon), there are 6 sides. The sum of the interior angles equals:

$180° \times (n - 2) = 180° \times (6 - 2) = 180° \times 4 = 720°$

Therefore, the more sides a polygon has, the larger the sum of its internal angles and, in the case of a convex polygon, the more closely it approximates to a circle.

See also lines of symmetry.



(Image © Research Machines plc)

The types of angles in a regular polygon are shown here. These are the angles in a regular hexagon.

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polygraph

technical name for a lie detector.

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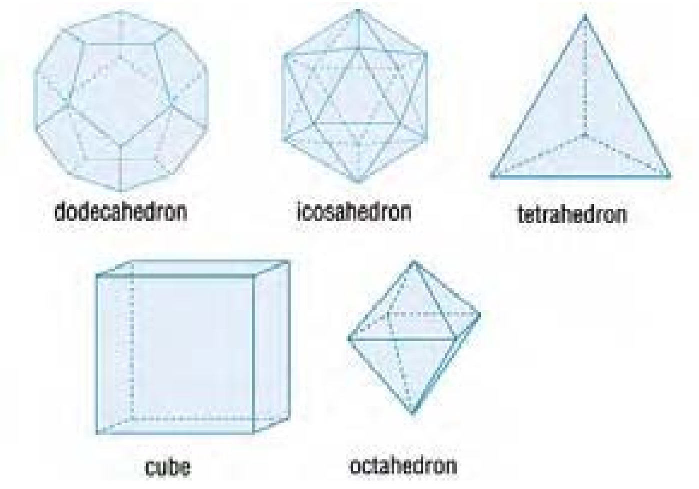
polyhedron

in geometry, a solid figure with four or more plane faces. The more faces there are on a polyhedron, the more closely it approximates to a sphere. Knowledge of the properties of polyhedra is needed in crystallography and stereochemistry to determine the shapes of crystals and molecules.

There are only five types of regular polyhedron (with all faces the same size and shape), as was deduced by early Greek mathematicians; they are the tetrahedron (four equilateral triangular faces), cube (six square faces), octahedron (eight equilateral triangles), dodecahedron (12 regular pentagons) and icosahedron (20 equilateral triangles).

polyhedron



(Image © Research Machines plc)

The five regular polyhedra or Platonic solids.

Pavilion of Polyhedreality

Go to site

Collection of images and instructions on how to make various polyhedrals, some from quite surprising materials.

polymer

very long-chain molecule made up of many repeated simple units (**monomers**) linked together by polymerization. There are many polymers, both natural (cellulose, chitin, lignin, rubber) and synthetic (polyethylene and nylon, types of plastic). Synthetic polymers belong to two groups: thermosoftening and thermosetting (see plastic).

The size of the polymer matrix is determined by the amount of monomer used; it therefore does not form a molecule of constant molecular size or mass.

Polymers and Electricity Conductance

electropolymers leave the laboratory

Polymers that conduct electricity – called electropolymers – are set to revolutionize material technology. New electrically conducting polymers can now be produced for use in many varied applications: aircraft de-icing heaters, cable shielding, gas sensors, lightweight electrodes in batteries, solar cells, and anti-static clothing, for example. Some pilot commercial production plants have been set up, and these products are now beginning to reach the marketplace.

Early conducting polymers were essentially insulators, embedded with a network of conducting particles that overlapped, allowing the flow of electricity. The new electropolymers, however, are intrinsically conducting, allowing the free movement of charge carriers – electrons or holes – along their molecular backbones. To conduct electricity in this way, a polymer must have a special structure. The chain of atoms that form its backbone must be joined together with double or triple bonds. Electrons can flow freely through chains of such bonds. A polymer, such as polythene, that only has single bonds cannot conduct electricity.

the first electropolymer

One electropolymer, called poly(sulphur nitride) was discovered in 1910. This material had a metallic lustre, became superconducting at very low temperatures, and is a true metal, despite containing no metal atoms. Crystals of poly(sulphur nitride) have a conductivity of up to 1,000 siemens per centimetre (S/cm). This is about one-tenth the conductivity of the metal mercury, and 1% of the conductivity of metals like silver and copper. The problem with poly(sulphur nitride) is that it tarnishes in air, just like the better-known metals, and is difficult to fabricate.

other electropolymers

A number of other electropolymers are now known, although much attention has centred on polyacetylene because of its high electrical conductivity and potential electronics applications. Other promising materials are polypyrrole (a substance chemically related to ammonia), polyaniline, and a group of substances halfway between ordinary covalent organic compounds and ionic salts, known as conducting adducts.

practical uses

Finding ways to turn these raw materials into useful products has not been easy. Many of these substances are unstable. All decompose or become nonconducting when melted, making them unsuitable for injection moulding. However, varying the chemical composition of the polymers without interfering with the conducting backbone of atoms has produced useful materials. Polypyrrole, for example, deteriorates rapidly in air but replacing chloride ions in its structure produces a material that can be washed in water, is stable in air, and loses only 10% of its conductivity in a year.

The first product is a black sheet with a conductivity of 10 S/cm. This is intended for use as cable screening, where it has advantages over aluminium-coated polyester or copper braiding: it does not fray, has no holes in it, and is more flexible. Another product is a light-brown powder, intended for use in making floor tiles and table tops that are conductive enough to eliminate static electricity.

Paints containing the new materials are being developed. These could be used as gas sensors because gas molecules absorbed by a painted surface change the conductivity of the paint, producing an electrical signal. Ammonia, nitrogen dioxide, sulphur dioxide, and other acid or alkaline gases have been shown to produce the necessary effect. Conductive paints could also protect enclosures against radio-frequency noise. Explosives could be made safer by using electropolymers as antistatic binders for the explosive; accidental discharge of static electricity, with disastrous consequences, would be reduced.

Chemistry World

Go to site

Make your own 'silly putty'-style polymer from the instructions at this chemistry site, which also contains further information on polymers, general safety guidelines, and a 'how-to' video clip.

Polymers: They're Everywhere

Go to site

Designed for children, this attractive Web site from the US National Geographic Society is a thought-provoking look at the world of polymers. Using 'clickable' images and lively text, the site moves through the world of natural polymers (amber, silk, and turtle-shell are examples), to consider how we use and abuse human-made polymers, and how we could re-use and recycle them.

polymerization

chemical union of two or more (usually small) molecules of the same kind to form a new compound.
Addition polymerization produces simple multiples of the same compound.
Condensation polymerization joins molecules together with the elimination of water or another small molecule.

Addition polymerization uses only a single monomer (basic molecule); condensation polymerization may involve two or more different monomers (**co-polymerization**).

The Invention of Nylon

introduction

During the late 1920s, the Du Pont chemical company committed itself to a long-term programme of 'basic research', with particular emphasis on the development of new synthetic materials. In 1928, Wallace Hume Carothers (1896-1937), a young Harvard chemist, was appointed to lead the fledgling project. Within four years Carothers' team had developed and marketed neoprene, the first successful synthetic rubber; during the next decade numerous new materials were patented, culminating with the commercial release of nylon in October 1938, 18 months after Carothers' tragic death.

polymer chemistry

By 1925, Du Pont had recognized the importance of the development of new materials; cheaper and better alternatives to expensive products such as silk were in great demand. Wallace Carothers, educated in Illinois and a teacher of chemistry at three Southern Universities, was plucked from Harvard to head Du Pont's research facility at Wilmington, Delaware, in 1928. The main goal of Carothers' team was to prepare and investigate organic compounds of high molecular weight; the group was then to develop ways in which each product's properties could be tailored to suit their desired final applications. This particular field, relatively unexplored at the time, was known as polymer chemistry; this branch of science was revolutionized by Carothers and his colleagues during the course of the next decade.

Carothers' first major contribution was the implementation of a technique known as 'condensation polymerization'. In this process, two compounds containing reactive groups at each end were combined in equimolar amounts to form a third complex, with the elimination of water as a by-product. The new complex, also containing reactive end-groups, could be further reacted, leading to the stepwise formation of a large polymeric material. The addition of a tiny amount of a 'termination agent', typically a monoacid or monoamine, halted the reaction, and prevented the generation of compounds of extremely high molecular weight, which would prove unmanageable. The final product could then be treated by one of several simple processes to produce polymers with specific properties.

Within three years the team had developed neoprene, the first commercially produced synthetic rubber. This was launched to great success in 1932. Subsequent experiments with polyesters proved moderately successful, but the company's overriding desire was to develop products which would emulate the properties of silk. For this reason Carothers turned to polyamide production. The reaction between dibasic acids and diamines generated a polymeric salt. Subsequent heating of this salt formed the polyamide resin. This process produced the series of products which would ultimately revolutionize materials science and make Du Pont's fortune - the nylons.

nylon development

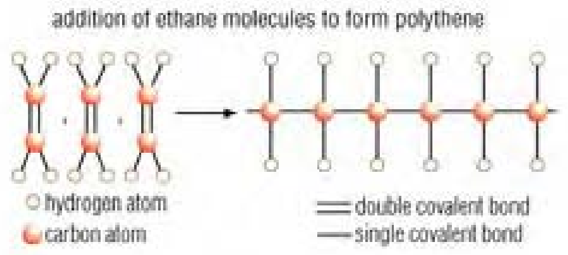
Upon production, the polyamides were treated by a process known as 'melt-spinning'. During this process, the hot, molten polymer is passed into a stream of cold air, whereupon it solidifies into a filament; depending on the final intended use of the product, this filament can range in size from finer than a human hair to thick bristles, akin to those used in toothbrushes. The filaments are then stretched, a process known as 'drawing', to make the component molecules pack more closely: this increase in the order, or crystallinity, of the material provides increased strength and elasticity in the resulting fibre. Nylon can be drawn to four times its original length.

Although nylon was the name given to the class of polyamide compounds produced by this process, commercial nylon is formed from the reaction between hexamethylenediamine and adipic acid; each component contains six carbon atoms, hence the systematic name nylon-6,6. The nylons as a group are strong, tough materials, adaptable to moulding. Although nylon has since been used in a huge variety of commercial applications, such as mechanical parts, carpets and home furnishings, the initial and most famous use of nylon was in ladies hosiery.

commercial success

Carothers' life was blighted by a history of personal suffering; alcoholism and recurrent bouts of clinical depression ultimately led to his suicide, shortly after his 41st birthday in 1937. However, the development of nylon established his greatness as a chemical pioneer. When Charles Stine unveiled nylon to an unsuspecting world in New York, New York, on 27 October 1938, the product was greeted by near-hysteria; on their first day of sales, a remarkable 5 million pairs of nylon stockings were bought by the public. Du Pont presently sells over 3 billion pounds worth of nylon annually, confirming the durability and importance of the product. However, Du Pont's legacy of success transcends nylon production. Carothers' research team pioneered modern polymer chemistry and sparked the materials revolution which has galvanized the chemical industry in the second half of the 20th century.

polymerization



(Image © Research Machines plc)

In polymerization, small molecules (monomers) join together to make large molecules (polymers). In the polymerization of ethene to polyethene (polythene), electrons are transferred from the carbon-carbon double bond of the ethene molecule, allowing the molecules to join together as a long chain of carbon-carbon single bonds.

polymorph

in biology, white blood cell that has a nucleus of irregular shape. Polymorphs constitute about 70% of the white blood cells and are involved in the immune response.

polymorphism

in genetics, the coexistence of several distinctly different types in a population (groups of animals of one species). Examples include the different blood groups in humans, different colour forms in some butterflies, and snail shell size, length, shape, colour, and stripiness.

Analysis of the human genome has revealed different kinds of polymorphisms. The simplest type are those locations, where only one base is different, known as single nucleotide polymorphisms or SNPs.

polymorphism

in mineralogy, the ability of a substance to adopt different internal structures and external forms, in response to different conditions of temperature and/or pressure. For example, diamond and graphite are both forms of the element carbon, but they have very different properties and appearance.

Silica (SiO_2) also has several polymorphs, including quartz, tridymite, cristobalite, and stishovite (the latter a very high-pressure form found in meteoritic impact craters).

polymytosis

in medicine, a disease that usually affects the muscles in the shoulder or hip areas. The disease can be acute or chronic. The muscles weaken and may become tender and inflamed.

polynomial

in mathematics, an algebraic expression that has one or more variables (denoted by letters). A polynomial equation has the form:

$f(x) = a_nx^n + a_{n-1}x^{n-1} +) + a_2x^2 + a_1x + a_0$

where a_n, a_{n-1},), a_0 are all constants, n is a positive integer, and $a_n \neq 0$. Examples of polynomials are:

$f(x) = 3x^4 + 2x^2 + 1$

or

$f(x) = x^5 - 18x + 71$

or

$f(x) = 2x + 3$

A polynomial of degree one, that is, whose highest power of x is 1, as in $2x + 1$, is called a linear polynomial;

$3x^2 + 2x + 1$ is quadratic;

$4x^3 + 3x^2 + 2x + 1$ is cubic.

polyp

or polypus

small 'stalked' benign tumour, usually found on mucous membrane of the nose or bowels. Intestinal polyps are usually removed, since some have been found to be precursors of cancer.

polyp

in zoology, the sedentary stage in the life cycle of a coelenterate (such as a coral or jellyfish), the other being the free-swimming **medusa**.

polypeptide

long-chain peptide.

polyploid

in genetics, possessing three or more sets of chromosomes in cases where the normal complement is two sets (diploid). Polyploidy arises spontaneously and is common in plants (mainly among flowering plants), but rare in animals. Many crop plants are natural polyploids, including wheat, which has four sets of chromosomes per cell (durum wheat) or six sets (common wheat).

Plant breeders can induce the formation of polyploids by treatment with a chemical, colchicine.

polypropylene

or polypropene

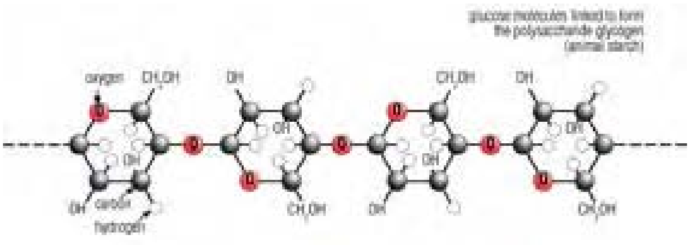
plastic made by the polymerization, or linking together, of propene molecules ($CH_2=CH=CH_3$). Polypropylene is one of the most important plastics and has a large number of different uses, including packaging, house ware, textiles, carpets, artificial turf, and ropes. It is a very light synthetic fibre, which does not absorb moisture, and so stays dry and warm. These properties make it a good fibre for use in clothing designed for cold environments.

polysaccharide

long-chain carbohydrate made up of hundreds or thousands of linked simple sugars (monosaccharides) such as glucose and closely related molecules.

The polysaccharides are natural polymers. They either act as energy-rich food stores in plants (starch) and animals (glycogen), or have structural roles in the plant cell wall (cellulose, pectin) or the tough outer skeleton of insects and similar creatures (chitin). See also carbohydrate.

polysaccharide


glucose molecules linked to form the polysaccharide glycogen (animal starch)
oxygen
CH_2OH
OH
OH
CH_2OH
OH
OH
OH
OH
OH
carbon
hydrogen
CH_2OH
OH
CH_2OH

(Image © Research Machines plc)

A typical polysaccharide molecule, glycogen (animal starch), is formed from linked glucose ($C_6H_{12}O_6$) molecules. A glycogen molecule has 100-1,000 linked glucose units.

polystyrene

type of plastic used in kitchen utensils or, in an expanded form, in insulation and ceiling tiles. CFCs (chlorofluorocarbons) are used to produce expanded polystyrene so alternatives are being sought.

polytetrafluoroethene

PTFE

polymer made from the monomer tetrafluoroethene (CF_2CF_2). It is a thermosetting plastic with a high melting point that is used to produce 'nonstick' surfaces on pans and to coat bearings. Its trade name is Teflon.

polythene

or polyethylene or polyethene

polymer of the gas ethene (C_2H_4). It is a tough, white, translucent, waxy thermoplastic (which means it can be repeatedly softened by heating). It is used for packaging, bottles, toys, wood preservation, electric cable, pipes, and tubing.

Polythene is produced in two forms: low-density polythene, made by high-pressure polymerization of ethene gas (the monomer), and high-density polythene, which is made at lower pressure by using catalysts. This form, first made in 1953 by German chemist Karl Ziegler, is more rigid at low temperatures and softer at higher temperatures than the low-density type. Polythene was first made in the 1930s at very high temperatures by ICI.

polyunsaturate

type of fat or oil containing a high proportion of triglyceride molecules whose fatty acid chains contain several double bonds. By contrast, the fatty-acid chains of the triglycerides in saturated fats (such as lard) contain only single bonds. Medical evidence suggests that polyunsaturated fats, used widely in margarines and cooking fats, are less likely to contribute to cardiovascular disease than saturated fats, but there is also some evidence that they may have adverse effects on health.

The more double bonds the fatty-acid chains contain, the lower the melting point of the fat. Unsaturated chains with several double bonds produce oils, such as vegetable and fish oils, which are liquids at room temperature. Saturated fats, with no double bonds, are solids at room temperature. The polyunsaturated fats used for margarines are produced by taking a vegetable or fish oil and turning some of the double bonds to single bonds, so that the product is semi-solid at room temperature. This is done by bubbling hydrogen through the oil in the presence of a catalyst, such as platinum. The catalyst is later removed.

Monounsaturated oils, such as olive oil, whose fatty-acid chains contain a single double bond, are probably healthier than either saturated or polyunsaturated fats. Butter contains both saturated and unsaturated fats, together with cholesterol, which also plays a role in heart disease.

polyurethane

polymer made from the monomer urethane. It is a thermoset plastic, used in liquid form as a paint or varnish, and in foam form for upholstery and in lining materials (where it may be a fire hazard).

polyvinyl chloride

PVC

type of plastic used for drainpipes, floor tiles, audio discs, shoes, and handbags. It is derived from vinyl chloride ($CH_2 = CHCl$).

Swedish scientists identified a link between regular exposure to PVC and testicular cancer, in 1998, increasing the demand for a ban on PVC in commercial products.

pome

type of pseudocarp, or false fruit, typical of certain plants belonging to the Rosaceae family. The outer skin and fleshy tissues are developed from the receptacle (the enlarged end of the flower stalk) after fertilization, and the five carpels (the true fruit) form the pome's core, which surrounds the seeds. Examples of pomes are apples, pears, and quinces.

pomegranate

round, leathery, reddish-yellow fruit of the pomegranate tree, a deciduous shrub or small tree native to southwestern Asia but cultivated widely in tropical and subtropical areas. The fruit contains a large number of seeds that can be eaten fresh or made into wine. (Genus*Punica granatum*, family Punicaceae.)

Pomegranates in California

Go to site

In-depth guide to this fruit which contains images and 'Fruit facts'. It also indexes a host of more complex information on growing pomegranates and help with the common problems related to growing pomegranates.

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pomeranian

breed of toy dog, about 15 cm/6 in high, weighing about 3 kg/6.5 lb. It has long straight hair with a neck frill, and the tail is carried over the back.

Pompeii

ancient city in Italy, near the volcano Vesuvius, 21 km/13 mi southeast of Naples.

In AD 63 an earthquake destroyed much of the city, which had been a Roman port and pleasure resort; it was completely buried beneath volcanic ash when Vesuvius, a composite – and therefore explosive – volcano erupted in AD 79. Over 2,000 people were killed. Pompeii was rediscovered in 1748 and the systematic excavation begun in 1763 still continues.

Pompeii Forum Project

Go to site

'Clickable' map of the Forum at Pompeii provides the interface to this virtual reconstruction of the Roman town, analysing the archaeological evidence and materials found on the site of Pompeii. The project aims not just to look at how Pompeii was in the Roman world, but also to fit this picture into a broader context of urban development, drawing parallels with modern urban studies.

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pondweed

any of a group of aquatic plants that either float on the surface of the water or are submerged. The leaves of floating pondweeds are broad and leathery, whereas leaves of the submerged forms are narrower and translucent; the flowers grow in green spikes. (Genus *Potamogeton*, family Potamogetonaceae.)

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pony

small horse under 1.47 m/4.5 ft (14.2 hands) shoulder height. Although of Celtic origin, all the pony breeds have been crossed with thoroughbred and Arab stock, except for the smallest – the hardy Shetland, which is less than 105 cm/42 in shoulder height.

pony

(Image © Research Machines plc)

The Welsh cob has existed as a separate breed of pony since before the Middle Ages. Traditionally used to haul carts loaded with timber or for general farm work, their gentle disposition and compact size make them ideally suited to drawing small, private carriages, such as this stick-back gig at the Tregony Horse Show in Cornwall.

pony

(Image © Research Machines plc)

Shetland ponies, Cornwall. The Shetland pony is a small but hardy breed, about 10.5 hands, or 70 cm/27 in high. Traditionally, the Shetland Islanders used these strong animals to carry seaweed from the shore up to the fields, where it was spread as a fertilizer. Shetland ponies can still be found at country fairs competing in weight-pulling competitions.

pony

(Image © Research Machines plc)

Dartmoor ponies. The first known reference to the Dartmoor pony appears in the will of a Saxon bishop, dated 1012. Their use as a working pony peaked during the heyday of tin mining on Dartmoor, when they carried tin to the stannary towns in Cornwall. Although the breed is now domesticated, and popular with young riders, wild ponies can still be seen roaming freely on Dartmoor.

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poodle

breed of gun dog, including standard (above 38 cm/15 in at shoulder), miniature (below 38 cm/15 in), and toy (below 28 cm/11 in) varieties. The dense curly coat, usually cut into an elaborate style, is often either black or white, although greys and browns are also bred.

The poodle probably originated in Russia, was naturalized in Germany, where it was used for retrieving ducks and gained its name (from the German *pudeln*, 'to splash'), and became a luxury dog in France.

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poplar

deciduous tree of the genus *Populus*, or cottonwood trees of the willow family Salicaceae. When ripe, the feathery seeds borne on elongated clusters are blown far and wide by the wind. Balsam poplar *P. balsamifera* and eastern cottonwood *P. deltoides* are native to North America. Eurasian white poplar *P. alba* and Lombardy poplar *P. nigra* are grown widely as ornamentals. Aspens belong to the same genus.

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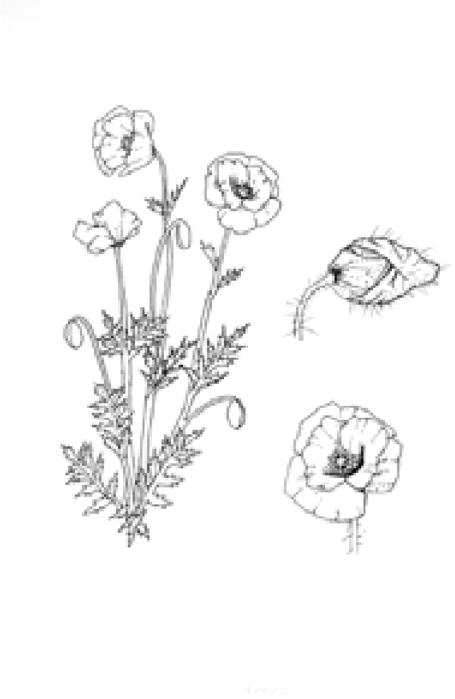
poppy

any of a group of plants belonging to the poppy family. They have brightly coloured mainly red and orange flowers, often with dark centres, and yield a milky sap. Species include the crimson European field poppy (*P. rhoeas*) and the Asian opium poppy (*P. somniferum*), source of the drug opium. Closely related are the California poppy (*Eschscholtzia californica*) and the yellow horned or sea poppy (*Glaucium flavum*). (Poppy genus *Papaver*, family Papaveraceae.)

poppy



(Image © Research Machines plc)

Common poppy (*Papaver rhoeas*), also known as the field poppy or Flanders poppy. The common poppy is an annual plant native to Africa, temperate and tropical Asia, and Europe. During the summer, its bright scarlet flowers are a common sight along roadsides and at waste sites. The poppy's red flowers became a symbol of World War I because of the plant's quick colonization of the disturbed ground of battlefields. The flowers are also a source of red dye used in some wines and medicines.

poppy

(Image © Research Machines plc)

Field poppies (*Papaver rhoeas*) and cornflowers (*Centaurea cyanus*). These plants were once common among arable crops but their numbers have dwindled in Britain with the advent of intensive agriculture and the growing use of herbicides. Both species flower from May until August, in northern Europe.

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population

in biology and ecology, a group of organisms of one species, living in a certain area. The organisms are able to interbreed. It also refers to the members of a given species in a community of living things. The area can be small. For example, one can refer to the population of duckweed (a small floating plant found on the surface of ponds) on a pond. Since the pond is a habitat, one can consider the population of duckweed in a habitat and forming part of the community of plants and animals there. However, it is also possible to use the term population for all the organisms of one species in a large geographical area, for example the elephant population in Africa. It could also be used to describe all the organisms of that species on Earth, for example the world population of humans. Population sizes in habitats change over a period of time. The timescale may be daily, seasonal, or there may be changes over the years.

The success of an organism can be determined by measuring the size of a population or by measuring biomass. Measuring the size of a population is quite difficult and requires careful sampling of the habitat and careful calculation to estimate population size. It is rarely possible to count directly all the individuals in a population. Typically, sampling techniques require random sampling to get a fair estimate of the population and may use equipment such as quadrats (a way of defining a square sampling area of a certain size). However, these techniques have their limitations – for example, animals move around and may also be difficult to find. Species may also be difficult to identify. There may not be time to take a large enough sample to make the estimate accurate.

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population control

measures taken by some governments to limit the growth of their countries' populations by trying to reduce birth rates. Propaganda, freely available contraception, and tax disincentives for large families are some of the measures that have been tried.

The population-control policies introduced by the Chinese government are the best known. In 1979 the government introduced a 'one-child policy' that encouraged family planning and penalized couples who have more than one child. It has been only partially successful since it has been difficult to administer, especially in rural areas, and has in some cases led to the killing of girls in favour of sons as heirs.

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population cycle

in biology, regular fluctuations in the size of a population, as seen in lemmings, for example. Such cycles are often caused by density-dependent mortality: high mortality due to overcrowding causes a sudden decline in the population, which then gradually builds up again. Population cycles may also result from an interaction between a predator and its prey.

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porbeagle

medium-sized shark.

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porcupine

any rodent with quills on its body, belonging to either of two families: Old World porcupines (family Hystricidae), terrestrial in habit and having long black-and-white quills; or New World porcupines (family Erethizontidae), tree-dwelling, with prehensile tails and much shorter quills.

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pore

in biology, a small opening in the skin that releases sweat and sebum. Sebum acts as a natural lubricant and protects the skin from the effects of moisture or excessive dryness.

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porphyria

group of rare genetic disorders caused by an enzyme defect. Porphyria affects the digestive tract, causing abdominal distress; the nervous system, causing psychotic disorder, epilepsy, and weakness; the circulatory system, causing high blood pressure; and the skin, causing extreme sensitivity to light. No specific treatments exist.

In porphyria the body accumulates and excretes (rather than utilizes) one or more porphyrins, the pigments that combine with iron to form part of the oxygen-carrying proteins haemoglobin and myoglobin; because of this urine turns reddish brown on standing. It is sometimes known as the 'royal disease' because sufferers are believed to have included Mary Queen of Scots, James I, and George III.

porphyry

any igneous rock containing large crystals in a finer matrix.

porpoise

any small whale of the family Delphinidae that, unlike dolphins, have blunt snouts without beaks. Common porpoises of the genus *Phocaena* can grow to 1.8 m/6 ft long; they feed on fish and crustaceans.

Porsche, Ferdinand (1875-1951)

German automotive designer and engineer who designed the Volkswagen Beetle, first mass produced in 1945. By 1972 more than 15 million had been sold, making it the world's most popular model. He also designed the original Porsche sports cars, further developed by his son Ferry Porsche from 1948.

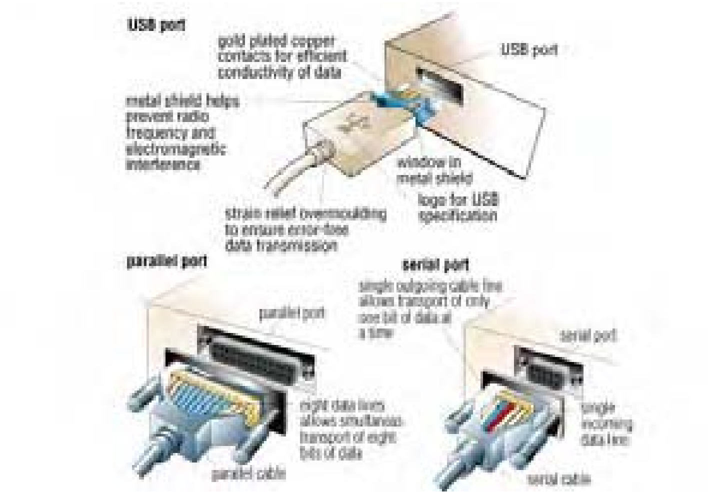
Ferdinand Porsche designed his first racing car in the mid-1930s, which was successfully developed by Auto-Union for their racing team. Ferry's Porsche Company produced Grand Prix cars, sports cars, and prototypes. Their Formula 1 racing car was not successful and it was at sports-car and Can-Am racing that they proved to be more dominant.

port

in computing, a socket that enables a computer processor to communicate with an external device. It may be an **input port** (such as a joystick port), or an **output port** (such as a printer port), or both (an **i/o port**).

Microcomputers may provide ports for cartridges, televisions and/or monitors, printers, and modems, and sometimes for hard disks and musical instruments (MIDI, the musical-instrument digital interface). Ports may be serial or parallel.

port


USB port
gold plated copper contacts for efficient conductivity of data
USB port
metal shield helps prevent radio frequency and electromagnetic interference
window in metal shield
logo for USB specification
strain relief overmoulding to ensure error-free data transmission
parallel port
serial port
single outgoing cable line allows transport of only one bit of data at a time
parallel port
serial port
eight data lines allows simultaneous transport of eight bits of data
single incoming data line
parallel cable
serial cable

(Image © Research Machines plc)

The three types of communications port in a microcomputer. The USB port transmits data at a faster rate than a serial or parallel port.

port

point where goods are transferred between water-based and land-based forms of transport. Most ports are coastal, though inland ports on rivers also exist. Ports often have specialized equipment to handle cargo in large quantities (for example, container or roll-on/roll-off facilities).

Porter, Rodney Robert (1917-1985)

English biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1972 for his work on the chemical structure of antibodies. In 1962 he proposed a structure for human immunoglobulin (antibody) in which the molecule was seen as consisting of four chains.

Portuguese man-of-war

any of a genus *Physalia* of phylum *Coelenterata* (see coelenterate). They live in the sea, in colonies, and have a large air-filled bladder (or 'float') on top and numerous hanging tentacles made up of feeding, stinging, and reproductive individuals. The float can be 30 cm/1 ft long.

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positron

antiparticle of the electron; an elementary particle having the same mass as an electron but exhibiting a positive charge. The positron was discovered in 1932 by US physicist Carl Anderson at the California Institute of Technology, USA, its existence having been predicted by the British physicist Paul Dirac in 1928.

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positron emission tomography

PET

imaging technique that enables doctors to observe the metabolic activity of the human body by following the progress of a radioactive chemical that has been inhaled or injected, detecting gamma radiation given out when positrons emitted by the chemical are annihilated. The technique has been used to study a wide range of conditions, including schizophrenia, Alzheimer's disease, and Parkinson's disease.

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possum

another name for the opossum, a marsupial animal with a prehensile tail found in North, Central and South America. The name is also used for many of the smaller marsupials found in Australia.

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post-coital contraception

in medicine, contraception used to prevent conception after intercourse has taken place.

Hormonal contraceptives ('morning-after pills') containing a high dose of an oestrogen and a progestogen are effective if they are taken within three days of unprotected intercourse. Insertion of an intrauterine device (IUD) is more effective than hormonal post-coital contraceptives. It can be inserted up to five days after unprotected intercourse has taken place.

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post-mortem

(Latin 'after death')

another name for autopsy.

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postpartum

in medicine, any events occurring immediately after childbirth.

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post-viral fatigue syndrome

in medicine, another name for chronic fatigue syndrome.

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potash

general name for any potassium-containing mineral, most often applied to potassium carbonate (K_2CO_3) or potassium hydroxide (KOH). Potassium carbonate, originally made by roasting plants to ashes in earthenware pots, is commercially produced from the mineral sylvite (potassium chloride, KCl) and is used mainly in making artificial fertilizers, glass, and soap.

The potassium content of soils and fertilizers is also commonly expressed as potash, although in this case it usually refers to potassium oxide (K_2O).

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potassium

chemical symbol K

(Dutch potassa 'potash')

soft, waxlike, silver-white, metallic element, atomic number 19, relative atomic mass 39.0983. Its chemical symbol comes from the Latin *kalium*. It is one of the alkali metals (in Group 1 of the periodic table of the elements), and has a very low density – it floats on water, and is the second lightest metal (after lithium). It is one of the most reactive in the reactivity series of metals, oxidizing rapidly when exposed to air and reacting violently with water. Of great abundance in the Earth's crust, it is widely distributed. It is found in salt and mineral deposits in the form of potassium aluminium silicates and potassium nitrate (saltpetre). Potassium has to be extracted from its compounds by electrolysis because of its high reactivity.

Potassium is the main base ion of the fluid in the body's cells. Along with sodium, it is important to the electrical potential of the nervous system and, therefore, for the efficient functioning of nerve and muscle. Shortage, which may occur with excessive fluid loss (prolonged diarrhoea, vomiting), may lead to muscular paralysis; potassium overload may result in cardiac arrest. It is also required by plants for growth. The element was discovered and named in 1807 by English chemist Humphry Davy, who isolated it from potash in the first instance of a metal being isolated by electrolysis.

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potato

perennial plant with edible tuberous roots that are rich in starch and are extensively eaten as a vegetable. Used by the Andean Indians for at least 2,000 years before the Spanish Conquest, the potato was introduced to Europe by the mid-16th century, and reputedly to England by the explorer Walter Raleigh. (Genus *Solanum tuberosum*, family Solanaceae.)

In Ireland, the potato famine of 1845, caused by a parasitic fungus, resulted in many thousands of deaths from starvation, and led to large-scale emigration to the USA.

potato

It takes 500 l/880 pt of water to produce 1 kg/2.2 lb of potatoes.

potato

(Image © Research Machines plc)

Potatoes planted early, in March or April, can be ready for harvesting by late June. Commercially-grown potatoes are mechanically harvested. The same machine digs the potatoes out of the ground, cleans them of most of the dirt, then carries them by means of conveyor chains up to a grading table, where they are cleaned and sorted by hand before being loaded into a truck.

Potatoes, Peppers, and Eggplants

Go to site

Informative guide to these vegetables from the Virginia Cooperative Extension. There is a guide to planting them, as well as the types of soil, sunlight, and moisture that yield best results. This site also features solutions to common problems and information about harvesting and storage.

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potato blight

disease of the potato caused by a parasitic fungus *Phytophthora infestans*. It was the cause of the 1845 potato famine in Ireland. New strains of *P. infestans* continue to arise. The most virulent version so far is *P. infestans US-8*, which arose in Mexico in 1992 , spreading to North America in 1994.

In 2000, US scientists managed to extract and sequence fungal DNA from dried potato leaves that had been kept preserved since the Irish potato famine. This will enable them to track how the fungus has evolved since then.

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potential difference

PD

difference in the electrical potential (see potential, electric) of two points, being equal to the electrical energy converted by a unit electric charge moving from one point to the other. Electrons flow in a conducting material towards the part that is relatively more positive (fewer negative charges). The SI unit of potential difference is the volt (V). The potential difference between two points in a circuit is commonly referred to as voltage (and can be measured with a voltmeter). See also Ohm's law.

One volt equals one joule of energy used for each coulomb of charge. In equation terms, potential difference V may be defined by: $V = E/Q$, where E is the electrical energy converted in joules and Q is the charge in coulombs. Chemical energy from a battery is converted to electrical energy in a circuit, this energy being given by rearranging the above formula: $E = Q \times V$.

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potential, electric

energy required to bring a unit electric charge from infinity to the point at which potential is defined. The SI unit of potential is the volt (V). Positive electric charges will flow 'downhill' from a region of high potential to a region of low potential.

A positively charged conductor, for example, has a higher potential than the Earth, the potential of which is taken by convention to be zero. An electric cell (battery) has a potential difference between its terminals, which can make current flow in an external circuit. The difference in potential - potential difference (pd) - is expressed in volts so, for example, a 12 V battery has a pd of 12 volts between its negative and positive terminals.

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potential energy

PE

energy possessed by an object by virtue of its relative position or state (for example, as in a compressed spring or a muscle). It can be thought of as 'stored' energy. An object that has been raised up has energy stored due to its height. It is described as having gravitational potential energy.

If a ball is raised to a certain height and released, the ball falls to the ground. The potential energy changes to kinetic energy. As the ball hits the ground some of the kinetic energy is lost as sound and elastic energy. A stretched spring has stored elastic energy; this is known as elastic potential energy. Springs and elastics are designed to store energy and release it either rapidly or slowly. For example, a mechanical toy works by an unwinding spring coil inside the toy. As the spring coil turns, elastic potential energy changes into kinetic and sound energy as the toy operates.

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potentiometer

electrical resistor that can be divided so as to compare, measure, or control voltages. In radio circuits, any rotary variable resistance (such as volume control) is referred to as a potentiometer.

A simple type of potentiometer consists of a length of uniform resistance wire (about 1 m/3 ft long) carrying a constant current provided by a battery connected across the ends of the wire. The source of potential difference (voltage) to be measured is connected (to oppose the cell) between one end of the wire, through a galvanometer (instrument for measuring small currents), to a contact free to slide along the wire. The sliding contact is moved until the galvanometer shows no deflection. The ratio of the length of potentiometer wire in the galvanometer circuit to the total length of wire is then equal to the ratio of the unknown potential difference to that of the battery.

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potto

arboreal, nocturnal, African prosimian primate *Perodicticus potto* belonging to the loris family. It has a thick body, strong limbs, and grasping feet and hands, and grows to 40 cm/16 in long, with horny spines along its backbone, which it uses in self-defence. It climbs slowly, and eats insects, snails, fruit, and leaves.

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poultry

domestic birds such as chickens, turkeys, ducks, and geese. They were domesticated for meat and eggs by early farmers in China, Europe, Egypt, and the Americas. Chickens were domesticated from the Southeast Asian jungle fowl *Gallus gallus* and then raised in the East as well as the West. Turkeys are New World birds, domesticated in ancient Mexico. Geese and ducks were domesticated in Egypt, China, and Europe.

Good egg-laying breeds of chicken are Leghorns, Minorcas, and Anconas; varieties most suitable for eating are Dorkings, Australorps, Brahmas, and Cornish; those useful for both purposes are Orpingtons, Rhode Island Reds, Wyandottes, Plymouth Rocks, and Jersey White Giants. Most farm poultry are hybrids, selectively crossbred for certain characteristics, including feathers and down.

factory farming

Since World War II, the development of battery-produced eggs and the intensive breeding of broiler fowls and turkeys has roused a public outcry against 'factory' methods of farming. The birds are often kept constantly in small cages, have their beaks and claws removed to prevent them from pecking their neighbours, and are given feed containing growth hormones and antibacterial drugs, which eventually make their way up the food chain to humans. Factory farming has led to a growing interest in deep-litter and free-range systems, although these account for only a small percentage of total production.

poultry

(Image © Corel)

A great variety of domestic fowl are selectively bred for meat and egg production.

Poultry Breeds

Go to site

Masses of information on poultry breeds from all over the world, offered by the Department of Animal Science of Oklahoma State University. It includes photos and elaborate descriptions of about a hundred different species of chickens, ducks, geese, turkeys, and other poultry. Other experts on ornithology are invited to contribute textual and visual material.

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pound

abbreviation lb

imperial unit of mass equal to 16 ounces (7,000 grains) avoirdupois, or 12 ounces (5,760 grains) troy; the metric equivalents are 0.45 kg and 0.37 kg respectively. It derives from the Roman *libra*, which weighed 0.327 kg.

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poundal

abbreviation pdl

imperial unit of force, now replaced in the SI system by the newton. One poundal equals 0.1383 newtons.

It is defined as the force necessary to accelerate a mass of one pound by one foot per second per second.

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powder metallurgy

method of shaping heat-resistant metals such as tungsten. Metal is pressed into a mould in powdered form and then sintered (heated to very high temperatures so that the particles bond together).

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power

in mathematics, that which is represented by an exponent or index, denoted by a superior numeral. A number or symbol raised to the power of 2 - that is, multiplied by itself - is said to be squared (for example, 3^2, x^2), and when raised to the power of 3, it is said to be cubed (for example, 2^3, y^3). Any number to the power zero always equals 1.

Powers can be negative. Negative powers produce fractions, with the numerator as one, as a number is divided by itself, rather than being multiplied by itself, so for example $2^{-1} = 1/2$ and $3^{-3} = 1/27$.

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power

in optics, a measure of the amount by which a lens will deviate light rays. A powerful converging lens will converge parallel rays strongly, bringing them to a focus at a short distance from the lens. The unit of power is the **dioptre**, which is equal to the reciprocal of focal length in metres. By convention, the power of a converging (or convex) lens is positive and that of a diverging (or concave) lens negative.

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power

in physics, the rate of doing work or transferring energy from one form to another. It is measured in watts (joules per second) or other units of work per unit time.

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power house

building where electrical energy is generated from a fuel or from another form of energy. Fuels used include fossil fuels such as coal, gas, and oil, and the nuclear fuel uranium. Renewable sources of energy include gravitational potential energy, used to produce hydroelectric power, and wind power.

The energy supply is used to turn turbines either directly by means of water or wind pressure, or indirectly by steam pressure, steam being generated by burning fossil fuels or from the heat released by the fission of uranium nuclei. The turbines in their turn spin alternators, which generate electricity at very high voltage.

The world's largest power house is Turukhansk, on the Lower Tunguska River, Russia, with a capacity of 20,000 megawatts.

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prairie

central North American plain, formerly grass-covered, extending over most of the region between the Rocky Mountains to the west, and the Great Lakes and Ohio River to the east.

The term was first applied by French explorers to vast, largely level grasslands in central North America, centred on the Mississippi River valley, which extend from the Gulf of Mexico to central Alberta, Canada, and from west of the Appalachian system into the Great Plains. When first seen by explorers, the prairies were characterized by unbroken, waist-high, coarse grasses. Trees were common only along rivers and streams, or in occasional depressions in the land. This prairie is now almost gone, altered by farming to become what is known as the 'Corn Belt', much of the 'Wheat Belt', and other ploughed lands. Its humus-rich black loess soils, adequate rainfall, and warm summers foster heavily productive agriculture. In the west - west Kansas, Nebraska, and the Dakotas - is the **short-grass prairie**, occupying large parts of the Great Plains. Higher, drier land here has been used primarily for wheat production (aided by deep-well irrigation) and stock raising.

The prairies were formerly the primary habitat of the American bison; other prominent species include prairie dogs, deer and antelope, grasshoppers, and a variety of prairie birds.

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prairie dog

any of the North American genus *Cynomys* of burrowing rodents in the squirrel family (Sciuridae). They grow to 30 cm/12 in, plus a short 8 cm/3 in tail. Their 'towns' can contain up to several thousand individuals. Their barking cry has given them their name. Persecution by ranchers has brought most of the five species close to extinction.

prairie dog

(Image © Corel)

The prairie dog *Cynomys* is a small North American rodent that lives in burrows on the plains. Its diet consists of grasses and other prairie plants. It builds a cone of soil at the burrow entrance from which it can look out for predators.

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praseodymium

chemical symbol Pr

(Greek prasios 'leek-green' + didymos 'twin')

silver-white, malleable, metallic element of the lanthanide series, atomic number 59, relative atomic mass 140.907. It occurs in nature in the minerals monzanite and bastnaesite, and its green salts are used to colour glass and ceramics. It was named in 1885 by Austrian chemist Carl von Welsbach.

He fractionated it from dydymium (originally thought to be an element but actually a mixture of rare-earth metals consisting largely of neodymium, praseodymium, and cerium) and named it for its green salts and spectroscopic line.

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prawn

any of various shrimps of the suborder Natantia ('swimming'), of the crustacean order Decapoda, as contrasted with lobsters and crayfishes, which are able to 'walk'. Species called prawns are generally larger than species called shrimps.

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praying mantis

another name for mantis.

Precambrian era

in geology, the time from the formation of the Earth (4.6 billion years ago) up to 570 million years ago. Its boundary with the succeeding Cambrian period marks the time when animals first developed hard outer parts (exoskeletons) and so left abundant fossil remains. It comprises about 85% of geological time and is divided into two eons: the Archaean and the Proterozoic.

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precession of the equinoxes

slow wobble of the Earth on its axis, like that of a spinning top. The gravitational pulls of the Sun and Moon on the Earth's equatorial bulge cause the Earth's axis to trace out a circle on the sky every 25,800 years. The position of the celestial poles (see celestial sphere) is constantly changing owing to precession, as are the positions of the equinoxes (the points at which the celestial equator intersects the Sun's path around the sky). The **precession of the equinoxes** means that there is a gradual westward drift in the ecliptic - the path that the Sun appears to follow - and in the coordinates of objects on the celestial sphere.

This is why the dates of the astrological signs of the zodiac no longer correspond to the times of year when the Sun actually passes through the constellations. For example, the Sun passes through Leo from mid-August to mid-September, but the astrological dates for Leo are between about 23 July and 22 August.

The Earthseverals precession is caused by the gravitational pull of the Sun and Moon on the equatorial bulge of our planet. Precession also occurs in other planets. Uranus has the Solar System's fastest known precession (264 days). Planetary precession is a particular example of the phenomenon of precession shown by rotating objects in general - the wobbling of a spinning top is another instance.

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precipitation

in chemistry, the formation of an insoluble solid in a liquid as a result of a reaction within the liquid between two or more soluble substances. For example, if solutions of lead nitrate and potassium iodide are added together, bright yellow, insoluble lead iodide appears as a precipitate in the solution, making it cloudy. The **precipitation reaction** is: lead nitrate + potassium iodide → lead iodide + potassium nitrate. If the newly formed solid settles, it forms a **precipitate**; if the particles of solid are very small, they will remain in suspension, forming a **colloidal precipitate**.

Precipitation reactions are used in the preparation of salts; in qualitative analysis reactions; and in the formation of some sedimentary rocks.

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precipitation

in meteorology, water that falls to the Earth from the atmosphere. It is part of the water (hydrological) cycle. Forms of precipitation include rain, snow, sleet, hail, dew, and frost.

The amount of precipitation in any one area depends on climate, weather, and phenomena like trade winds and ocean currents. The cyclical change in the Peruvian Current off the coasts of Ecuador and Peru, known as El Niño, causes dramatic shifts in the amount of precipitation in South and Central America and throughout the Pacific region.

Precipitation can also be influenced by people. In urban areas dust, smoke, and other particulate pollution that comprise **condensation nuclei**, cause water in the air to condense more readily. Fog is one example. Precipitation also can react chemically with airborne pollutants to produce acid rain.

pre-eclampsia

or toxaemia of pregnancy

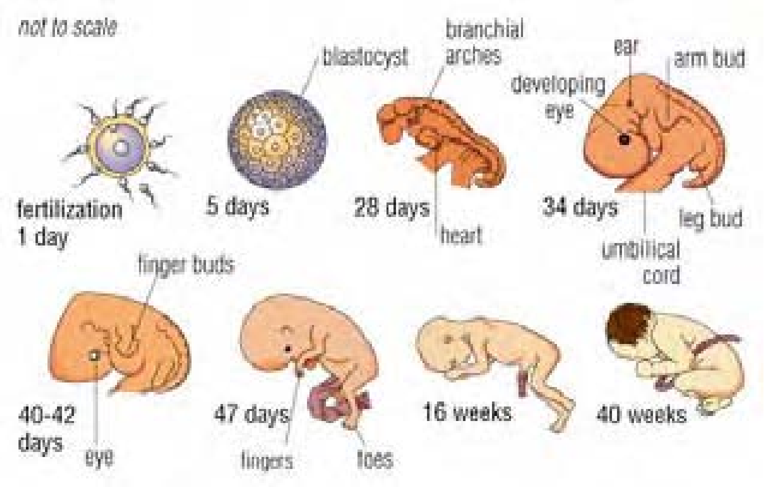
potentially serious condition developing in the third trimester and marked by high blood pressure and fluid retention. Arising from unknown causes, it disappears when pregnancy is over. It may progress to eclampsia if untreated. Pre-eclampsia affects 5-10% of pregant women globally.

pregnancy

in humans, the process during which a developing embryo grows within the woman's womb. It begins at conception and ends at birth, and the normal length is 40 weeks, or around nine months.

Menstruation usually stops on conception. About one in five pregnancies fails, but most of these failures occur very early on, so the woman may notice only that her period is late. After the second month, the breasts become tender, and the areas round the nipples become darker. Enlargement of the uterus can be felt at about the end of the third month, and after this the abdomen enlarges progressively. Fetal movement can be felt at about 18 weeks; a heartbeat may be heard during the sixth month. Pregnancy in animals is called gestation.

pregnancy



(Image © Research Machines plc)

The development of a human embryo. Division of the fertilized egg, or ovum, begins within hours of conception. Within a week a ball of cells - a blastocyst - has developed. After the third week, the embryo has changed from a mass of cells into a recognizable shape. At four weeks, the embryo is 3 mm/0.1 in long, with a large bulge for the heart and small pits for the ears. At six weeks, the embryo is 1.5 cm/0.6 in, with a pulsating heart and ear flaps. At the eighth week, the embryo is 2.5 cm/1 in long and recognizably human, with eyelids, small fingers, and toes. From the end of the second month, the embryo is almost fully formed and further development is mainly by growth. After this stage, the embryo is termed a fetus.

prehistoric art

art that predates written records. The history of the fine arts - painting, engraving, and sculpture - begins around 40000 BC in the Palaeolithic period (Old Stone Age). The oldest known rock engravings are in Australia, but within the next 30,000 years art occurs on every continent. The earliest surviving artefacts in Europe date from approximately 30000-10000 BC, a period of hunter-gatherer cultures. Small sculptures are generally of fecund female nudes and relate to the cult of the Mother Goddess; for example, the stone *Willendorf Venus* (Kunsthistorisches Museum, Vienna) about 21000 BC. The murals of the caves of Lascaux, France, and Altamira, Spain, depict mostly animals.

During the Neolithic period (New Stone Age) 10000-2000 BC, settled communities were established, which led to a greater technical and aesthetic sophistication in tools, ceramic vessels, jewellery, and human and animal figures. Human figures appear more often in wall paintings, and are skilfully composed into groups.

The period 4000-2000 BC saw the erection of the great megalith monuments, such as those at Carnac, France, and Stonehenge, England, and the production of ceramic pots and figurines with decorative elements that were later to be developed in Celtic art.

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prehistoric life

diverse organisms that inhabited Earth from the origin of life about 3.5 billion years ago to the time when humans began to keep written records, about 3500 BC. During the course of evolution, new forms of life developed and many other forms, such as the dinosaurs, became extinct. Prehistoric life evolved over this vast timespan from simple bacteria-like cells in the oceans to algae and protozoans and complex multicellular forms such as worms, molluscs, crustaceans, fishes, insects, land plants, amphibians, reptiles, birds, and mammals. On a geological timescale humans evolved relatively recently, about 4 million years ago, although the exact dating is a matter of some debate. See also geological time.

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prematurity

condition of an infant born before the full term. In obstetrics, an infant born before 37 weeks' gestation is described as premature.

Premature babies are often at risk. They lose heat quickly because they lack an insulating layer of fat beneath the skin; there may also be breathing difficulties. In hospitals with advanced technology, specialized neonatal units can save some babies born as early as 23 weeks.

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premedication

combination of drugs given before surgery to prepare a patient for general anaesthesia.

One component (an anticholinergic) dries excess secretions produced by the airways when a tube is passed down the trachea, and during inhalation of anaesthetic gases. Other substances act to relax muscles, reduce anxiety, and relieve pain.

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premenstrual syndrome

(PMS) a hormonal condition comprising a number of physical and emotional features that occur cyclically before menstruation, and which disappear with its onset. Symptoms include mood changes, breast tenderness, a feeling of bloatedness, and headache.

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premolar

in mammals, one of the large teeth toward the back of the mouth. In herbivores they are adapted for grinding. In carnivores they may be carnassials. Premolars are present in milk dentition as well as permanent dentition.

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presbyopia

vision defect, an increasing inability with advancing age to focus on near objects. It is caused by thickening and loss of elasticity in the lens, which is no longer able to relax to the near-spherical shape required for near vision.

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prescription

in medicine, an order written in a recognized form by a practitioner of medicine, dentistry, or veterinary surgery to a pharmacist for a preparation of medications to be used in treatment.

By tradition it used to be written in Latin, except for the directions addressed to the patient. It consists of (1) the superscription *recipe* ('take'), contracted to Rx; (2) the inscription or body, containing the names and quantities of the drugs to be dispensed; (3) the subscription, or directions to the pharmacist; (4) the signature, followed by directions to the patient; and (5) the patient's name, the date, and the practitioner's name.

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preservative

substance (additive) added to a food in order to inhibit the growth of bacteria, yeasts, moulds, and other micro-organisms, and therefore extend its shelf life. The term sometimes refers to anti-oxidants (substances added to oils and fats to prevent their becoming rancid) as well. All preservatives are potentially damaging to health if eaten in sufficient quantity. Both the amount used, and the foods in which they can be used, are restricted by law.

Alternatives to preservatives include faster turnover of food stocks, refrigeration, better hygiene in preparation, sterilization, and pasteurization (see food technology).

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pressure

in a fluid, the force exerted normally (at right angles) on the surface of a body immersed in the fluid. The SI unit of pressure is the pascal (Pa), equal to a pressure of one newton per square metre. In the atmosphere, the pressure declines with increasing height from about 100 kPa at sea level to zero where the atmosphere fades into space. Pressure is commonly measured with a barometer, manometer, or Bourdon gauge. Other common units of pressure are the bar and the torr.

Pressure can be worked out using the formula: pressure = force/area. For example, farm tractors have wide tyres with relatively large areas in contact with the ground. This means that the pressure exerted by these areas is less (the force, or weight, is spread out over a larger area), which helps prevent the tractor wheels from sinking into the ground. Similarly, the head of a safety pin pressed down onto a table will not penetrate into the table; the force exerted by the head is spread out over a relatively large area and the pressure is lower. On the point of the pin, the force is spread over a much smaller area, the pressure is consequently greater, and the point will penetrate into the table.

Absolute pressure is measured from a vacuum; **gauge pressure** is the difference between the absolute pressure and the local atmospheric pressure. In a liquid, the pressure at a depth h is given by ρgh where ρ is the density and g is the acceleration of free fall.

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pressure cooker

closed pot in which food is cooked in water under pressure, where water boils at a higher temperature than normal boiling point (100°C/212°F) and therefore cooks food quickly. The modern pressure cooker has a quick-sealing lid and a safety valve that can be adjusted to vary the steam pressure inside.

The French scientist Denis Papin invented the pressure cooker in England in 1679.

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pressurized water reactor

PWR

nuclear reactor design used in nuclear power stations in many countries, and in nuclear-powered submarines. In the PWR, water under pressure is used in a closed system, as a coolant, passing through the reactor to the generator. Boric acid is added as a moderator. The pressurized water circulates through a steam generator, where its heat boils water to provide steam to drive power turbines.

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prickly heat

acute skin condition characterized by small white or red itchy blisters (miliaria), resulting from inflammation of the sweat glands in conditions of heat and humidity.

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prickly pear

any of several cacti (see cactus) native to Central and South America, mainly Mexico and Chile, but naturalized in southern Europe, North Africa, and Australia, where it is a pest. The common prickly pear (*O. vulgaris*) is low-growing, with flat, oval stem joints, bright yellow flowers, and prickly, oval fruit; the flesh and seeds of the peeled fruit have a pleasant taste. (Genus *Opuntia*, family Cactaceae.)

prickly pear

(Image © Research Machines plc)

Prickly pear plant, southern Mexico. The name refers to the edible fruit of some species of cactus, which are an important food source in many tropical and subtropical areas. The prickly pear is grown as a forage crop, as well as for its fruit, and its seeds are used to produce oil. The water-storing flat stems (particularly of spineless varieties) are also used to feed stock during times of severe drought.

Priestley, Joseph (1733-1804)

English chemist and Unitarian minister. He identified oxygen in 1774 and several other gases. Dissolving carbon dioxide under pressure in water, he began a European craze for soda water.

gases

Swedish chemist Karl Scheele independently prepared oxygen in 1772, but his tardiness in publication resulted in Priestley being credited with the discovery.

Priestley discovered nitric oxide (nitrogen monoxide, NO) in 1772 and reduced it to nitrous oxide (dinitrogen monoxide, N_2O). In the same year he became the first person to isolate gaseous ammonia by collecting it over mercury (previously ammonia was known only in aqueous solution). In 1774 he found a method for producing sulphur dioxide (SO_2).

Prigogine, Ilya (1917-2003)

Viscount Prigogine

Russian-born Belgian chemist who, as a highly original theoretician, has made major contributions to the field of thermodynamics. Earlier theories had considered systems at or about equilibrium; Prigogine began to study 'dissipative' or nonequilibrium structures frequently found in biological and chemical reactions. He was awarded the Nobel Prize for Chemistry in 1977 for his work in the thermodynamics of irreversible and dissipative processes. He became Viscount in 1989.

primary sexual characteristic

endocrine gland producing maleness and femaleness. In males, the primary sexual characteristic is the testis; in females it is the ovary. Both are endocrine glands that produce hormones responsible for secondary sexual characteristics, such as facial hair and a deep voice in males, and breasts in females.

primate

in zoology, any member of the order of mammals that includes monkeys, apes, and humans (together called **anthropoids**), as well as lemurs, bushbabies, lorises, and tarsiers (together called **prosimians**).

Generally, they have forward-directed eyes, gripping hands and feet, opposable thumbs, and big toes. They tend to have nails rather than claws, with gripping pads on the ends of the digits, all adaptations to the arboreal, climbing mode of life.

In 1996 a new primate genus (probably extinct) was identified by a US anthropologist from a collection of bones believed to belong to a potto. The animal has been named *Pseudopotto martini*.

In the same year, the Red List of endangered species published by the World Conservation Union indicated that 46% of the world's 310 primate species are threatened with extinction. By 2000, this figure had increased to 50% and at least 10% of primate species are likely to become extinct in the wild over the next two decades. The first to be declared extinct, in autumn 2000, was Miss Waldron's red colobus, *Procolobus badius waldroni*.

prime factor

any factor of a number that is a prime number. The fundamental theorem of arithmetic states that every number is either prime or can be expressed as a unique product of primes.

prime number

number that can be divided only by 1 and itself, that is, having no other factors. There is an infinite number of primes, the first ten of which are 2, 3, 5, 7, 11, 13, 17, 19, 23, and 29 (by definition, the number 1 is excluded from the set of prime numbers). The number 2 is the only even prime because all other even numbers have 2 as a factor. Numbers other than primes can be expressed as a product of their prime factors.

Over the centuries mathematicians have sought general methods (algorithms) for calculating primes, from Eratosthenes' sieve to programs on powerful computers.

Mersenne primes are in the form 2^q-1, where q is also a prime.

As of 2003 only 40 Mersenne prime numbers were known. In that year the largest prime number was discovered, as part of the Great Internet Mersenne Prime Search (GIMPS), which involves volunteers downloading software to search for primes while their computers are idle. The largest prime number - calculated by the computer of Michael Shafer, an engineering student at Michigan State University, USA - was $2^{20,996,011}$-1.

Prime numbers

A prime number is a number that can be divided only by 1 and itself, that is, having no other factors. There is an infinite number of primes. Below are all the prime numbers between 1 and 1,000.

All the prime numbers between 1 and 1,000									
2	3	5	7	11	13	17	19	23	29
31	37	41	43	47	53	59	61	67	71
73	79	83	89	97	101	103	107	109	113
127	131	137	139	149	151	157	163	167	173
179	181	191	193	197	199	211	223	227	229
233	239	241	251	257	263	269	271	277	281
283	293	307	311	313	317	331	337	347	349
353	359	367	373	379	383	389	397	401	409
419	421	431	433	439	443	449	457	461	463
467	479	487	491	499	503	509	521	523	541
547	557	563	569	571	577	587	593	599	601
607	613	617	619	631	641	643	647	653	659
661	673	677	683	691	701	709	719	727	733
739	743	751	757	761	769	773	787	797	809
811	821	823	827	829	839	853	857	859	863
877	881	883	887	907	911	919	929	937	941
947	953	967	971	977	983	991	997		

Great Internet Mersenne Prime Search

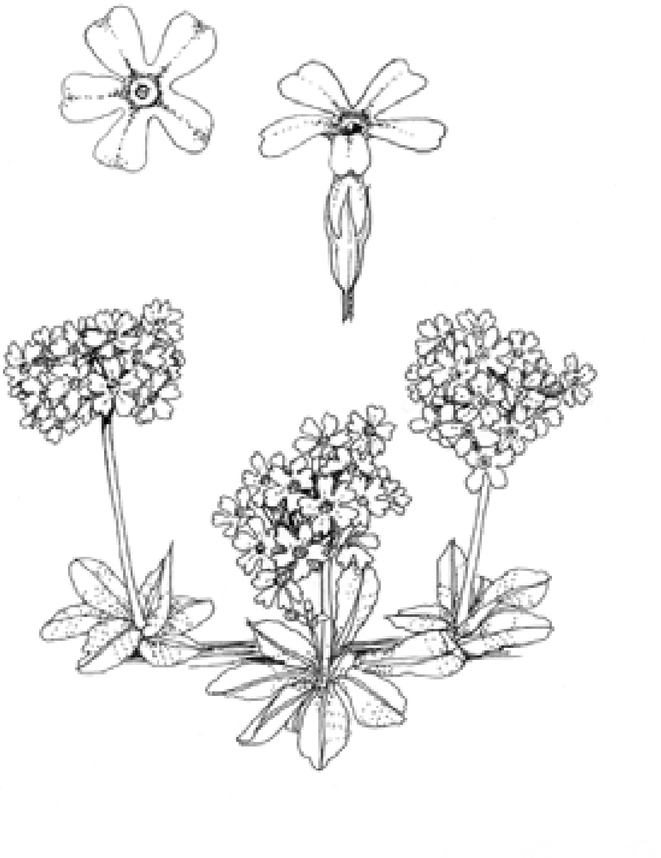
Go to site

In January 1996 the 'Great Internet Mersenne Prime Search' was launched by George Woltman, a programmer in Florida, to enlist the help of volunteers in tracking down the largest prime number. Software can be downloaded that will search for primes while the computer is idle.

primrose

any of a group of plants belonging to the primrose family, with showy five-lobed flowers. The common primrose (*P. vulgaris*) is a woodland plant, native to Europe, with abundant pale yellow flowers in spring. Related to it is the cowslip. (Genus *Primula*, family Primulaceae.)

primrose



(Image © Research Machines plc)

Drumstick primula (*Primula denticulata*). Native to the Himalayas, the drumstick primula is one of 500 species of the Primulaceae, or primrose, family. Primroses thrive in cool or alpine regions, and most are native to the northern hemisphere. The five petals of the drumstick primula are white or mauve in colour.

Primrose

Go to site

Contains detailed information about the primrose, including an informative description of the plant and its habitat. This site also features details of the plant's constituents, as well as notes on the medicinal uses of the primrose, which range from being used as a sedative to treating muscular rheumatism.

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principal focus

point towards which incident rays parallel to the principal axis of a lens converge, or from which they diverge, after refraction. The distance from the lens to its principal focus is its focal length.

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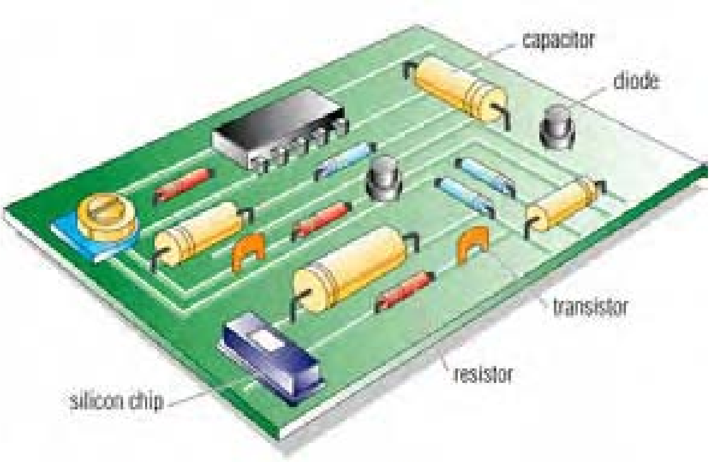
printed circuit board

PCB

electrical circuit created by laying (printing) 'tracks' of a conductor such as copper on one or both sides of an insulating board. The PCB was invented in 1936 by Austrian scientist Paul Eisler, and was first used on a large scale in 1948.

Components such as integrated circuits (chips), resistors, and capacitors can be soldered to the surface of the board (surface-mounted) or, more commonly, attached by inserting their connecting pins or wires into holes drilled in the board. The increased component density and complexity required by the electronics industry demands increasing use of multilayer PCBs which may have three, four, or more intermediate layers of copper conductor. PCBs include motherboards, expansion boards, and adaptors.

printed circuit board



(Image © Research Machines plc)

A typical printed circuit board (PCB). The PCB contains sockets for the integrated circuits, or chips, and the connecting tracks.

printer

in computing, an output device for producing printed copies of text or graphics. Types include the daisywheel printer, which produces good-quality text but no graphics; the dot matrix printer, which produces text and graphics by printing a pattern of small dots; the ink-jet printer, which creates text and graphics by spraying a fine jet of quick-drying ink onto the paper; and the laser printer, which uses electrostatic technology very similar to that used by a photocopier to produce high-quality text and graphics.

Printers may be classified as **impact printers** (such as daisywheel and dot matrix printers), which form characters by striking an inked ribbon against the paper, and **non-impact printers** (such as ink-jet and laser printers), which use a variety of techniques to produce characters without physical impact on the paper.

printing

reproduction of multiple copies of text or illustrative material on paper, as in books or newspapers, or on an increasing variety of materials; for example, on plastic containers or on fabrics. The first printing used woodblocks, followed by carved wood type or moulded metal type and hand-operated presses. Modern printing is effected by electronically controlled machinery. Current printing processes include electronic phototypesetting with offset printing, and gravure print.

origins

In China the art of printing from a single wooden block was known by the 6th century AD, and movable type was being used by the 11th century. In Europe printing was unknown for another three centuries, and it was only in the 15th century that movable type was reinvented, traditionally by Johannes Gutenberg in Germany. From there printing spread to Italy, France, and England, where it was introduced by William Caxton.

steam power, linotype, and monotype

There was no further substantial advance until, in the 19th century, steam power replaced hand-operation of printing presses, making possible long 'runs'. Hand-composition of type, each tiny metal letter being taken from the case and placed individually in the narrow stick that carried one line of text, was replaced by machines operated by a keyboard.
Linotype, a hot-metal process that produced a line of type in a solid slug, was invented by Ottmar Mergenthaler in 1886, and commonly used in newspapers, magazines, and books until the 1980s. The **Monotype**, used in bookwork was invented by Tolbert Lanston (1844-1913) in the USA in 1889. It produced a series of individual characters, which could be hand-corrected.

Important as these developments were, they represented no fundamental change but simply a faster method of carrying out the same basic typesetting operations. The actual printing process still involved pressing the inked type on to paper by **letterpress**.

20th-century developments

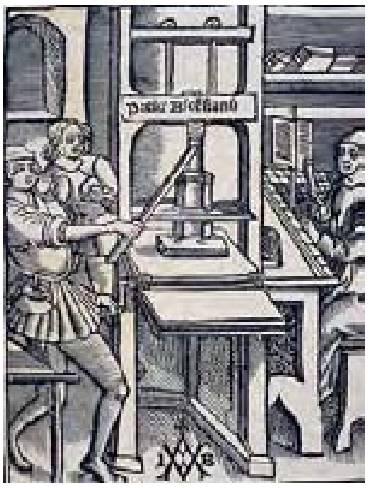
In the 1960s, letterpress began to face increasing competition from **offset printing**, a method that prints from an inked flat surface, and from the **gravure** method (used for high-circulation magazines), which uses recessed plates. The introduction of electronic phototypesetting machines, also in the 1960s, allowed the entire process of setting and correction to be done in the same way that a typist operates, thus eliminating the hot-metal composing room, with its hazardous fumes, lead scraps, and noise, and leaving only the making of plates and the running of the presses to be done traditionally.

By the 1970s some final steps were taken to plateless printing, using various processes, such as a computer-controlled laser beam, or continuous jets of ink acoustically broken up into tiny equal-sized drops, which are electrostatically charged under computer control. Pictures can be fed into computer typesetting systems by optical scanners.

fabric printing

A wide range of different techniques are used in fabric printing, including block printing, silk-screen printing, and roller printing. Other techniques are mono printing, card printing, and etching. In **mono printing**, ink or paint is applied freehand to the surface of a flat plate or piece of Perspex. This is then pressed on to a piece of fabric, transferring the design to the surface. In **card printing**, the design is cut into the surface of the card which is then given a thin coat of varnish. When the varnish is dry, printing ink is applied to the card, which is placed on the fabric. The card and fabric are then run through a printing press or subjected to very firm pressure, which transfers the ink to the fabric. The process of **etching** involves a design being scratched on the surface of an etching plate, before applying printing ink, placing the plate on top of fabric, and running through a printing press. Once dry, watercolours, inks, or thin fabric paint can be used to colour the design, if required. Computers can also be used in fabric printing. A design or picture can be prepared on screen, and an inkjet printer and specially-made paper used to prepare a transfer that can be ironed on to fabric.

printing



(Image © Philip Sauvain Picture Collection)

William Caxton produced both the first printed book in English, *Recuyell of the Historyes of Troy* 1475, and also the first book to be printed in England, *Dictes or Sayengis of the Philosophers* 1477.

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prion

acronym, by rearrangement, for PROteinaceous INfectious particle

infectious agent, a hundred times smaller than a virus. Composed of protein, and without any detectable nucleic acid (genetic material), it is strongly linked to a number of fatal degenerative brain diseases in mammals, such as bovine spongiform encephalopathy (BSE) in cattle, scrapie in sheep, and Creutzfeldt-Jakob disease (CJD) and kuru in humans.

The existence of prions was postulated by US neurologist Stanley Prusiner in 1982, when he and his colleagues isolated a single infectious agent for scrapie that consisted only of protein and had no associated nucleic acid (RNA or DNA). His theory has been upheld by subsequent research, which has identified the protein concerned as well as a mechanism for its action.

A US researcher proved that prions are capable of spreading disease, in July 2000, three years after Prusiner was awarded the Nobel Prize for Physiology or Medicine for his prion theory.

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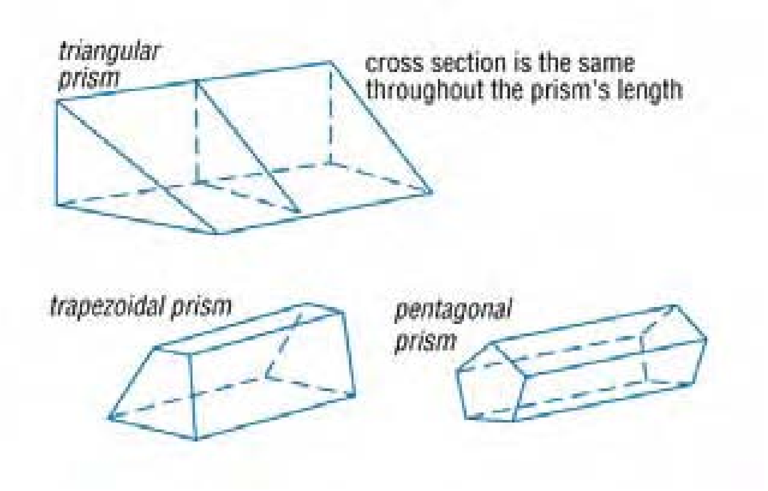
prism

in mathematics, a solid figure whose cross-section is the same along its length. When a slice is cut through a prism, the size and shape of the cross-section is always the same. A cube, for example, is a rectangular prism with all faces (bases and sides) the same shape and size. A cylinder is a prism with a circular cross section. The name of a prism is often derived from the shape of its prism, such as a triangular prism and a cuboid.

prism



(Image © Research Machines plc)

The volume of a prism is determined by multiplying the area of the cross section by the length of the prism.

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prism

in optics, a triangular block of transparent material (plastic, glass, or silica) commonly used to 'bend' a ray of light or split a light beam (for example, white light) into its component colours. Prisms are used as mirrors to define the optical path in binoculars, camera viewfinders, and periscopes. The dispersive property of prisms is used in the spectroscope.

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privet

any of a group of evergreen shrubs with dark green leaves, belonging to the olive family. They include the European common privet (*L. vulgare*) with white flowers and black berries, naturalized in North America, and the native North American California privet (*L. ovalifolium*), also known as hedge privet. (Genus *Ligustrum*, family Oleaceae.)

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probability

likelihood, or chance, that an event will occur, often expressed as odds, or in mathematics, numerically as a fraction or decimal.

In general, the probability that n particular events will happen out of a total of m possible events is n/m. A certainty has a probability of 1; an impossibility has a probability of 0.

Probability = number of successful events/total possible number of events

In tossing a coin, the chance that it will land 'heads' is the same as the chance that it will land 'tails', that is, 1 to 1 or even; mathematically, this probability is expressed as 1/2 or 0.5. An estimate for probability can be achieved by experiment; this is known as the **relative frequency**. The probability of any chosen number coming up on the roll of a fair die is 5 to 1; the probability is 1/6 or 0.1666. If two dice are rolled there are 6 × 6 = 36 different possible combinations. The probability of a double (two numbers the same) is 6/36 or 1/6 since there are six doubles in the 36 events: (1,1), (2,2), (3,3), (4,4), (5,5), and (6,6).

Independent events are those that do not affect each other, for example rolling two dice are independent events, as the rolling of the first die does not affect the outcome of the rolling of the second die. If events are described as **mutually exclusive** it means that if one happens, then it prevents the other from happening. So tossing a coin is a mutually exclusive event as it can result in a head or a tail but not both. The sum of the probabilities of mutually exclusive events is always equal to 1. For example, if one has a bag containing 3 marbles, each of a different colour, the probability of selecting each colour would be 1/3.

$1/3 + 1/3 + 1/3 = 1$

To find out the probability of two or more mutually exclusive events occurring, their individual probabilities are added together. So, in the above example, the probability of selecting either a blue marble or a red marble is

$1/3 + 1/3 = 2/3$

The probability of two independent events both occurring is smaller than the probability of one such event occurring. For example, the probability of throwing a 3 when rolling a die is 1/6, but the probability of throwing two 3s when rolling two dice is 1/36.

Conditional probability is when the outcome of the first event affects the outcome of the second event. For example, if a ball is chosen at random from a bag of 4 blue balls and 5 red balls, and not replaced, the probability of selecting 2 blue balls is:

$P(b) = 4/9 \times 3/8 = 12/72 = 1/6$

This can be displayed in a tree diagram.

Probability theory was developed by the French mathematicians Blaise Pascal and Pierre de Fermat in the 17th century, initially in response to a request to calculate the odds of being dealt various hands at cards. Today probability plays a major part in the mathematics of atomic theory and finds application in insurance and statistical studies.

Ken White's Coin Flipping Page

Go to site

Virtual coin flipper! Select how many coins you want to flip and the computer will do it for you. This is a simple but very helpful resource for probability homework.

Maths Goodies: Probability

Go to site

US maths teacher Mrs Glosser's Web lessons on probability. Beginning with an introduction to probability, the lessons progress to mutually exclusive events and independent events. Each lesson has four to six experiments, and contains interactive features such as spinners to spin and dice to roll.

Maths Mistakes

Go to site

Fun site examining the common maths mistakes that are found in the media. It outlines why statistics and probability are often misused, and includes some challenging problems and puzzles.

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procedure

in computing, a small part of a computer program that performs a specific task, such as clearing the screen or sorting a file. A **procedural language**, such as BASIC, is one in which the programmer describes a task in terms of how it is to be done, as opposed to a **declarative language**, such as PROLOG, in which it is described in terms of the required result. See programming.

Careful use of procedures is an element of structured programming. In some programming languages there is an overlap between procedures, functions, and subroutines.

---

processing cycle

in computing, the sequence of steps performed repeatedly by a computer in the execution of a program. The computer's central processing unit (CPU) continuously works through a loop, involving fetching a program instruction from memory, fetching any data it needs, operating on the data, and storing the result in the memory, before fetching another program instruction.

---

processor

in computing, another name for the central processing unit or microprocessor of a computer.

Procyon

or Alpha Canis Minoris

brightest star in the constellation Canis Minor and the eighth-brightest star in the night sky. Procyon is a white star 11.4 light years from the Sun, with a mass 1.7 times that of the Sun. It has a white dwarf companion that orbits it every 40 years.

The name, derived from Greek, means 'before the dog', and reflects the fact that in mid-northern latitudes Procyon rises shortly before Sirius, the Dog Star. Procyon and Sirius are sometimes called 'the Dog Stars'. Both are relatively close to us and have white dwarf companions.

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productivity, biological

in an ecosystem, the amount of material in the food chain produced by the primary producers (plants) that is available for consumption by animals. Plants turn carbon dioxide and water into sugars and other complex carbon compounds by means of photosynthesis. Their net productivity is defined as the quantity of carbon compounds formed, less the quantity used up by the respiration of the plant itself.

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progesterone

steroid hormone that occurs in vertebrates. In mammals, it regulates the menstrual cycle and pregnancy. Progesterone is secreted by the corpus luteum (the ruptured Graafian follicle of a discharged ovum).

progestogen

in medicine, drug closely related to progesterone, a female sex hormone that stimulates growth and secretion of the endometrial glands of the uterus in the first half of the menstrual cycle. Oral contraceptives contain progestogens, either alone or in combination with oestrogens.

The contraceptive action of progestogens is due to their disruption of the menstrual cycle by their effect on the pituitary gland and because they make fertilization of an ovum less likely because of their effects on uterine tissue.

prognosis

in medicine, prediction of the course or outcome of illness or injury, particularly the chance of recovery.

prograde orbit

or direct-motion orbit

in an orbiting satellite, an orbit in which the satellite travels in the same direction as the planet's rotation. It is the opposite of a retrograde orbit.

A planet has a prograde orbit or rotation if the sense of rotation is the same as the general sense of rotation of the Solar System. On the celestial sphere, it refers to motion from west to east against the background of stars.

program

in computing, a set of instructions that controls the operation of a computer. There are two main kinds: applications programs, which carry out tasks for the benefit of the user - for example, word processing; and systems programs, which control the internal workings of the computer. A utility program is a systems program that carries out specific tasks for the user. Programs can be written in any of a number of programming languages but are always translated into machine code before they can be executed by the computer.

program counter

in computing, an alternative name for sequence-control register.

program loop

part of a computer program that is repeated several times. The loop may be repeated a fixed number of times (**counter-controlled loop**) or until a certain condition is satisfied (**condition-controlled loop**). For example, a counter-controlled loop might be used to repeat an input routine until exactly ten numbers have been input; a condition-controlled loop might be used to repeat an input routine until the data terminator 'XXX' is entered.

programming

writing instructions in a programming language for the control of a computer.
Applications programming is for end-user programs, such as accounts programs or word-processing packages.
Systems programming is for operating systems and the like, which are concerned more with the internal workings of the computer.

There are several programming styles.
Procedural programming, in which programs are written as lists of instructions for the computer to obey in sequence, is by far the most popular. It is the 'natural' style, closely matching the computer's own sequential operation.
Declarative programming, as used in the programming language PROLOG, does not describe how to solve a problem, but rather describes the logical structure of the problem. Running such a program is more like proving an assertion than following a procedure.
Functional programming is a style based largely on the definition of functions. There are very few functional programming languages, HOPE and ML being the most widely used, though many more conventional languages (for example C) make extensive use of functions.
Object-oriented programming, the most recently developed style, involves viewing a program as a collection

of objects that behave in certain ways when they are passed certain 'messages'. For example, an object might be defined to represent a table of figures, which will be displayed on screen when a 'display' message is received.

programming language

in computing, a special notation in which instructions for controlling a computer are written. Programming languages are designed to be easy for people to write and read, but must be capable of being mechanically translated (by a compiler or an interpreter) into the machine code that the computer can execute. Programming languages may be classified as high-level languages or low-level languages. See also source language.

program trading

in finance, buying and selling a group of shares using a computer program to generate orders automatically whenever there is an appreciable movement in prices.

One form in use in the USA in 1989 was **index arbitrage**, in which a program traded automatically whenever there was a difference between New York and Chicago prices of an equivalent number of shares. Program trading comprised some 37% of daily trading on the New York Stock Exchange by volume in June 2006, but has been widely criticized for lessening market stability. It was blamed, among other factors, for the Stock Market crashes of 1987 and 1989.

progression

sequence of numbers each occurring in a specific relationship to its predecessor. An **arithmetic progression** has numbers that increase or decrease by a common sum or difference (for example, 2, 4, 6, 8); a **geometric progression** has numbers each bearing a fixed ratio to its predecessor (for example, 3, 6, 12, 24); and a **harmonic progression** has numbers whose reciprocals are in arithmetical progression, for example 1, 1/2, 1/3, 1/4.

projectile

particle that travels with both horizontal and vertical motion in the Earth's gravitational field. If the frictional forces of air resistance are ignored, the two components of its motion can be analysed separately: its vertical motion will be accelerated due to its weight in the gravitational field; its horizontal motion may be assumed to be at constant velocity. In a uniform gravitational field and in the absence of frictional forces the path of a projectile is a parabola.

projection

representation of the surface of the Earth on paper, see map projection.

projector

apparatus that projects a picture on to a screen. In a **slide projector**, a lamp shines a light through the photographic slide or transparency, and a projection lens throws an enlarged image of the slide onto the screen. A **film projector** has similar optics, but incorporates a mechanism that advances the film and then holds it still while light is transmitted through each frame (picture). A shutter covers the film when it moves between frames. A **television projector**, often used at sports events, produces an enlarged image of the television screen. It shines an intense light through a small LCD (liquid crystal display) throwing the television picture onto a large screen. A **digital projector** is used for computer-aided presentations. The oldest types use cathode-ray tube technology. One newer type has LCD screens like those used in calculators and flat-screen televisions, through which light shines onto the screen. A third type has a million or more tiny mirrors mounted on a microchip. Each mirror can be deflected or vibrated to control the light going to a single pixel (picture element) in the image.

prokaryote

in biology, an organism whose cells lack organelles (specialized segregated structures such as nuclei, mitochondria, and chloroplasts). Prokaryote DNA is not arranged in chromosomes but forms a coiled structure called a **nucleoid**. The prokaryotes comprise the **bacteria** (including the **cyanobacteria**), formerly known as blue-green algae and the archaea; in contrast, organisms with a nucleus are known as eukaryotes.

prolapse

displacement of an organ due to the effects of strain in weakening the supporting tissues. The term is most often used with regard to the rectum (due to chronic bowel problems) or the uterus (following several pregnancies).

PROLOG

contraction of programming in logic

high-level computer programming language based on logic. Invented in 1971 at the University of Marseille, France, it did not achieve widespread use until more than ten years later. It is used mainly for artificial intelligence programming.

PROM

acronym for Programmable Read-Only Memory

in computing, a memory device in the form of an integrated circuit (chip) that can be programmed after manufacture to hold information permanently. PROM chips are empty of information when manufactured, unlike ROM (read-only memory) chips, which have information built into them. Other memory devices are EPROM (erasable programmable read-only memory) and RAM (random-access memory).

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promethium

chemical symbol Pm

radioactive, metallic element of the lanthanide series, atomic number 61, relative atomic mass 145. It occurs in nature only in minute amounts, produced as a fission product/by-product of uranium in pitchblende and other uranium ores; for a long time it was considered not to occur in nature. The longest-lived isotope has a half-life of slightly more than 20 years.

Promethium is synthesized by neutron bombardment of neodymium and is a product of the fission of uranium, thorium, or plutonium; it can be isolated in large amounts from the fission-product debris of uranium fuel in nuclear reactors. It is used in phosphorescent paints and as an X-ray source.

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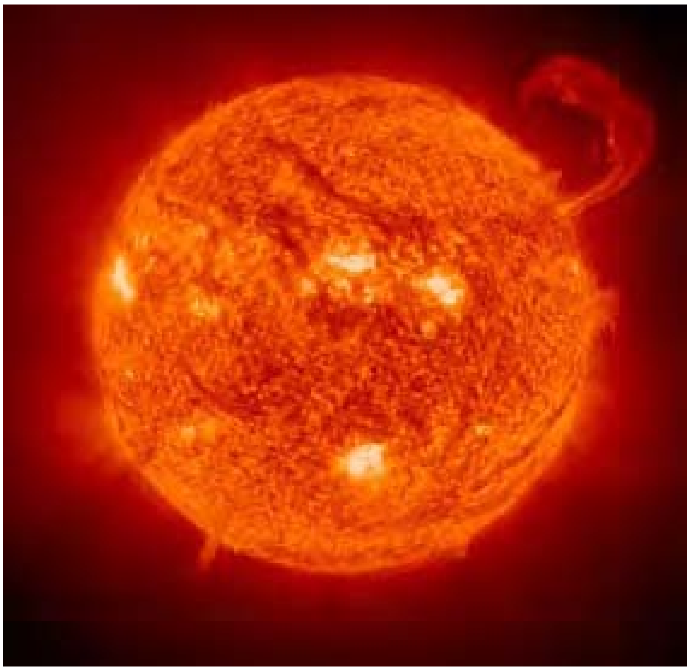
prominence

bright cloud of gas projecting from the Sun into space 100,000 km/60,000 mi or more.
Quiescent prominences last for months, and are held in place by magnetic fields in the Sun's corona.
Surge prominences shoot gas into space at speeds of 1,000 kps/600 mps.

Loop prominences are gases falling back to the Sun's surface after a solar flare.

prominence



(Image © NASA)

Extreme-Ultraviolet Imaging Telescope (EIT) image of a solar prominence, taken on 14 September 1999. Prominences are huge clouds of relatively cool dense plasma suspended in the Sun's corona. The lightest areas seen on the Sun's surface are the hottest and the darkest are the coolest.

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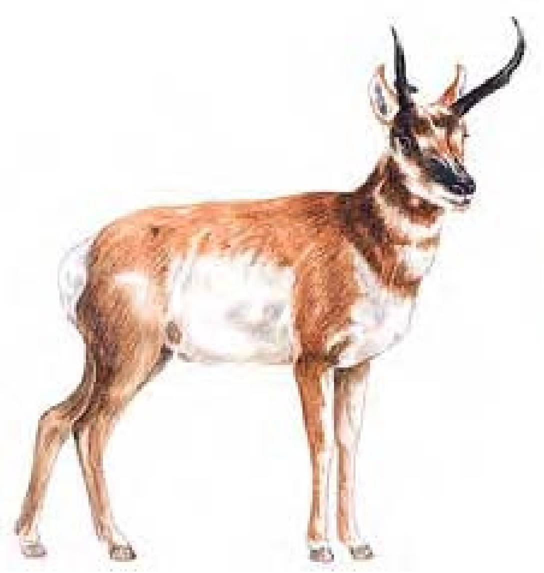
pronghorn

ruminant mammal *Antilocapra americana* constituting the family Antilocapridae, native to the western USA. It is not a true antelope. It is light brown and about 1 m/3 ft high. It sheds its horns annually and can reach speeds of 100 kph/60 mph. The loss of prairies to agriculture, combined with excessive hunting, has brought this unique animal close to extinction.

pronghorn



(Image © Research Machines plc)

The pronghorn is unique in that it sheds annually the sheaths that cover the horns. The sheath, more prominent in the male pronghorn, appears to form part of the horn itself.

pronghorn

(Image © Corel)

The pronghorn *Antilocapra americana* is the only remaining representative of an ancient animal family that evolved in North America. It lives in deserts and grasslands of western Canada, western United States, and northern Mexico. It is one of the fastest mammals of North America, and can reach a speed of 80 kph over short distances to avoid predators such as the coyote.

Pronghorn

Go to site

Profile of the pronghorn, its characteristics, and distribution. There is a high-resolution photo of the USA's fastest native mammal.

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proof spirit

numerical scale used to indicate the alcohol content of an alcoholic drink. Proof spirit (or 100% proof spirit) acquired its name from a solution of alcohol in water which, when used to moisten gunpowder, contained just enough alcohol to permit it to burn.

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propane

C_3H_8

gaseous hydrocarbon of the alkane series, found in petroleum and used as a fuel and as a refrigerant.

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propanol

or propyl alcohol

third member of the homologous series of alcohols. Propanol is usually a mixture of two isomeric compounds (see isomer): propan-1-ol ($CH_3CH_2CH_2OH$) and propan-2-ol ($CH_3CHOHCH_3$). Both are colourless liquids that can be mixed with water and are used in perfumery.

---

propanone

common name acetone; CH_3COCH_3

colourless flammable liquid used extensively as a solvent, as in nail-varnish remover, and for making acrylic plastics. It boils at 56.5°C/133.7°F, mixes with water in all proportions, and has a characteristic odour. Propanone is the simplest example of a ketone.

---

propellant

substance burned in a rocket for propulsion. With **bipropellant**, two propellants are used: oxidizer and fuel are stored in separate tanks and pumped independently into the combustion chamber. Liquid oxygen (oxidizer) and liquid hydrogen (fuel) are common propellants, used, for example, in the space shuttle main engines. The explosive charge that propels a projectile from a gun is also called a propellant.

---

propeller

screwlike device used to propel some ships and aeroplanes. A propeller has a number of curved blades that describe a helical path as they rotate with the hub, and accelerate fluid (liquid or gas) backwards during rotation. Reaction to this backward movement of fluid sets up a propulsive thrust forwards. The marine screw propeller was developed by Francis Pettit Smith in the UK and Swedish-born John Ericson in the USA and was first used in 1839.

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propene

common name propylene; $CH_3CH=CH_2$

second member of the alkene series of hydrocarbons. A colourless, flammable gas, it is widely used by industry to make organic chemicals, including polypropylene plastics.

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propenoic acid

common name acrylic acid; $H_2C=CHCOOH$

acid obtained from the aldehyde propenal (acrolein) derived from glycerol or fats. Glasslike thermoplastic resins are made by polymerizing esters of propenoic acid or methyl propenoic acid and used for transparent components, lenses, and dentures. Other acrylic compounds are used for adhesives, artificial fibres, and artists' acrylic paint.

---

proper motion

gradual change in the position of a star that results from its motion in orbit around our Galaxy, the Milky Way. Proper motions are slight and undetectable to the naked eye, but can be accurately measured on telescopic photographs taken many years apart.

Barnard's Star is the star with the largest proper motion, 10.3 arc seconds per year.

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properties

in chemistry, the characteristics a substance possesses by virtue of its composition.

Physical properties of a substance can be measured by physical means, for example boiling point, melting point, hardness, elasticity, colour, and physical state.
Chemical properties are the way it reacts with other substances; whether it is acidic or basic, an oxidizing or a reducing agent, a salt, or stable to heat, for example.

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prophylaxis

any measure taken to prevent disease, including exercise and vaccination. Prophylactic (preventive) medicine is an aspect of public-health provision that is receiving increasing attention.

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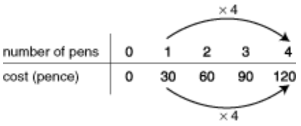
proportion

relation of a part to the whole (usually expressed as a fraction or percentage). In mathematics two variable quantities *x* and *y* are proportional if, for all values of *x*, $y = kx$, where *k* is a constant. This means that if *x* increases, *y* increases in a linear fashion.

direct proportion

If *A* and *B* are in direct proportion, then as one grows bigger the other also grows bigger by the same proportion (or ratio). For example, if *B* doubles then *A* doubles. This can be written as $A \propto B$ or $A = kB$ (where *k* is a constant multiplier). For example, when costing a number of pens:



number of pens	0	1	2	3	4
cost (pence)	0	30	60	90	120

For every extra pen bought, the cost goes up by the same amount (30p). So the cost of the pens will be proportional to the number bought.

If *A* is proportional to *B* there are two things that are true:

the multiplier rule - if *A* is multiplied by a value then *B* must be multiplied by the same value.

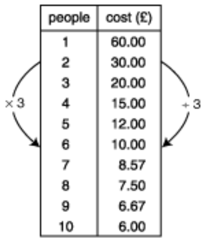
the graph of *A* against *B* is always a straight line through (0,0) and the gradient of the graph is the same as the ratio of *A*:*B*.

inverse proportion

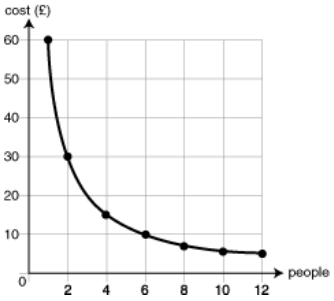
If *A* is inversely proportional to *B*, then as *B* gets bigger *A* gets smaller by the same factor. For example, if *B* is increased by a factor of 2 (*B* doubles) then *A* decreases by a factor of 2 (*A* is halved). This can be written as:

$A \propto 1/B$ or $A = k/B$

For example, a group of people want to hire a minibus at a charge of £60 a day. If only 1 person uses the minibus it will cost them £60, for 2 people the cost will be £30 each, and for 3 people the cost will be £20 each. A table and graph showing the number of people and cost can be completed:



people	cost (£)
1	60.00
2	30.00
3	20.00
4	15.00
5	12.00
6	10.00
7	8.57
8	7.50
9	6.67
10	6.00



cost per person $\propto$ 1/people cost per person = *k*/people

k = the hire of the bus (£60), so cost per person = 60/people

The shape of the graph is typical of an inversely proportional relationship.

Many laws of science relate quantities that are proportional (for example, Boyle's law).

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proprioceptor

one of the sensory nerve endings that are located in muscles, tendons, and joints. They relay information on the position of the body and the state of muscle contraction.

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prop root

or stilt root

modified root that grows from the lower part of a stem or trunk down to the ground, providing a plant with extra support. Prop roots are common on some woody plants, such as mangroves, and also occur on a few herbaceous plants, such as maize.
Buttress roots are a type of prop root found at the base of tree trunks, extended and flattened along the upper edge to form massive triangular buttresses; they are common on tropical trees.

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propyl alcohol

common name for propanol.

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propylene

common name for propene.

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prosimian

or primitive primate

in zoology, any animal belonging to the suborder Strepsirhin of primates. Prosimians are characterized by a wet nose with slitlike nostrils, the tip of the nose having a prominent vertical groove. Examples are lemurs, pottos, tarsiers, and the aye-aye.

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prostaglandin

any of a group of complex fatty acids present in the body that act as messenger substances between cells. Effects include stimulating the contraction of smooth muscle (for example, of the womb during birth), regulating the production of stomach acid, and modifying hormonal activity. In excess, prostaglandins may produce inflammatory disorders such as arthritis. Synthetic prostaglandins are used to induce labour in humans and domestic animals.

The analgesic actions of substances such as aspirin are due to inhibition of prostaglandin synthesis.

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prostate cancer

cancer of the prostate gland. It is a slow progressing cancer, and about 60% of cases are detected before metastasis (spreading), so it can be successfully treated by surgical removal of the gland and radiotherapy. It is, however, the second commonest cancer-induced death in males (after lung cancer). It kills 32,000 men a year in the USA alone.

Symptoms include a frequent need to urinate, with weak, painful, and interrupted urine flow.

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prostatectomy

surgical removal of the prostate gland. In many men over the age of 60 the prostate gland enlarges, causing obstruction to the urethra. This causes the bladder to swell with retained urine, leaving the sufferer more prone to infection of the urinary tract.

The treatment of choice is transurethral resection of the prostate, in which the gland is removed by passing an endoscope (slender optical instrument) up the urethra and using diathermy to burn away the prostatic tissue. This procedure has now largely replaced 'open' prostatectomy, in which the prostate is removed via an incision in the abdomen.

---

prostate gland

gland surrounding and opening into the urethra at the base of the bladder in male mammals.

The prostate gland produces an alkaline fluid that is released during ejaculation; this fluid activates sperm, and prevents their clumping together. Older men may develop **benign prostatic hyperplasia** (BPH), a painful condition in which the prostate becomes enlarged and restricts urine flow. This can cause further problems of the bladder and kidneys. It is treated by prostatectomy.

prosthesis

artificial device used to substitute for a body part which is defective or missing. Prostheses include artificial limbs, hearing aids, false teeth and eyes, heart pacemakers and plastic heart valves and blood vessels.

Prostheses in the form of artificial limbs, such as wooden legs and metal hooks for hands, have been used for centuries, although artificial limbs are now more natural-looking and comfortable to wear. The comparatively new field of bionics has developed myoelectric, or bionic, arms, which are electronically operated and worked by minute electrical impulses from body muscles.

Prosthetic History Page

Go to site

History of prosthetics from prehistory to modern times. The Web site describes artificial limbs in historical terms, citing many cases from classical texts. The Web site lacks the graphics which would make it much more interesting, but the text descriptions made are reasonably lengthy and complete.

protactinium

chemical symbol Pa

(Latin protos 'before' + aktis 'first ray')

silver-grey, radioactive, metallic element of the actinide series, atomic number 91, relative atomic mass 231.036. It occurs in nature in very small quantities in pitchblende and other uranium ores. It has 14 known isotopes; the longest-lived, Pa-231, has a half-life of 32,480 years.

protandry

in a flower, the state where the male reproductive organs reach maturity before those of the female. This is a common method of avoiding self-fertilization. See also protogyny.

protease

general term for a digestive enzyme capable of splitting proteins. Examples include pepsin, found in the stomach, and trypsin, found in the small intestine.

protein

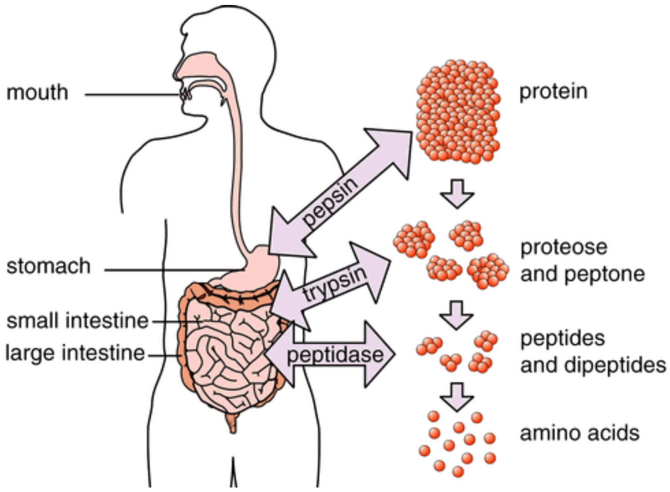
large, complex, biologically-important molecules composed of amino acids joined by peptide bonds. The number of amino acids used can be many hundreds. There are 20 different amino acids and they can be joined in any order. Proteins are essential to all living organisms. As enzymes they regulate all aspects of metabolism. Structural proteins such as keratin and collagen make up skin, claws, bones, tendons, and ligaments; muscle proteins produce movement; haemoglobin transports oxygen; and membrane proteins regulate the movement of substances into and out of cells. For humans, protein is an essential part of the diet, and is found in greatest quantity in soy beans and other grain legumes, meat, eggs, and cheese. During digestion protein molecules are broken down into amino acids which are then easily absorbed into the body.

Protein synthesis occurs in cells. The information describing the order in which the different amino acids are joined is found in DNA in the form of a code. The part of the DNA that carries the code for making one protein is called a gene. Each protein described in the code has an effect on the appearance and characteristics of the organism.

During digestion in the body, proteases (any enzymes that break down a protein) are produced by the stomach, the pancreas, and the small intestine. These enzymes catalyse the breakdown of protein into amino acids. Pepsin is an enzyme which is produced by the walls of the stomach. It digests large protein molecules into smaller protein molecules (smaller polypeptides). The conditions in the stomach are very acid and pepsin works at its fastest rate in such conditions.

The amino acids produced by the digestion of proteins are absorbed into the blood in the small intestine. They are transported around the body by the blood for use by cells to make the proteins they need. This protein synthesis needs energy and this energy is provided by respiration.

protein



(Image © Research Machines plc)

The digestion of protein. Protein is broken down into amino acids by the enzymes pepsin (secreted by the stomach) and trypsin and peptidase (in the small intestine).

Introduction to Proteins

Go to site

Introduction to the world of proteins with discussions of their structures and sequences, as well as descriptions of some major kinds of proteins. The site also includes a useful glossary and offers a variety of photographic shots.

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protein engineering

creation of synthetic proteins designed to carry out specific tasks. For example, an enzyme may be designed to remove grease from soiled clothes and remain stable at the high temperatures in a washing machine.

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protein synthesis

manufacture, within the cytoplasm of the cell, of the proteins an organism needs. The building blocks of proteins are amino acids, of which there are 20 types. The pattern in which the amino acids are linked decides what kind of protein is produced. In turn it is the genetic code, contained within DNA, that determines the precise order in which the amino acids are linked up during protein manufacture.

Interestingly, DNA is found only in the nucleus, yet protein synthesis occurs only in the cytoplasm. The information necessary for making the proteins is carried from the nucleus to the cytoplasm by another nucleic acid, RNA.

Proterozoic Eon

eon of geological time, 3.5 billion to 570 million years ago, the second division of the Precambrian. It is defined as the time of simple life, since many rocks dating from this eon show traces of biological activity, and some contain the fossils of bacteria and algae.

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prothallus

short-lived gametophyte of many ferns and other pteridophytes (such as horsetails or clubmosses). It bears either the male or female sex organs, or both. Typically it is a small, green, flattened structure that is anchored in the soil by several rhizoids (slender, hairlike structures, acting as roots) and needs damp conditions to survive. The reproductive organs are borne on the lower surface close to the soil. See also alternation of generations.

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protist

single-celled organism which has a eukaryotic cell, but which is not a member of the plant, fungal, or animal kingdoms. The main protists are protozoa.

Single-celled photosynthetic organisms, such as diatoms and dinoflagellates, are classified as protists or algae. Recently the term has also been used for members of the kingdom Protista, which features in certain five-kingdom classifications of the living world (see also plant classification). This kingdom may include slime moulds, all algae (seaweeds as well as unicellular forms), and protozoa.

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protocol

in computing, an agreed set of **standards** for the transfer of data between different devices. They cover transmission speed, format of data, and the signals required to synchronize the transfer. See also interface.

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protogyny

in a flower, the state where the female reproductive organs reach maturity before those of the male. Like protandry, in which the male organs reach maturity first, this is a method of avoiding self-fertilization, but it is much less common.

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proton

(Greek 'first')

in physics, a positively charged elementary particle, a constituent of the nucleus of all atoms. It belongs to the baryon group of hadrons and is composed of two up quarks and one down quark. A proton is extremely long-lived, with a lifespan of at least 10^{32} years. It carries a unit positive charge equal to the negative charge of an electron. Its mass is almost 1,836 times that of an electron, or 1.673×10^{-24} g. The number of protons in the atom of an element is equal to the atomic number of that element.

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proton number

alternative name for atomic number.

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protoplasm

contents of a living cell. Strictly speaking it includes all the discrete structures (organelles) in a cell, but it is often used simply to mean the jellylike material in which these float. The contents of a cell outside the nucleus are called cytoplasm.

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protostar

in astronomy, early formation of a star that has recently condensed out of an interstellar cloud and which is not yet hot enough for hydrogen burning to start. Protostars derive their energy from gravitational contraction. See Hayashi track.

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prototype

in technology, any of the first few versions of a new design. Prototypes are tested for performance, reliability, economy, and safety; then the main design can be modified before full-scale production begins.

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protozoa

group of single-celled organisms without rigid cell walls. Some, such as amoeba, ingest other cells, but most are saprotrophs or parasites. The group is polyphyletic (containing organisms which have different evolutionary origins).

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protractor

instrument used to measure a flat angle.

Prout, William (1785-1850)

British physician and chemist. In 1815 Prout published his hypothesis that the relative atomic mass of every atom is an exact and integral multiple of the mass of the hydrogen atom. The discovery of isotopes (atoms of the same element that have different masses) in the 20th century bore out his idea.

In 1827, Prout became the first scientist to classify the components of food into the three major divisions of carbohydrates, fats, and proteins.

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provitamin

any precursor substance of a vitamin. Provitamins are ingested substances that become converted to active vitamins within the organism. One example is ergosterol (provitamin D_2), which through the action of sunlight is converted to calciferol (vitamin D_2); another example is beta-carotene, which is hydrolysed in the liver to vitamin A.

Proxima Centauri

closest star to the Sun, 4.2 light years away from the Sun. It is a faint red dwarf, visible only with a telescope, and is a member of the Alpha Centauri triple-star system.

It is called Proxima because it is about 0.1 light years closer to us than its two partners.

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prussic acid

former name for hydrocyanic acid.

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pseudocarp

fruitlike structure that incorporates tissue that is not derived from the ovary wall. The additional tissues may be derived from floral parts such as the receptacle and calyx. For example, the coloured, fleshy part of a strawberry develops from the receptacle and the true fruits are small achenes - the 'pips' embedded in its outer surface. Rose hips are a type of pseudocarp that consists of a hollow, fleshy receptacle containing a number of achenes within. Different types of pseudocarp include pineapples, figs, apples, and pears.

A **coenocarpium** is a fleshy, multiple pseudocarp derived from an inflorescence rather than a single flower. The pineapple has a thickened central axis surrounded by fleshy tissues derived from the receptacles and floral parts of many flowers. A fig is a type of pseudocarp called a **syconium**, formed from a hollow receptacle with small flowers attached to the inner wall. After fertilization the ovaries of the female flowers develop into one-seeded achenes.

Apples and pears are pomes, another type of pseudocarp.

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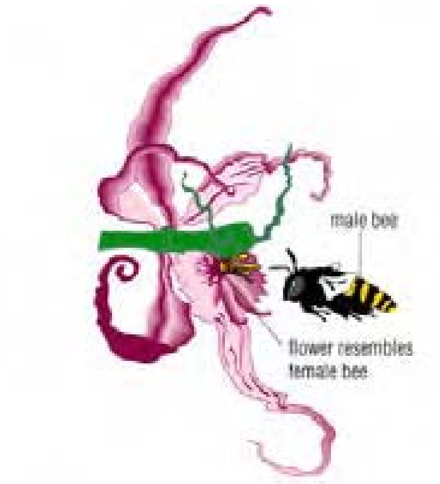
pseudocopulation

attempted copulation by a male insect with a flower. It results in pollination of the flower and is common in the orchid family, where the flowers of many species resemble a particular species of female bee. When a male bee attempts to mate with a flower, the pollinia (groups of pollen grains) stick to its body. They are transferred to the stigma of another flower when the insect attempts copulation again.

pseudocopulation



(Image © Research Machines plc)

The male bee, attracted to the orchid because of its resemblance to a female bee, attempts to mate with the flower. The bee's efforts cover its body with pollen, which is carried to the next flower it visits.

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pseudomorph

mineral that has replaced another in situ and has retained the external crystal shape of the original mineral.

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psi

in parapsychology, a hypothetical faculty common to humans and other animals, said to be responsible for extrasensory perception, telekinesis, and other paranormal phenomena.

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psittacosis

infectious acute or chronic disease, contracted by humans from birds (especially parrots), which produces pneumonialike symptoms. It is caused by a bacterium (*Chlamydia psittaci*, see chlamydia) and treated with tetracycline.

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psoriasis

chronic, recurring skin disease characterized by raised, red, scaly patches, on the scalp, elbows, knees, and elsewhere. Tar preparations, steroid creams, and ultraviolet light are used to treat it, and sometimes it disappears spontaneously. Psoriasis may be accompanied by a form of arthritis (inflammation of the joints). It affects 100 million people worldwide.

Psoriasis is believed to be an autoimmune disease, in which the body's immune system attacks cells in the skin as if they were invading pathogens. A psoriasis vaccine (PVAC), containing heat-killed bacteria that alter the body's immune response by disrupting the body's T-lymphocytes, was developed in New Zealand. Tests showed that half of those vaccinated underwent significant improvement in their condition.

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psychedelic drug

any drug that produces hallucinations or altered states of consciousness. Such sensory experiences may be in the auditory, visual, tactile, olfactory, or gustatory fields or in any combination. Among drugs known to have psychedelic effects are LSD (lysergic acid diethylamide), mescaline, and, to a mild degree, marijuana, along with a number of other plant-derived or synthetically prepared substances.

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psychiatry

branch of medicine dealing with the diagnosis and treatment of mental disorder, normally divided into the areas of **neurotic conditions**, including anxiety, depression, and hysteria, and **psychotic disorders**, such as schizophrenia. Psychiatric treatment consists of drugs, analysis, or electroconvulsive therapy.

In practice there is considerable overlap between psychiatry and clinical psychology, the fundamental difference being that psychiatrists are trained medical doctors (holding an MD degree) and may therefore prescribe drugs, whereas psychologists may hold a doctorate but do not need a medical qualification to practise. See also psychoanalysis.

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psychoanalysis

theory and treatment method for neuroses, developed by Sigmund Freud in the 1890s. Psychoanalysis asserts that the impact of early childhood sexuality and experiences, stored in the unconscious, can lead to the development of adult emotional problems. The main treatment method involves the free association of ideas, and their interpretation by patient and analyst, in order to discover these long-buried events and to grasp their significance to the patient, linking aspects of the patient's historical past with the present relationship to the analyst. Psychoanalytic treatment aims to free the patient from specific symptoms and from irrational inhibitions and anxieties.

concepts

As a theoretical system, psychoanalysis rests on three basic concepts. The central concept is that of the **unconscious**, a reservoir within one's mental state which contains elements and experiences of which one is unaware, but which may to some extent be brought into preconscious and conscious awareness, or inferred from aspects of behaviour. The second and related basic concept is that of **resistance**, a process by which unconscious elements are forcibly kept out of the conscious awareness by an active repressive force. Freud came to experience the third basic concept in his work, known as **transference**, with his earliest patients, who transferred to him aspects of their past relationships with others, so that their relationship with him was coloured by their previous feelings. The analysis of the transference in all its manifestations has become a vital aspect of current psychoanalytic practice.

id, ego, and superego

Freud proposed a model of human psychology based on the concept of the conflicting id, ego, and superego. The id is the mind's instinctual element which demands pleasure and satisfaction; the ego is the conscious mind which deals with the demands of the id and superego; the superego is the ethical element which acts as a conscience and may produce feelings of guilt. The conflicts between these three elements can be used to explain a range of neurotic symptoms.

other schools

In the early 1900s a group of psychoanalysts gathered around Freud. Some of these later broke away and formed their own schools, notably Alfred Adler in 1911 and Carl Jung in 1913. The significance of early infantile experience has been further elaborated in the field of child analysis, particularly in the work of Melanie Klein and her students, who pay particular attention to the development of the infant in the first six to eight months of life.

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psychology

systematic study of human and animal behaviour. The first psychology laboratory was founded in 1879 by Wilhelm Wundt at Leipzig, Germany. The subject includes diverse areas of study and application, among them the roles of instinct, heredity, environment, and culture; the processes of sensation, perception, learning, and memory; the bases of motivation and emotion; and the functioning of thought, intelligence, and language. Significant psychologists have included Gustav Fechner, founder of psychophysics; Wolfgang Köhler, one of the Gestalt or 'whole' psychologists; Sigmund Freud and his associates Carl Jung and Alfred Adler; William James, Jean Piaget; Carl Rogers; Hans Eysenck; J B Watson; and B F Skinner.

Experimental psychology emphasizes the application of rigorous and objective scientific methods to the study of a wide range of mental processes and behaviour, whereas **social psychology** concerns the study of individuals within their social environment; for example, within groups and organizations. This has led to the development of related fields such as **occupational psychology**, which studies human behaviour at work, and **educational psychology**.
Clinical psychology concerns the understanding and treatment of mental health disorders, such as anxiety, phobias, or depression; treatment may include behaviour therapy, cognitive therapy, counselling, psychoanalysis, or some combination of these.

Modern studies have been diverse; for example, the psychological causes of obesity; the nature of religious experience; and the underachievement of women seen as resulting from social pressures. Other related subjects are the nature of sleep and dreams, and the possible extensions of the senses, which leads to the more contentious ground of parapsychology.

Psychology: Experiments on Perception

the great cookie-cutter experiment

One of the basic questions examined by psychology is: 'How do humans perceive things?' Perception is the process of forming a coherent picture of the world. But how does perception work?

Until the 1960s, a rather simplistic view was taken of perception. The organs of perception – the eyes and ears, for example – were considered as passive receptors of data from the surroundings. It was thought that the act of perception simply consisted of constructing a world-picture from the external data. However, there were some early indications that this could not be the whole story.

stimulus … and no response

Early experiments on perception maintained a person in as passive a condition as possible, so that he or she became a simple receptor. The person was then subjected to stimuli of various sorts – sounds, flashing lights, and so on – to see how the stimuli were perceived. These experiments produced alarming results: a person held in a completely passive condition did not perceive the world as made up of things and, furthermore, after a short time did not perceive anything at all! These experiments should have warned psychologists that something was wrong with their theories of perception. But psychologists are very conservative, and in the middle of the 20th century the experimental study of perception continued along lines established in the 19th century.

Another very simple experiment demonstrates that perception cannot be regarded as a completely passive process. When the head is moved, the images produced on the retina of the eye move; yet the world is perceived as stationary. Presumably, when a moving object passes in front of a stationary eye, the images on the retina move in much the same way. In this case, however, we perceive that it is the object which is moving. In other words, the same retinal stimulus can produce different perceptions.

Mr and Mrs Gibson's work

The mechanism of perception was clarified by the work of US psychologist James Gibson in the early 1960s. Gibson was born in McConnelsville, Ohio, in 1904. He was educated at Princeton University. In 1932 he married his wife Eleanor, also a psychologist, and much of his later work was done in collaboration with her. Most of his work was done at Cornell University. He is credited with a discovery that revolutionized the teaching of pilots to land. He found that, as an aircraft descends, only one point appears not to change in relation to its surroundings; this is the point at which the aircraft will touch down. This discovery perhaps revealed to Gibson the importance of those things which appear unchanging in our environment. He put forward a new theory that perception was based on an active exploration of the world. According to Gibson, our world-picture is built up from observation of invariants or unchanging quantities.

active exploration

To prove his ideas correct, Gibson undertook a series of experiments using cookie cutters, perhaps from his own kitchen. The cutters were of different shapes – some square, some star-shaped, and so on. In the first part of the experiment, the cutters were pressed onto the upturned palm of a hand with a standard pressure. The subject was held still, and he could not see the cutter. This corresponded to the passive condition so well loved by earlier experimenters. It was found that only 29% of the subjects could correctly identify the shape of the cutter. Next, the subject was allowed to use his fingers to feel the cutter, to turn it, and actively explore the shape. Now 95% of the subjects identified the shape correctly. Another experiment was done in which the cutters were pressed to the palm of the hand, and then rotated gently. In this case, 72% of the subjects correctly identified the shape.

The best explanation of the results is that accurate perception of shape requires changing stimuli. The unchanging stimulus when the cutter is pressed onto the palm is least helpful in perceiving shape. The most accurate perception occurs when the fingers are used to actively explore a cutter; in this case, the subject receives changing stimuli not only from the hand but also from the arm and hand muscles. When the cutter is rotated on the palm, stimuli are received from the hand but not the arm - an intermediate case. From among the changing stimuli, the brain extracts the unchanging information and constructs a picture of the cutter from this.

In this simple experiment, Gibson demonstrated that perception is a process of active exploration, not a passive reception of information. The reason why we know whether an object is moving, or whether our head is moving, is now clear. We receive information from our head muscles and neck joints when the head moves. Put another way, we use information which does not arise from external stimuli when we perceive the world.

Psychology: key events

1846	E H Weber reports on his pioneering quantitative investigations of touch in *On Touch and Common Sensibility*.
1860	G T Fechner publishes *Elements of Psychophysics*, in which he presents the first statistical treatment of psychological data.
1879	Wilhelm Wundt founds the first psychological laboratory in Leipzig.
1885	H Ebbinghaus publishes his experimental research into memory.
1890	William James publishes the first comprehensive psychology text, *Principles of Psychology*.
1895	Joseph Breuer and Sigmund Freud publish *Studies on Hysteria*, containing the first writings on psychoanalysis.
1896	The first psychology clinic is founded by Lightner Witner at the University of Pennsylvania; the first use of the term 'clinical psychology'.
1900	Freud's *Interpretation of Dreams* is published.
1905	Alfred Binet and Théodore Simon develop the first effective intelligence test.
1906	Ivan Pavlov first lectures in the West on conditioned reflexes in animals.
1908	The first textbook of social psychology is published by William McDougall and E A Ross.
1911	Max Wertheimer, Wolfgang Köhler, and Kurt Koffka found the Gestalt School in Frankfurt.
1913	John B Watson's article 'Psychology as a Behaviorist Views It' is published and the behaviourist movement is thus launched.
1923	Jean Piaget's *The Language and the Thought of the Child* is published, the first of his many books on the development of thinking.
1927	C Spearman proposes in *The Abilities of Man* that intelligence comprises two kinds of factors, a general factor ('g') and specific factors.
1929	H Berger publishes his findings on the electroencephalogram (EEG).
1938	B F Skinner publishes *The Behavior of Organisms*, detailing his study of operant conditioning and his radical behaviourism.
1943	C L Hull publishes his influential book *Principles of Behavior*, the most rigorous account of conditioning and learning from the perspective of behaviourism.
1947	Hans Eysenck publishes *Dimensions of Personality*, a large-scale study of neuroticism and extraversion.
1948	Norbert Wiener coins the term 'cybernetics' and publishes *Cybernetics: Control and Communication in the Animal and Machine*.
1949	D O Hebb's *Organization of Behaviour* re-emphasizes the role of central (brain) processes in the explanation of behaviour.
1950	Alan Turing proposes his test of whether a machine can be said to think, in the article 'Computing Machinery and Intelligence'. *The Authoritarian Personality* by Theodor Adorno and others is published.
1953	E Aserinksy and N Kleitman publish the first account of REM (rapid eye movement) sleep.
1957	Noam Chomsky publishes *Syntactic Structures*, a seminal work of psycholinguistics, which revolutionizes the study of language. L Festinger publishes *A Theory of Cognitive Dissonance*.
1958	A Newell and H A Simon, with J C Shaw, publish their article on human problem-solving, the first account of the information-processing approach to human psychology.
1958	Donald E Broadbent publishes *Perception and Communication*, a detailed account of information-processing psychology.
1960	G A Miller, E Galanter, and K Pribam apply the idea of a hierarchically structured computer program to the whole of psychology in their *Plans and the Structure of Behaviour*.
1961	A Newell and H A Simon publish their pioneering computational model of human problem-solving, the General Problem Solver.
1961	Carl Jung dies. Jung's theory of the ego, personal unconcious and collective unconcious led to the development of personality tests such as the Myers-Briggs test.
1962	M S Gazzaniga, J E Bogen, and R W Sperry first report on the 'split brain' phenomenon in epileptic patients.
1963	Stanley Milgram publishes his first studies of obedience and the conditions under which individuals will inflict harm when so instructed.
1967	Konovski publishes *Integrative Activity of the Brain*, a melding of conditioning principles with sensation and motivation. Ulrich Neisser's *Cognitive Psychology* marks renewed interest in the study of cognition after years in which behaviourism has dominated.
1968	R C Atkinson and R M Shiffin develop their theory of interacting memory systems in cognitive processing.
1970	T Shallice and E K Warrington provide the first of much evidence from brain-damaged patients that short-term memory is parallel with long-term memory and is best viewed as a collection of separate processing modules.
1972	E Tulving distinguishes episodic memory (for personal experience) and semantic memory (for general knowledge and facts about the world).

1983	J A Fodor publishes *The Modularity of Mind*, dividing the mind into independent cognitive processors and defining their activity.
1985	A new view of intelligence is proposed by Robert J Sternberg in *Beyond IQ: A Triarchic Theory of Intelligence*.
1986	J L McClelland and D E Rumelhart develop complex computational networks using parallel processing to simulate human learning and categorization.
1989	The mathematician Roger Penrose, in *The Emperor's New Mind*, argues that the computational account of the mind is incomplete, particularly concerning consciousness.
1992	The philosopher John Searle, in *The Rediscovery of the Mind*, argues for the return of consciousness to its position as the central topic in psychology and cognitive science.

Experimental Psychology Lab

Go to site

Take part in online psychology experiments carried out by the University of Tübingen's Psychology Institute. There are a variety of experiments here, some requiring Java and ActiveX, and some only in German.

Museum of the History of Psychological Instrumentation

Go to site

Museum of mad scientists' tools. If you expect to see pictures of couches and clipboards on this Web site you are going to be disappointed since a disturbingly high proportion of the tools listed have electrodes attached. The instruments described and pictured on these pages were the tools of a generation of psychology experimenters, and as with all historic science equipment look bizarre to the modern eye. So if you've ever wondered what a 'Wundt's tachistoscope' does and what it looks like, this is the place to find out.

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psychometrics

measurement of mental processes. This includes intelligence and aptitude testing to help in job selection and in the clinical assessment of cognitive deficiencies resulting from brain damage.

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psychopathy

personality disorder characterized by chronic antisocial behaviour (violating the rights of others, often violently) and an absence of feelings of guilt about the behaviour.

Because the term 'psychopathy' has been misused to refer to any severe mental disorder, many psychologists now prefer the term 'antisocial personality disorder', though this also includes cases in which absence or a lesser degree of guilt is not a characteristic feature.

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psychosis

or psychotic disorder

general term for a serious mental disorder in which the individual commonly loses contact with reality and may experience hallucinations (seeing or hearing things that do not exist) or delusions (fixed false beliefs). For example, in a paranoid psychosis, an individual may believe that others are plotting against him or her. A major type of psychosis is schizophrenia.

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psychosomatic

of a physical symptom or disease thought to arise from emotional or mental factors.

The term 'psychosomatic' has been applied to many conditions, including asthma, migraine, hypertension, and peptic ulcers. Whereas it is unlikely that these and other conditions are wholly due to psychological factors, emotional states such as anxiety or depression do have a distinct influence on the frequency and severity of illness.

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psychosurgery

operation to relieve severe mental illness. See leucotomy.

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psychotherapy

any treatment for psychological problems that involves talking rather than surgery or drugs. Examples include cognitive therapy and psychoanalysis.

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psychotic disorder

another name for psychosis.

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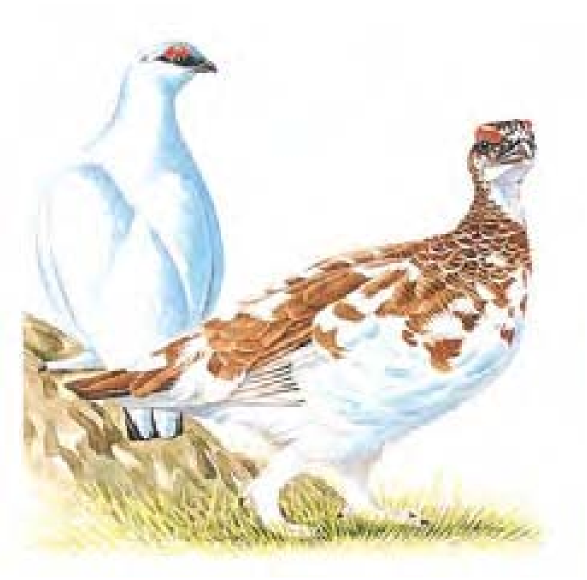
ptarmigan

hardy, northern ground-dwelling bird of genus *Lagopus*, family Phasianidae (which also includes grouse), with feathered legs and feet.

The willow ptarmigan *L. lagopus*, found in bushes and heather in northern parts of North America, Europe, and Asia, grows to 38 cm/15 in and turns white in the winter.

ptarmigan



(Image © Research Machines plc)

This member of the grouse family inhabits the high mountains, remote forests, and tundra of northern latitudes around the world. It relies mainly on camouflage for defence and, in winter, turns from a speckled greyish brown to pure white with dark tail feathers. It feeds mainly on fruit, seeds, and buds.

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pteridophyte

simple type of vascular plant. The pteridophytes comprise four classes: the Psilosida, including the most primitive vascular plants, found mainly in the tropics; the Lycopsida, including the club mosses; the Sphenopsida, including the horsetails; and the Pteropsida, including the ferns. They do not produce seeds.

They are mainly terrestrial, non-flowering plants characterized by the presence of a vascular system; the possession of true stems, roots, and leaves; and by a marked alternation of generations, with the sporophyte forming the dominant generation in the life cycle. The pteridophytes formed a large and dominant flora during the Carboniferous period, but many are now known only from fossils.

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pterodactyl

genus of pterosaur.

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pterosaur

extinct flying reptile of the order Pterosauria, existing in the Mesozoic age. They ranged from the size of a starling to the 12 m/39 ft wingspan of *Arambourgiania philadelphiae*; the largest of the pterosaurs discovered so far. Some had horns on their heads that, when in flight, made a whistling to roaring sound.

Pterosaurs were formerly assumed to be smooth-skinned gliders, but recent discoveries show that at least some were furry, probably warm-blooded, and may have had muscle fibres and blood vessels on their wings, stiffened by moving the hind legs, thus allowing controlled and strong flapping flight.

Ptolemy (c.AD 100-c.AD 170)

born Claudius Ptolemaeus

Egyptian astronomer and geographer. His *Almagest* developed the theory that Earth is the centre of the universe, with the Sun, Moon, and stars revolving around it. In 1543 the Polish astronomer Copernicus proposed an alternative to the **Ptolemaic system**. Ptolemy's *Geography* was a standard source of information until the 16th century.

The *Almagest* (he called it *Syntaxis*) contains all his works on astronomical themes, the only authoritative works until the time of Copernicus. Probably inspired by Plato, Ptolemy began with the premise that the Earth was a perfect sphere; all planetary orbits were circular, but those of Mercury and Venus, and possibly Mars (Ptolemy was not sure), were epicyclic (the planets orbited a point that itself was orbiting the Earth); and the sphere of the stars formed a dome with points of light attached or pricked through.

Ptolemy's Geography

Go to site

Door into the ancient world – particularly the way the ancient Greek astronomer Ptolemy envisioned the earth. It includes expandable images of various texts and diagrams written by, or about, Ptolemy.

Ptolemy's Table Of Chords

Go to site

Demonstration of how trigonometry tables were constructed prior to the invention of infinite series. Ptolemy's methods are deciphered into modern notation, and the standard is such that secondary school students will find it challenging, but not unreadable.

Ptolemy, The Man

Go to site

Profile of the astronomer, mathematician, and geographer. The few known biographical facts are related, together with summaries of his achievements. The text is supported by a number of diagrams and a map. There are links to a number of other Ptolemy, astronomy, and Greek geography sites.

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ptomaine

any of a group of toxic chemical substances (alkaloids) produced as a result of decomposition by bacterial action on proteins.

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puberty

stage in human development when the individual becomes sexually mature. It may occur from the age of ten upwards, but each person is individual. The sexual organs take on their adult form and pubic hair grows. In girls, menstruation begins, and the breasts develop; in boys, the voice breaks and becomes deeper, and facial hair develops. Both boys and girls will experience emotional as well as physical changes.

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pubes

lowest part of the front of the human trunk, the region where the external generative organs are situated. The underlying bony structure, the pubic arch, is formed by the union in the midline of the two pubic bones, which are the front portions of the hip bones. In women this is more prominent than in men, to allow more room for the passage of the child's head at birth, and it carries a pad of fat and connective tissue, the *mons veneris* (mount of Venus), for its protection.

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public health

or community medicine

science of preventing disease and promoting health at community level rather than on an individual basis. At its most basic it includes the provision of an adequate supply of clean water and the safe disposal of sewage. It also includes the provision of an adequate number of doctors, nurses, and hospitals to serve each community, and ensuring that medical services are available to everyone, whatever their financial circumstances.

Other facets of public health are epidemiology, the study of disease and its occurrence within a community, immunization against disease, microbiology, the study of disease-causing bacteria, and virology, the study of viruses.

basic needs

In the most isolated communities in developing countries, the first essential for public health is a supply of clean drinking water. Polluted water is a major cause of disease. The second requirement is to ensure that human and other waste is disposed of in such a way that it cannot contaminate the wells or springs from which drinking water is drawn. Both these steps are vital in the prevention of disease.

statistics

The next necessity is a supply of qualified doctors. In some developing countries these may be supplemented by paramedics, people with limited medical training who can handle simple medical problems. Medical statistics based on the number of doctors in relation to the population show a great variation, ranging from 1 doctor for every 282 people in Uruguay to 1 for every 22,452 in Ghana. Statistics also show a great variation in the number of hospital beds available per head of population.

puddle clay

clay, with sand or gravel, that has had water added and mixed thoroughly so that it becomes watertight. The term was coined in 1762 by the canal builder James Brindley, although the use of such clay in dams goes back to Roman times.

puerperal fever

infection of the genital tract of the mother after childbirth, due to lack of aseptic conditions. Formerly often fatal, it is now rare and treated with antibiotics.

puff adder

variety of adder, a poisonous snake.

puffball

ball-shaped fruiting body of certain fungi (see fungus) that cracks open when it ripens, releasing the enclosed spores in the form of a brown powder; for example, the common puffball (*L. perlatum*). (Genera *Lycoperdon* and *Calvatia*.)

puffball

The giant puffball fungus can grow up to 1.8 m/6 ft in circumference.

puffer fish

fish of the family Tetraodontidae. As a means of defence it inflates its body with water until it becomes spherical and the skin spines become erect. Puffer fish are mainly found in warm waters, where they feed on molluscs, crustaceans, and coral.

There are approximately 120 puffer fish species. They vary in size, up to 50 cm/20 in long. To allow inflation, they have elastic skin and no ribs. The skin of some puffer fish is poisonous (gram for gram, it is 10,000 times more toxic than cyanide). In Japan, where they are called *fugu*, they are prized as a delicacy after the poison has been removed. Nevertheless, the death of about 100 diners is recorded each year.

blue-striped puffer fish

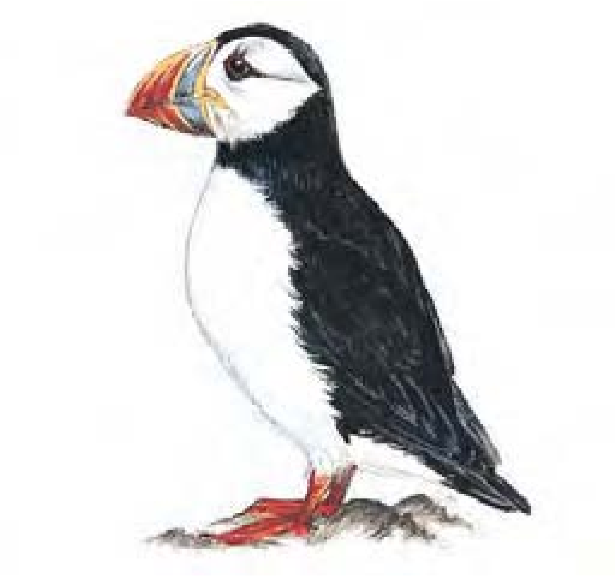
(Image © Corel)

When threatened the blue-striped puffer fish. can inflate itself by swallowing water. The skin and some internal organs are poisonous.

puffin

any of various sea birds of the genus *Fratercula* of the auk family, found in the northern Atlantic and Pacific. The puffin is about 35 cm/14 in long, with a white face and front, red legs, and a large deep bill, very brightly coloured in summer. Having short wings and webbed feet, puffins are poor fliers but excellent swimmers. They nest in rock crevices, or make burrows, and lay a single egg.

puffin



(Image © Research Machines plc)

The puffin *Fratercula arctica* breeds in burrows in colonies distributed around the coast and islands of NW Europe. For breeding success it relies heavily upon shoals of sand eels that thrive in the waters in this area.

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pug

breed of small dog with short wrinkled face, hanging ears, chunky body, and tail curled over the hip. It weighs 6-8 kg/13-18 lb. Its short coat may be black, beige or grey; the beige or grey dogs have black on the face and ears.

Pug

Go to site

Profile of the pug from the American Kennel Club. There is a history of the breed, description of the ideal breed standard, a note on the dog's temperament, and some interesting facts about pugs. There is also a high-resolution photo of this long-established breed.

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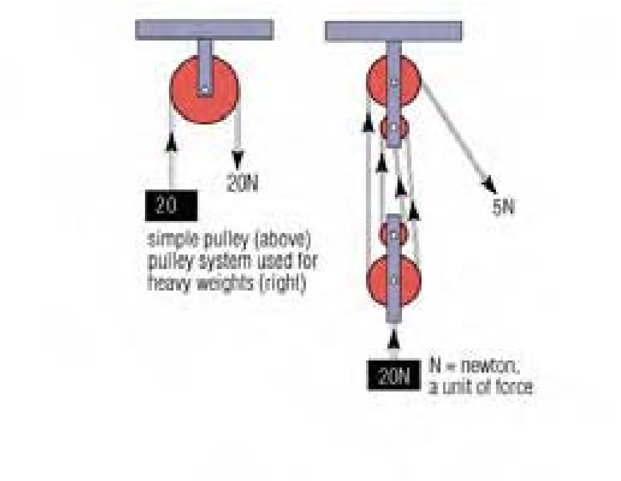
pulley

simple machine consisting of a fixed, grooved wheel, sometimes in a block, around which a rope or chain can be run. A simple pulley serves only to change the direction of the applied effort (as in a simple hoist for raising loads). The use of more than one pulley results in a mechanical advantage, so that a given effort can raise a heavier load.

The mechanical advantage depends on the arrangement of the pulleys. For instance, a block and tackle arrangement with three ropes supporting the load will lift it with one-third of the effort needed to lift it directly (if friction is ignored), giving a mechanical advantage of three.

pulley



(Image © Research Machines plc)

The mechanical advantage of a pulley increases with the number of rope strands. If a pulley system has four ropes supporting the load, the mechanical advantage is four, and a 5 newton force will lift a 20 newton load.

Pullman, George Mortimer (1831-1897)

US engineer and entrepreneur who developed the Pullman railway car from 1864. It was not the first sleeping carriage but it was the most luxurious. Pullman cars were initially staffed entirely by black porters whose only income was from tips. In 1937 the Brotherhood of Sleeping Car Porters became the first black union recognized by a US corporation.

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pulmonary

pertaining to the lungs.

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pulmonary embolism

in medicine, condition in which a blood clot becomes lodged in the lungs. The clot usually migrates in the circulatory system from a vein in the lower abdomen or legs. The condition is characterized by a sudden pain in the chest. It can be fatal if the clot is large. Smaller clots can be removed surgically or dissolved by the use of fibrinolytic drugs.

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pulmonary hypertension

in medicine, high blood pressure in the lungs due to a resistance to blood flow caused by constriction of the smaller arteries. Lung diseases, such as chronic bronchitis and emphysema, bring about pulmonary hypertension.

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pulmonary oedema

in medicine, the accumulation of fluids in the lung. It is caused by heart diseases, such as left ventricular failure or mitral stenosis (narrowing of the bicuspid valve).

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pulmonary surfactant

in medicine, substance that lowers the surface tension in the finer branches of the lungs, protecting them from collapse. Pulmonary surfactants are used to treat respiratory distress syndrome in premature babies.

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pulsar

celestial source that appears to flash at radio and other wavelengths at regular intervals, ranging from a few seconds to a few thousandths of a second. Pulsars are rapidly rotating neutron stars. They were discovered in 1967 by Jocelyn Bell Burnell and Antony Hewish at the Mullard Radio Astronomy Observatory, Cambridge, England.

Pulsars slow down as they get older, and eventually the flashes fade. Millisecond pulsars (flashing about 1,000 times a second) are thought to be more than a billion years old. A few pulsars, one (estimated to be 1,000 years old) in the Crab nebula and one (estimated to be 11,000 years old) in the constellation Vela, give out flashes of visible light.

Pulsar: Discovery

little green men?

Making a major scientific discovery is not as many people imagine; often, there is no 'eureka moment' or single instant of discovery. Discovery is more often a process of checking and rechecking, of gradually eliminating spurious effects, until the truth is apparent. The discovery of the first pulsar shows this process in action.

Luck played a part in the discovery. In 1967 Antony Hewish at the Mullard Radio Astronomy Laboratory, Cambridge, England, constructed a new type of radio telescope – a large array of 2,048 aerials covering an area of 1.8 hectares/4.4 acres – to study the 'twinkling' or scintillation of radio galaxies. This is caused by clouds of ionized gas ejected from the Sun. It is most noticeable at metre wavelengths, so the new telescope had to be sensitive to radiation of this wavelength. Most radio telescopes achieve high sensitivity by averaging incoming signals for several seconds, and so are unsuitable for studying rapidly varying signals. They collect radiation with wavelengths of around a centimetre. The new telescope's ability to detect rapidly varying signals of metre wavelength was just what was needed to detect a pulsar.

twinkle, twinkle, little galaxy

The telescope began work in July 1967. Its first task was to locate all radio galaxies twinkling in the area of sky accessible to it. Each day, as the Earth rotated, the telescope swept its radio eye across a band of sky. A complete scan took four days. Initially a graduate student, Jocelyn Bell, ran the survey and analysed the results, output on about 30 m/100 ft of chart paper each day.

After a few weeks, Bell noticed an unusual signal: not a single blip, but an untidy bunch of squiggles on the chart. It was nothing like the signals she was looking for, so she marked a query on the chart and did not investigate further. Later, when she saw the same signal on another chart, she realized it merited closer attention. The signal came from a part of the sky where scintillations were normally weak. It occurred at night, and scintillations are strongest during the day. A faster chart recorder was installed for a more detailed look at the signal. It would stretch out the signal over a longer chart, like a photographic enlargement.

what was going on?

For a while, Bell and Hewish's efforts were frustrated – the signal weakened and vanished. For a month, there was no sign of it. The researchers feared that they had seen a one-off event: possibly a star flaring brightly for a short time. If so, they had missed the chance to study it in detail. However, on 28 November, it returned. This time, the new recorder revealed the true nature of the signal. It was a series of short pulses about 1.3 seconds apart. Timing the pulses more accurately showed that they were in step to within one-millionth of a second. Their short duration indicated that they were coming from a very small object. Something peculiar was going on, but what?

The task now was to rule out spurious effects. Did the signal result from a machine malfunction? Was it caused by a satellite signal? Or a radar echo from the Moon? The fact that the signal appeared at regular intervals hinted that it was not a machine malfunction. Having calculated when the signal would next appear, at the appointed time the research team stood around the recorder. Nothing! Hewish and the others began to wander away. But before they reached the door, they were called back. 'Here it is!' said a student. They had miscalculated when the signal would be picked up. They knew now that it came from outside the laboratory.

is there anybody there?

Further study established that the signal rotated with the stars, and came from beyond the Solar System, but from within our galaxy. At one stage, Hewish thought that the signal might be a message from an extraterrestrial civilization. It was given the name 'LGM', for 'little green men'. However, this possibility was ruled out. Other beings must live on a planet circling round a star. The planetary motion would show up as a slight variation in the pulse rate. After carefully timing the pulses for several weeks, the idea of a planetary origin was given up.

On 21 December 1967 Bell discovered a second signal elsewhere in the sky. This clinched the reality of the phenomenon, and the name 'pulsar' was quickly coined to describe the object radiating the pulsation. The results were published in February 1968; within a year it was generally accepted that the signals came from rapidly spinning neutron stars. Since then more than 500 pulsars have been discovered. Antony Hewish shared the 1974 Nobel Prize for physics with British radio astronomer Martin Ryle for their work in radio astronomy and, in particular, the discovery of pulsars.

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pulse

in biology, impulse transmitted by the heartbeat throughout the arterial systems of vertebrates. When the heart muscle contracts, it forces blood into the aorta (the chief artery). Because the arteries are elastic, the sudden rise of pressure causes a throb or sudden swelling through them. The actual flow of the blood is about 60 cm/2 ft a second in humans. The average adult pulse rate is generally about 70 per minute. The pulse can be felt where an artery is near the surface, for example in the wrist or the neck.

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pulse

crop such as peas and beans. Pulses are grown primarily for their seeds, which provide a concentrated source of vegetable protein, and make a vital contribution to human diets in poor countries where meat is scarce, and among vegetarians. Soybeans are the major temperate protein crop in the West; most are used for oil production or for animal feed. In Asia, most are processed into soymilk and beancurd. Peanuts dominate pulse production in the tropical world and are generally consumed as human food.

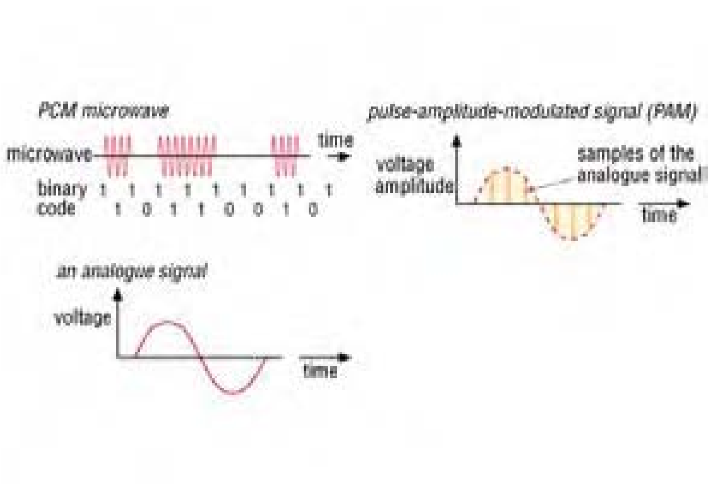
Pulses play a useful role in crop rotation as they help to raise soil nitrogen levels as well as acting as break crops. In the mid-1980s, world production was about 50 million tonnes a year.

pulse-code modulation

PCM

in physics, a form of digital modulation in which radio waves, microwaves, light waves, or other 'carrier waves' are switched on and off in pulses of varying length according to a binary code. It is a relatively simple matter to transmit data that are already in binary code, such as those used by computer, by these means. However, if an analogue audio signal is to be transmitted, it must first be converted to a **pulse-amplitude modulated** signal (PAM) by regular sampling of its amplitude. The value of the amplitude is then converted into a binary code for transmission on the carrier wave.

pulse-code modulation



(Image © Research Machines plc)

The amplitude, duration, and timing of a series of pulses are controlled in pulse-code modulation, which is relatively simple for digital data already in binary code. Analogue signals need to be converted into a recognizable binary code (a pulse-amplitude modulated signal) by regular sampling of its amplitude. Morse code is a very simple example of pulse-code modulation.

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pulsed high frequency (PHF)

instrumental application of high-frequency radio waves in short bursts to damaged tissue to relieve pain, reduce bruising and swelling, and speed healing.

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puma

or cougar or mountain lion

large wild cat *Felis concolar* found in North and South America. Tawny-coated, it is 1.5 m/4.5 ft long with a 1-m/3-ft tail. Pumas live alone, with each male occupying a distinct territory; they eat deer, rodents, and cattle. Pumas need large territories, with females maintaining up to 100 sq km and males even more. Two to four cubs are born and will remain with the mother till they are 18–24 months old (they are completely weaned at six months).

Although in some areas they have been hunted nearly to extinction, in California puma populations have grown, with numbers reaching an estimated 5,000–6,000 by 1996.

GWF Felis Concolor Cougar (Eastern Cougar)

Go to site

Good profile of *Felis concolor*, the largest cat in the USA. The contents include a description, information on its habitat, diet, hunting technique, reproduction, and survival threats. There is also an extensive list of references.

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pumice

light volcanic rock produced by the frothing action of expanding gases during the solidification of lava. It has the texture of a hard sponge and is used as an abrasive.

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pump

any device for moving liquids and gases, or compressing gases.

Some pumps, such as the traditional **lift pump** used to raise water from wells, work by a reciprocating (up-and-down) action. Movement of a piston in a cylinder with a one-way valve creates a partial vacuum in the cylinder, thereby sucking water into it.

Gear pumps, used to pump oil in a car's lubrication system, have two meshing gears that rotate inside a housing, and the teeth move the oil.
Rotary pumps contain a rotor with vanes projecting from it inside a casing, sweeping the liquid round as they move.

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pumped storage

hydroelectric plant that uses surplus electricity to pump water back into a high-level reservoir. In normal working conditions the water flows from this reservoir through the turbines to generate power for feeding into the grid. At times of low power demand, electricity is taken from the grid to turn the turbines into pumps that then pump the water back again. This ensures that there is always a 'head' of water in the reservoir to give the maximum output when required.

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pumpkin

creeping plant whose large round fruit has a thick orange rind, pulpy flesh, and many seeds. Pumpkins are used in cookery (especially pies and soups) and are hollowed out to form candle lanterns at Halloween. (Genus *Cucurbita pepo*, family Cucurbitaceae.)

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punched card

in computing, an early form of data storage and input, now almost obsolete. The 80-column card widely used in the 1960s and 1970s was a thin card, measuring 190 mm × 84 mm/7.5 in × 3.33 in, holding up to 80 characters of data encoded as small rectangular holes.

The punched card was invented by French textile manufacturer Joseph Marie Jacquard in 1801 to control weaving looms. The first data-processing machine using punched cards was developed by US inventor Herman Hollerith in the 1880s for the US census.

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punctuated equilibrium model

evolutionary theory developed by Niles Eldredge and US palaeontologist Stephen Jay Gould in 1972 to explain discontinuities in the fossil record. It claims that evolution continues through periods of rapid change alternating with periods of relative stability (stasis), and that the appearance of new lineages is a separate process from the gradual evolution of adaptive changes within a species.

The pattern of stasis and more rapid change is now widely accepted, but the second part of the theory remains unsubstantiated.

The **turnover pulse hypothesis** of US biologist Elisabeth Vrba postulates that the periods of rapid evolutionary change are triggered by environmental changes, particularly changes in climate.

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pupa

nonfeeding, largely immobile stage of some insect life cycles, in which larval tissues are broken down, and adult tissues and structures are formed.

In many insects, the pupa is **exarate**, with the appendages (legs, antennae, wings) visible outside the pupal case; in butterflies and moths, it is called a chrysalis, and is **obtect**, with the appendages developing inside the case.

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purgative

substance used to ease constipation. See laxative.

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purpura

condition marked by purplish patches on the skin or mucous membranes due to localized spontaneous bleeding. It may be harmless, as sometimes with the elderly, or linked with disease, allergy, or drug reactions.

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pus

yellowish fluid that forms in the body as a result of bacterial infection; it includes white blood cells (leucocytes), living and dead bacteria, dead tissue, and serum. An enclosed collection of pus is called an abscess.

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putrefaction

decomposition of organic matter by micro-organisms.

PVC

abbreviation for polyvinyl chloride.

P-wave

abbreviation of primary wave

in seismology, a class of seismic wave that passes through the Earth in the form of longitudinal pressure waves at speeds of 6-7 kps/3.7-4.4 mps in the crust and up to 13 kps/8 mps in deeper layers, the speed depending on the density of the rock. P-waves from an earthquake travel faster than S-waves and are the first to arrive at monitoring stations (hence primary waves). They can travel through both solid rock and the liquid outer core of the Earth.

P-waves are longitudinal waves; that is, they travel in the same direction as the rock is moving back and forth. P-waves cause one part of the rock to compress together and another section to be pushed apart. This process is known as compression and rarefaction, similar to the propagation of sound waves.

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pyelitis

inflammation of the renal pelvis, the central part of the kidney where urine accumulates before discharge. It is caused by bacterial infection and is more common in women than in men.

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pylorus

in biology, the lower opening of the stomach. Food that has been softened and partially digested in the mouth and the stomach passes into the intestine through the pylorus.

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pyorrhoea

former name for gum disease, now known as periodontal disease.

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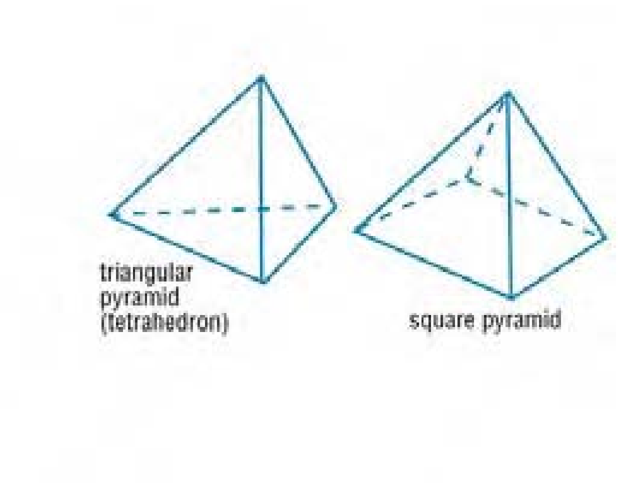
pyramid

in geometry, a solid shape with triangular side-faces meeting at a common vertex (point) and with a polygon as its base. The volume V of a pyramid is given by $V = 1/3Bh$, where B is the area of the base and h is the perpendicular height.

Pyramids are generally classified by their bases. For example, the Egyptian pyramids have square bases, and are therefore called square pyramids. A triangular pyramid is also known as a tetrahedron ('four sides').

pyramid



(Image © Research Machines plc)

Types of pyramid.

pyramidal peak

angular mountain peak with three or more arêtes found in glaciated areas; for example, the Matterhorn in Switzerland. It is formed when three or four corries (steep-sided hollows) are eroded, back-to-back, around the sides of a mountain, leaving an isolated peak in the middle.

pyrethrum

popular name for several cultivated chrysanthemums. The ornamental species *C. coccineum*, and hybrids derived from it, are commonly grown in gardens. Pyrethrum powder, made from the dried flower heads of some species, is a powerful pesticide for aphids and mosquitoes. (Genus *Chrysanthemum*, family Compositae.)

pyridine

C_5H_5N

heterocyclic compound (see cyclic compounds). It is a liquid with a sickly smell and occurs in coal tar. It is soluble in water, acts as a strong base, and is used as a solvent, mainly in the manufacture of plastics.

pyridoxine

or vitamin B_6; $C_8H_{11}NO_3$

water-soluble vitamin of the B complex. There is no clearly identifiable disease associated with deficiency but its absence from the diet can give rise to malfunction of the central nervous system and general skin disorders. Good sources are liver, meat, milk, and cereal grains. Related compounds may also show vitamin B_6 activity.

pyrite

or fool's gold

iron sulphide FeS_2. It has a yellow metallic lustre and a hardness of 6–6.5 on the Mohs scale. It is used in the production of sulphuric acid.

pyroclastic

describing fragments of solidified volcanic magma, ranging in size from fine ash to large boulders, that are extruded during an explosive volcanic eruption; also the rocks that are formed by consolidation of such material. Pyroclastic rocks include tuff (ash deposit) and agglomerate (volcanic breccia).

pyroclastic deposit

deposit made up of fragments of rock, ranging in size from fine ash to large boulders, ejected during an explosive volcanic eruption.

pyrogallol

technical name trihydroxybenzene; $C_6H_3OH_3$

derivative of benzene, prepared from gallic acid. It is used in gas analysis for the measurement of oxygen because its alkaline solution turns black as it rapidly absorbs oxygen. It is also used as a developer in photography.

pyrolysis

decomposition of a substance by heating it to a high temperature in the absence of air. The process is used to burn and dispose of old tyres, for example, without contaminating the atmosphere.

pyrometer

any instrument used for measuring high temperatures by means of the thermal radiation emitted by a hot object. In a **radiation pyrometer** the emitted radiation is detected by a sensor such as a thermocouple. In an **optical pyrometer** the colour of an electrically heated filament is matched visually to that of the emitted radiation. Pyrometers are especially useful for measuring the temperature of distant, moving, or inaccessible objects.

pyroxene

any one of a group of minerals, silicates of calcium, iron, and magnesium with a general formula X,YSi_2O_6, found in igneous and metamorphic rocks. The internal structure is based on single chains of silicon and oxygen. Diopside (X = Ca, Y = Mg) and augite (X = Ca, Y = Mg,Fe,Al) are common pyroxenes.

Jadeite ($NaAlSi_2O_6$), which is considered the more valuable form of jade, is also a pyroxene.

Pythagoras (c. 580-500 BC)

Greek mathematician and philosopher who formulated the Pythagorean theorem.

Much of his work concerned numbers, to which he assigned mystical properties. For example, he classified numbers into triangular ones (1, 3, 6, 10, ...), which can be represented as a triangular array, and square ones (1, 4, 9, 16, ...), which form squares. He also observed that any two adjacent triangular numbers added together form a square number (for example, 1 + 3 = 4; 3 + 6 = 9; 6 + 10 = 16).

Pythagorean theorem

in geometry, a theorem stating that in a right triangle, the square of the hypotenuse (the longest side) is equal to the sum of the squares of the other two sides (legs). If the hypotenuse is c units long and the lengths of the legs are a and b, then $c^2 = a^2 + b^2$.

The theorem provides a way of calculating the length of any side of a right triangle if the lengths of the other to sides are known. It is also used to determine certain trigonometrical relationships such as $\sin^2 \theta + \cos^2 \theta = 1$.

python

any constricting snake of the Old World subfamily Pythoninae of the family Boidae, which also includes boas and the anaconda. Pythons are found in the tropics of Africa, Asia, and Australia. Unlike boas, they lay eggs rather than produce living young. Some species are small, but the reticulated python *Python reticulatus* of Southeast Asia can grow to 10 m/33 ft.

A healthy adult can survive from six to twelve months without food. When food is scarce females do not ovulate so energy is not used up in reproducing.

Carpet Python

Go to site

Illustrated guide to the carpet python including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

qat

or kat or khat

evergreen shrub with white flowers belonging to the staff-tree family, native to Africa and Asia. The leaves are chewed as a mild narcotic drug in some Arab countries. Its use was banned in Somalia 1983. (Genus *Catha edulis*, family Celastraceae.)

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quadratic equation

in mathematics, a polynomial equation of second degree (that is, an equation containing as its highest power the square of a variable, such as x^2). The general formula of such equations is

$$ax^2 + bx + c = 0$$

in which a, b, and c are real numbers, and only the coefficient$a$ cannot equal 0.

In coordinate geometry, a quadratic function represents a parabola.

Some quadratic equations can be solved by factorization (see factor (algebra)), or the values of x can be found by using the formula for the general solution

$$x = [-b + \surd(b^2 - 4ac)]/2a \text{ or}$$

$$x = [-b - \surd(b^2 - 4ac)]/2a$$

Depending on the value of the discriminant, $b^2 - 4ac$, a quadratic equation has two real, two equal, or two complex roots (solutions). When $b^2 - 4ac > 0$, there are two distinct real roots. When $b^2 - 4ac = 0$, there are two equal real roots. When $b^2 - 4ac < 0$, there are two distinct complex roots.

Quadratic, Cubic, and Quartic Equations

Go to site

History and usage of quadratic equations in mathematics. The site chronicles the discovery and development of this area of mathematics, and also provides biographical background information on those mathematicians responsible.

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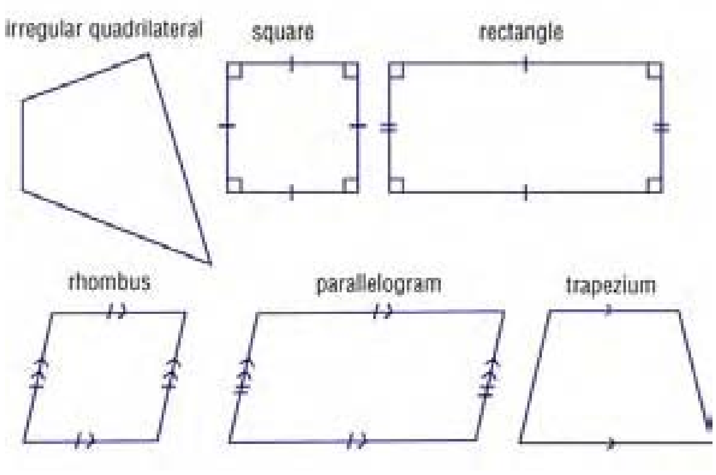
quadrilateral

plane (two-dimensional) figure with four straight sides. The sum of all interior angles is 360°. The following are all quadrilaterals, each with distinguishing properties: **square** with four equal angles and sides, and four axes of symmetry; **rectangle** with four equal angles, opposite sides equal, and two axes of symmetry; **rhombus** with four equal sides, and two axes of symmetry; **parallelogram** with two pairs of parallel sides, and rotational symmetry; **kite** with two pairs of adjacent equal sides, and one axis of symmetry; and **trapezium** with one pair of parallel sides.

quadrilateral



(Image © Research Machines plc)

Different types of quadrilateral.

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quagga

South African zebra that became extinct in the 1880s. It was brown, with a white tail and legs, and unlike surviving zebra species, had stripes only on its head, neck, and forequarters.

In the early 1980s DNA extracted from the skin of a stuffed quagga was found to be identical to that of the common zebra *Equus burchelli*, proving that the quagga was not a separate species but a subspecies of zebra. In 1987 the Quagga Project Committee was formed to attempt to recreate a quagga through selective breeding of *E. burchelli*. By 1998 the project consisted of 53 zebras with significant reduction in stripy markings on the body.

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quail

any of several genera of small ground-dwelling birds of the family Phasianidae, which also includes grouse, pheasants, bobwhites, and prairie chickens. Species are found in Africa, India, Australia, North America, and Europe.

species

The **common** or **European quail** *Coturnix coturnix* is about 18 cm/7 in long, reddish-brown, with a white throat with a black patch at the bottom, and a yellowish belly. It is found in Europe, Asia, and Africa, and has been introduced to North America. The nest is a small hollow in the ground, and in it are laid about ten yellowish-white eggs blotched with brown. The bird feeds upon grain seeds and insects.

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qualitative analysis

in chemistry, a procedure for determining the identity of the component(s) of a single substance or mixture. A series of simple reactions and tests can be carried out on a compound to determine the elements present.

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quantitative analysis

in chemistry, a procedure for determining the precise amount of a known component present in a single substance or mixture. A known amount of the substance is subjected to particular procedures.

Gravimetric analysis determines the mass of each constituent present; **volumetric analysis** determines the concentration of a solution by titration against a solution of known concentration.

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quantum chromodynamics

QCD

in physics, a theory describing the interactions of quarks, the elementary particles that make up all hadrons (subatomic particles such as protons and neutrons). In quantum chromodynamics, quarks are considered to interact by exchanging particles called gluons, which carry the strong nuclear force, and whose role is to 'glue' quarks together.

The mathematics involved in the theory is complex, and, although a number of successful predictions have been made, the theory does not compare in accuracy with quantum electrodynamics, upon which it is modelled. See forces, fundamental.

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quantum electrodynamics

QED

in physics, a theory describing the interaction of charged subatomic particles within electric and magnetic fields. It combines quantum theory and relativity, and considers charged particles to interact by the exchange of photons. QED is remarkable for the accuracy of its predictions; for example, it has been used to calculate the value of some physical quantities to an accuracy of ten decimal places, a feat equivalent to calculating the distance between New York and Los Angeles to within the thickness of a hair. The theory was developed by US physicists Richard Feynman and Julian Schwinger and by Japanese physicist Sin-Itiro Tomonaga in 1948.

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quantum mechanics

branch of physics dealing with the interaction of matter and radiation, the structure of the atom, the motion of atomic particles, and with related phenomena (see quantum theory).

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quantum number

in physics, one of a set of four numbers that uniquely characterize an electron and its state in an atom. The **principal quantum number** *n* defines the electron's main energy level. The **orbital quantum number**

l relates to its angular momentum. The **magnetic quantum number** m describes the energies of electrons in a magnetic field. The **spin quantum number** m_s gives the spin direction of the electron.

The principal quantum number, defining the electron's energy level, corresponds to shells (energy levels) also known by their spectroscopic designations K, L, M, and so on. The orbital quantum number gives rise to a series of subshells designated s, p, d, f, and so on, of slightly different energy levels. The magnetic quantum number allows further subdivision of the subshells (making three subdivisions p_x, p_y, and p_z in the p subshell, for example, of the same energy level). No two electrons in an atom can have the same set of quantum numbers (the Pauli exclusion principle).

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quantum theory

or quantum mechanics

in physics, the theory that energy does not have a continuous range of values, but is, instead, absorbed or radiated discontinuously, in multiples of definite, indivisible units called quanta. Just as earlier theory showed how light, generally seen as a wave motion, could also in some ways be seen as composed of discrete particles (photons), quantum theory shows how atomic particles such as electrons may also be seen as having wavelike properties. Quantum theory is the basis of particle physics, modern theoretical chemistry, and the solid-state physics that describes the behaviour of the silicon chips used in computers.

The theory began with the work of Max Planck in 1900 on radiated energy, and was extended by Albert Einstein to electromagnetic radiation generally, including light. Danish physicist Niels Bohr used it to explain the spectrum of light emitted by excited hydrogen atoms. Later work by Erwin Schrödinger, Werner Heisenberg, Paul Dirac, and others elaborated the theory to what is called quantum mechanics (or wave mechanics).

Quantum Theory: Testing Quantum Theory

exploring the quantum world

In the 1930s German physicist Albert Einstein and his colleagues Boris Podolsky and Nathan Rosen proposed an experiment which they thought would expose a flaw in quantum theory. The experiment was based on the behaviour of pairs of particles that were once close together but had become separated. Such pairs are formed when an atom gives out two particles of light, called photons. According to quantum theory, if we observe one photon of such a pair, the other photon instantly knows that we have made an observation and adjusts its behaviour in certain ways. This would happen even if we waited until the photons were billions of kilometres apart before making our observation. According to Albert Einstein's theory of relativity, no information can travel faster than the speed of light, so how can such widely separated particles react instantly after the observation? Quantum theory must be wrong, said Einstein.

Einstein was never comfortable with quantum theory. He could not accept the idea that in the subatomic world events happen almost by chance, and particles do not have exact positions. Instead there is a range of positions where the particle might be found and all we can do is calculate the probability of it being at any particular point. There is a similar uncertainty about other physical quantities, such as energy and momentum. Einstein felt that behind the uncertainty of quantum theory there must be an exact reality. Paradoxically, when his suggested experiment was eventually performed, it proved him wrong.

sunglasses for photons

It took a long time to convert Einstein's idea into a practicable experiment. However, in Paris in the early 1980s a series of experiments was carried out by a team of French scientists led by Alain Aspect, Jean Dalibard, and Gerard Roger. The apparatus used consisted of a source of light – calcium atoms – halfway along a long tube. Pairs of photons simultaneously emitted by the calcium atoms split so that each photon travelled towards opposite ends of the tube. At each end of the tube there were devices which would detect photons. Just before the detectors were further devices, called a light switch and polarizer, that could change a certain property – the polarization – of a photon within 0.000,000,01 second of the photon reaching it.

The light switches were ingenious devices. Each consisted of a small cell of water in which two vibrating piezoelectric crystals set up an ultrasonic wave. Depending upon the exact state of the ultrasonic vibration when a photon arrived, the photon either passed through the cell, or was deflected at right angles. The photons then passed through the polarizer, which worked just like sunglasses to change the polarization of the photon. There were two polarizers behind each light switch, set at different angles, so that the photons could be polarized in two different ways.

Why were such high-speed switches needed? Because the speed of the polarization change had to be faster than the time that it took a photon to travel to the end of the tube. This meant that, when the polarization was changed, there must be no possibility of a 'message' passing down the tube to the second photon (because by then the second photon would have reached the end of the tube and entered the detector). As the experiment proceeded, the light switch operated to continually change the polarization of the photons passing through it. The scientists measured the polarization of the photons arriving at each end of the tube. Photons which arrived simultaneously at the tube ends were obviously emitted simultaneously by the same calcium atom and therefore, according to quantum theory, should be linked in some mysterious way.

There were two possible results of this experiment. If quantum theory was correct, the polarization of photons arriving simultaneously at the detectors would always be the same. If quantum theory was incorrect, then the polarization of the photons would not always be the same.

faster than light?

The results went against Einstein. Aspect and his team found that if one of a pair of photons was polarized in a certain way, its twin at the other end of the apparatus would always be polarized in the same way. It is as if the photons know what is happening to each other, even though there can be no possible communication between them. So, there is a mysterious instantaneous faster-than-light 'action at a distance' between once-linked photons, and presumably between once-linked particles, too. Scientists and philosophers are still examining the implications of this result. According to the Big Bang theory, all particles now in existence originate from a common point at the birth of the universe. Does this mean that there is a hidden connection between all the particles in the universe? How does this web of connections manifest itself?

Recent Progress in Physics

atom lasers

Quantum mechanics predicts that particles can behave like waves. The wavelength of a particle gets shorter as the particle moves faster. For atoms this wavelength is usually much smaller than the size of the atom itself. However, if the atom is moving very slowly its wavelength can become quite large and the waves of nearby atoms begin to overlap. When this happens the atoms form a new state of matter known as a Bose-Einstein condensate. This new state of matter was created for the first time by American physicists in 1995. Bose-Einstein condensates have completely different properties from the other four states of matter: solid, liquid, gas and plasma.

To form a Bose-Einstein condensate it is necessary to trap a gas of atoms and then cool them to just a fraction of a degree above absolute zero. This is done using a combination of lasers and magnetic fields. By carefully releasing the atoms from the trap it is possible to make what is known as an atom laser. In an atom laser all the atoms travel in the same direction with the same speed – just like the photons (particles of light) in a conventional laser. American physicists used sodium atoms to make the first ever atom laser in 1996. Atom lasers could be used as a tool in other physics experiments, in atomic clocks or to print tiny circuits in electronics

quantum information technology

Recent years have seen exciting progress in a new field of physics called quantum information technology. Quantum information technology essentially involves three subjects: quantum computation, quantum cryptography and quantum communication.

In conventional computers, information is handled as a series of bits which can either be one or zero. Quantum computation is based on the ability of quantum particles to be in two or more places at the same time. This allows information to be handled as a series of 'qubits' which can be both one and zero at the same time. Therefore quantum computers can, in theory, work much faster than ordinary computers. So far physicists have built simple quantum logic gates and developed theoretical schemes to deal with the errors that can arise during computation.

Quantum cryptography allows two people, usually called Alice and Bob, to exchange information with complete security. Researchers in Switzerland and the UK have demonstrated that quantum cryptography can be made to work over distances greater than 10 km. In quantum communication Alice and Bob use the properties of quantum mechanics to communicate in ways that are not possible classically. Both quantum cryptography and quantum communication rely on a property of quantum mechanics called entanglement. Physicists in Austria and Italy have used entanglement to 'teleport' single photons in the laboratory.

Most work so far has concentrated on pairs of entangled photons. Entanglement means that certain properties of the photons are very closely related, even when the photons are very far apart. For example, if the polarization of the first photon is measured to be vertical, then the polarization of the second photon will instantly become horizontal. This happens even though the second photon could have had any value of polarization before the measurement on the first photon. Einstein called this 'spooky action at a distance'.

neutrino masses

Neutrinos are the most mysterious particles in the 'Standard Model of Particle Physics'. They have no charge and are thought to have no mass; and since neutrinos only experience one of the four fundamental forces, the weak force, they are difficult to detect.

One particular mystery concerns neutrinos from the Sun. The Sun produces energy by converting 600 tonnes of hydrogen into helium every second. According to theory this should result in 65 billion solar neutrinos bombarding every sq cm/0.15 sq in of the Earth's surface every second. To test this theory physicists have built massive experiments in underground mines. However none of these experiments has been able to detect any more than half the number of neutrinos predicted by theory.

One possible explanation for this shortage is that neutrinos do in fact have mass. This would allow the electron neutrinos produced in the centre of the Sun to oscillate into either muon or tau neutrinos on their journey to the surface. Existing experiments can only detect electron neutrinos although a Canadian experiment that can detect all three types is began in 1998.

To confirm that neutrinos do indeed oscillate, physicists are planning to send beams of muon neutrinos from high-energy accelerators to the various underground experiments. If electron neutrinos are detected in these beams it will provide conclusive evidence for oscillation and hence neutrino mass. One proposal for such an experiment would involve sending a beam from CERN in Switzerland to the Gran Sasso laboratory some 730 km/450 mi away in Italy. Similar experiments have been proposed in the USA and Japan.

Proof of neutrino mass would be a major breakthrough in particle physics. It might also help solve the 'dark matter' problem – the fact that less than 10% of the mass of the universe is visible – in astrophysics.

New Scientist: Guide to the Quantum World

Go to site

Highly readable articles from *New Scientist*. The stories cover many aspects of quantum science and attempt to answer some very interesting questions; many are feature articles from recent issues of the magazine.

Quantum Age Begins

Go to site

St Andrews University-run Web site chronicling the discovery of quantum theory. Biographical details of the mathematicians and physicists involved are also provided. The site also includes links to many other history of mathematics-related Web resources.

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quarantine

(from French quarantaine 'approximately 40 (days)')

any period for which people, animals, plants, or vessels may be detained in isolation to prevent the spread of contagious disease.

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quark

in physics, the elementary particle that is the fundamental constituent of all hadrons (subatomic particles that experience the strong nuclear force and divided into baryons, such as neutrons and protons, and mesons). Quarks have electric charges that are fractions of the electronic charge (+2/3 or -1/3 of the electronic charge). There are six types, or 'flavours': up, down, top, bottom, strange, and charmed, each of which has three varieties, or 'colours': red, green, and blue (visual colour is not meant, although the analogy is useful in many ways). To each quark there is an antiparticle, called an antiquark. See quantum chromodynamics (QCD).

Quark: The Top Quark at Last

top quark observed

Researchers at Fermilab, near Chicago, USA, announced in March 1995 that they had found the elusive top quark. The existence of the top quark is the final piece of evidence in support of the Standard Model, the theory that describes elementary particles and their behaviour. Two competing teams, working with different detectors attached to the Fermilab particle accelerator, both detected the top quark and measured its mass. One team observed 39 top quarks and estimated that its mass was 176 gigaelectronvolts (GeV), plus or minus 13 GeV. The other team observed 17 top quarks and estimated the mass as 199 GeV, plus or minus 30 GeV. The agreement was close enough for the researcher to be confident that they had found the particle. The mass of the top quark is astonishing – the pointlike particle is as heavy as a gold atom.

Hunting of the Quark

Go to site

Commentary on the research carried out at Arizona State University, USA, into sub-atomic particles. There is also a subsidiary page on the complexities of the subatomic world.

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quart

a unit of liquid or dry measure of volume or capacity. One liquid quart is equal to one-quarter of a gallon, or two pints, or 32 fluid ounces (0.946 litre), while a dry quart is equal to one-eighth of a peck, or two dry pints (1.101 litre).

The British and Canadian imperial quart equals two imperial pints or 1.136 litre.

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quartz

crystalline form of silica SiO_2, one of the most abundant minerals of the Earth's crust (12% by volume). Quartz occurs in many different kinds of rock, including sandstone and granite. It ranks 7 on the Mohs scale of hardness and is resistant to chemical or mechanical breakdown. Quartzes vary according to the size and purity of their crystals. Crystals of pure quartz are coarse, colourless, transparent, show no cleavage, and fracture unevenly; this form is usually called rock crystal. Impure coloured varieties, often used as gemstones, include agate, citrine quartz, and amethyst. Quartz is also used as a general name for the cryptocrystalline and noncrystalline varieties of silica, such as chalcedony, chert, and opal.

Quartz is used in ornamental work and industry, where its reaction to electricity makes it valuable in electronic instruments (see piezoelectric effect). Quartz can also be made synthetically.

Crystals that would take millions of years to form naturally can now be 'grown' in pressure vessels to a standard that allows them to be used in optical and scientific instruments and in electronics, such as quartz wristwatches.

quartzite

metamorphic rock consisting of pure quartz sandstone that has recrystallized under increasing heat and pressure.

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quasar

contraction of quasi-stellar object; or QSO

one of the most distant extragalactic objects known, discovered in 1963. Quasars appear starlike, but each emits more energy than 100 giant galaxies. They are thought to be at the centre of galaxies, their brilliance emanating from the stars and gas falling towards an immense black hole at their nucleus. The Hubble Space Telescope has revealed that quasars exist in a remarkable variety of galaxies.

Quasar light shows a large red shift, indicating that the quasars are very distant. The furthest are over 10 billion light years away. A few quasars emit radio waves (see radio astronomy), which is how they were first identified. They are more numerous at greater distances, when we see them as they were in the early universe (since their light has taken longer to reach us). This is strong evidence that the universe has changed in the last 15 billion years, rather than being in a steady state.

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quassia

any of a group of tropical American trees with bitter bark and wood. The heartwood of *Q. amara* is a source of quassiin, an infusion of which was formerly used as a tonic; it is now used in insecticides. (Genus *Quassia*, family Simaroubaceae.)

The quassia family includes the Asian ailanthus (*Ailanthus altissima*), also called the tree of heaven.

Quaternary Period

period of geological time from 1.64 million years ago through to the present. It is divided into the Pleistocene (1.64 million to 10,000 years ago) and Holocene (last 10,000 years) epochs.

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quebracho

any of several South American trees belonging to the cashew family, with very hard, tannin-rich wood; chiefly the red quebracho (*S. lorentzii*), used in the tanning of leather. (Genus *Schinopsis*, family Anacardiaceae.)

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quenching

heat treatment used to harden metals. The metals are heated to a certain temperature and then quickly plunged into cold water or oil.

Quetelet, (Lambert) Adolphe (Jacques) (1796-1874)

Belgian statistician. He developed tests for the validity of statistical information, and gathered and analysed statistical data of many kinds. From his work on sociological data came the concept of the 'average person'.

Quetelet, Lambert Adolphe Jacques

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of statistician Lambert Quetelet. In addition to biographical information, you will find a list of references about Quetelet and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Quetelet. There is also find an image of him, which can be enlarged, and a map of his birthplace.

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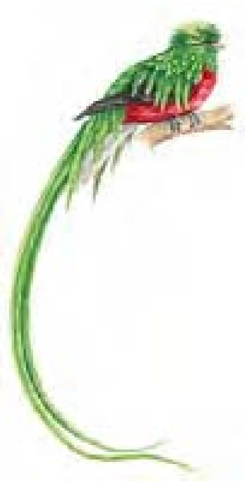
quetzal

long-tailed Central American bird *Pharomachus mocinno* of the trogon family, order Trogoniformes. The male is brightly coloured, with green, red, blue, and white feathers. It has a train of blue-green plumes (tail coverts) that hang far beyond the true tail feathers. There is a crest on the head and decorative drooping feathers on the wings. It is about 1.3 m/4.3 ft long including tail. The female is smaller and lacks the tail and plumage.

The quetzal eats fruit, insects, and small frogs and lizards. It is the national emblem of Guatemala, and was considered sacred by the Mayans and the Aztecs. The quetzal's forest habitat is rapidly being destroyed, and hunting of birds for trophies or souvenirs also threatens its survival.

quetzal



(Image © Research Machines plc)

The long-tailed quetzal of Mexico and Central America was associated by the ancient Maya and Aztecs with the plumed serpent god Quetzalcoatl. They used its magnificent tail feathers in religious ceremonies.

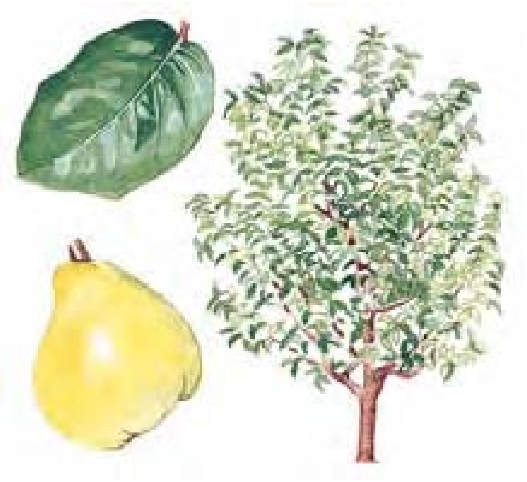
quicksilver

another name for the element mercury.

quince

small tree native to western Asia but widely cultivated elsewhere. The bitter, yellow, pear-shaped fruit is used in preserves. Flowering quinces are cultivated mainly for their attractive flowers. (*Cydonia oblonga*; flowering quince; genus *Chaenomeles*; family Rosaceae.)

quince



(Image © Research Machines plc)

The quince is related to the japonica and other plants of the rose family. The common species has been grown in Europe since Roman times. The golden fruits are too hard and acidic to be eaten raw but are used to make jam or jellies.

quinine

antimalarial drug extracted from the bark of the cinchona tree. Peruvian Indians taught French missionaries how to use the bark in 1630, but quinine was not isolated until 1820. It is a bitter alkaloid, with the formula $C_{20}H_{24}N_2O_2$.

Other antimalarial drugs have since been developed with fewer side effects, but quinine derivatives are still valuable in the treatment of unusually resistant strains.

rabbit

any of several genera of hopping mammals of the order Lagomorpha, which together with hares constitute the family Leporidae. Rabbits differ from hares in bearing naked, helpless young and in occupying burrows.

The Old World rabbit (*Oryctolagus cuniculus*), originally from southern Europe and North Africa, has now been introduced worldwide. It is bred for meat and for its fur, which is usually treated to resemble more expensive furs. It lives in interconnected burrows called 'warrens', unlike cottontails (genus *Sylvilagus*), of which 13 species are native to North and South America.

rabbit

Rabbits eat some of their droppings. This behaviour, called refection, is similar to chewing the cud in cows, and ensures that food is fully digested.

Paulson's Rabbit World

Go to site

Comprehensive guide to keeping these active and gregarious animals as pets. If you are contemplating getting a bunny, this is the site to visit. There is advice on providing accommodation (while giving the rabbit the run of the house), protecting rabbits from household dangers, toilet training, diet, and common rabbit ailments. There are useful links to the House Rabbit Society and other rabbit sites.

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rabies

or hydrophobia

(Greek 'fear of water')

viral disease of the central nervous system that can afflict all warm-blooded creatures. It is caused by a lyssavirus. It is almost invariably fatal once symptoms have developed. Its transmission to humans is generally by a bite from an infected animal. Rabies continues to kill hundreds of thousands of people every year; almost all these deaths occur in Asia, Africa, and South America.

After an incubation period, which may vary from ten days to more than a year, symptoms of fever, muscle spasm, and delirium develop. As the disease progresses, the mere sight of water is enough to provoke convulsions and paralysis. Death is usual within four or five days from the onset of symptoms. Injections of rabies vaccine and antiserum may save those bitten by a rabid animal from developing the disease. Louis Pasteur was the first to produce a preventive vaccine, and the Pasteur Institute was founded to treat the disease.

As a control measure for foxes and other wild animals, vaccination (by bait) is recommended. In France, Germany, and the border areas of Austria and the Czech Republic, foxes are now vaccinated against rabies with capsules distributed by helicopter; as a result, rabies has been virtually eradicated in Western Europe, and no-one has died of the disease in the European Union since 1973. In 1999 Switzerland became the first country to completely eradicate rabies by vaccinating foxes in this way.

Childhood Infections - Rabies

Go to site

Useful information about rabies. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

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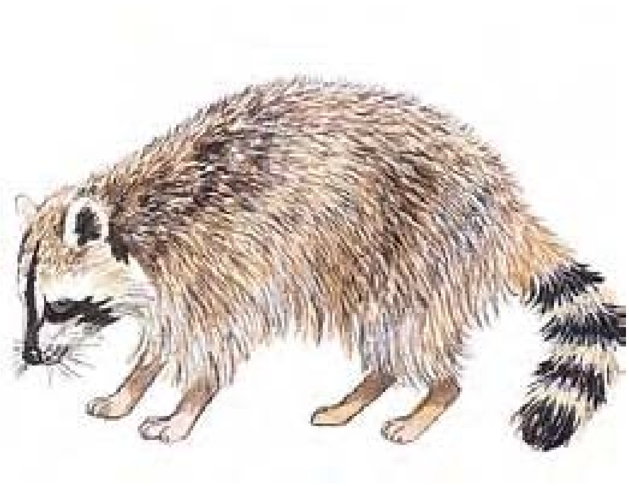
raccoon

any of several New World species of carnivorous mammals of the genus *Procyon*, in the family Procyonidae. The common raccoon *P. lotor* is about 60 cm/2 ft long, with a grey-brown body, a black-and-white ringed tail, and a black 'mask' around its eyes. The crab-eating raccoon *P. cancrivorus* of South America is slightly smaller and has shorter fur.

raccoon



(Image © Research Machines plc)

Raccoons are good climbers and spend much of their time in trees, usually near water. Their varied diet includes small aquatic animals such as frogs, crayfish, and fish. The common raccoon, found in North America from southern Canada to the Panama Canal, was adopted as a pet by the early settlers.

Raccoons

Go to site

Compiled with obvious enthusiasm, this site brings facts to life with images, sounds, and animations. It also includes a section on raccoons in the media, links to other sites of interest, and an interactive bulletin board for raccoon-related discussion.

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raceme

in botany, a type of inflorescence.

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rack railway

railway, used in mountainous regions, that uses a toothed pinion running in a toothed rack to provide traction. The rack usually runs between the rails. Ordinary wheels lose their grip even on quite shallow gradients, but rack railways, like that on Mount Pilatus in Switzerland, can climb slopes as steep as 50% (1 in 2).

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rad

unit of absorbed radiation dose, now replaced in the SI system by the gray (one rad equals 0.01 gray). It is defined as the dose when one kilogram of matter absorbs 0.01 joule of radiation energy.

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radar

acronym for radio direction and ranging

device for locating objects in space, direction finding, and navigation by means of transmitted and reflected high-frequency radio waves.

The direction of an object is ascertained by transmitting a beam of short-wavelength (1-100 cm/0.5-40 in), short-pulse radio waves, and picking up the reflected beam. Distance is determined by timing the journey of the radio waves (travelling at the speed of light) to the object and back again. Radar is also used to detect objects underground, for example service pipes, and in archaeology. Contours of remains of ancient buildings can be detected down to 20 m/66 ft below ground. Radar is essential to navigation in darkness, cloud, and fog, and is widely used in warfare to detect enemy aircraft and missiles. To avoid detection, various devices, such as modified shapes (to reduce their radar cross-section), radar-absorbent paints, and electronic jamming are used. To pinpoint small targets laser'radar', using light instead of radio waves, has been developed. Radar was developed independently in Britain, France, Germany, and the USA in the 1930s. It was first put to practical use for aircraft detection by the British, who had a complete coastal chain of radar stations installed by September 1938. It proved invaluable in the Battle of Britain in 1940, when the ability to spot incoming German aircraft did away with the need to fly standing patrols. Chains of ground radar stations are used to warn of enemy attack - for example, North Warning System 1985, consisting of 52 stations across the Canadian Arctic and northern Alaska. Radar is also used in meteorology and astronomy.

History of Radar

Go to site

A brief history of the development of radar, which gives credit to British researchers for their role in the winning of the Battle of Britain.

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radar astronomy

bouncing of radio waves off objects in the Solar System, with reception and analysis of the 'echoes'. Radar contact with the Moon was first made in 1945 and with Venus in 1961. The travel time for radio reflections allows the distances of objects to be determined accurately. Analysis of the reflected beam reveals the rotation period and allows the object's surface to be mapped topographically. The rotation periods of Venus and Mercury were first determined by radar. Radar maps of Venus were obtained first by Earth-based radar and subsequently by orbiting space probes.

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radial artery

artery that passes down the forearm and supplies blood to the hand and the fingers. The brachial artery, a large artery supplying blood to the arm, divides at the elbow to form the radial and ulnar arteries. The pulsation of blood through the radial artery can be felt at the wrist. This is generally known as the pulse.

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radial nerve

in biology, the nerve in the upper arm. Nervous impulses to regulate the function of the muscles which extend the arm, the wrist, and some fingers pass along these nerves. They also relay sensation to parts of the arm and hand. The radial nerve arises from the brachial plexus (network of nerves supplying the arm) in the armpit and descends the upper arm before dividing into the superficial radial and interosseous nerves.

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radial velocity

in astronomy, velocity of an object, such as a star or galaxy, along the line of sight, moving towards or away from an observer. The amount of Doppler shift (apparent change in wavelength) of the light reveals the object's velocity. If the object is approaching, the Doppler effect causes a blue shift in its light. That is, the wavelengths of light coming from the object appear to be shorter, tending toward the blue end of the spectrum. If the object is receding, there is a red shift, meaning the wavelengths appear to be longer, toward the red end of the spectrum.

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radian

symbol rad

SI unit of plane angles, an alternative unit to the degree. It is the angle at the centre of a circle when the centre is joined to the two ends of an arc (part of the circumference) equal in length to the radius of the circle. There are 2π (approximately 6.284) radians in a full circle (360°).

One radian is approximately 57°, and 1° is π/180 or approximately 0.0175 radians. Radians are commonly used to specify angles in polar coordinates.

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radiant heat

energy that is radiated by all warm or hot bodies. It belongs to the infrared part of the electromagnetic spectrum and causes heating when absorbed. Radiant heat is invisible and should not be confused with the red glow associated with very hot objects, which belongs to the visible part of the spectrum. The radiation that we feel as heat coming from a fire or hot object is infrared radiation.

Infrared radiation can travel through a vacuum and it is in this form that the radiant heat of the Sun travels through space. When this energy is re-emitted by the Earth, it is trapped by carbon dioxide and water vapour in the atmosphere, giving rise to the greenhouse effect.

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radiation

emission of radiant energy as particles or waves – for example, heat, light, alpha particles, and beta particles (see electromagnetic waves and radioactivity). See also atomic radiation.

All hot objects radiate heat. Radiated heat does not need a medium through which to travel (it can travel in a vacuum).

Most of the energy received on Earth arrives by radiation of heat energy from the Sun. Of the radiation given off by the Sun, only a tiny fraction of it, called insolation, reaches the Earth's surface; much of it (for example, radio waves, ultraviolet rays, and X-rays) is absorbed and scattered as it passes through the atmosphere. Visible light and infrared rays pass through the atmosphere, the infrared rays causing a rise in temperature. The radiation given off by the Earth itself is called **ground radiation**.

How much a surface radiates heat depends on its temperature and the type of surface. Dull black surfaces absorb more heat and therefore radiate more heat that polished shiny surfaces, which reflect heat and are therefore poor radiators of heat. For example, engine-cooling mantles in cars are black so that they radiate heat from the engine. A vacuum flask has a polished, silvery surface so as to keep hot liquids hot and cold liquids cold as no heat is radiated or absorbed.

The human body radiates heat at a rate of 100 joules every second. This is the same energy as radiated by a 100-watt light bulb.

Radiation Reassessed

Go to site

Part of the Why Files project published by the National Institute for Science Education (NISE) and funded by the National Science Foundation, this page provides insight into the controversy concerning the health effects of ionizing radiation. The highly readable text, laid out over 12 pages, includes information about what radiation studies from Hiroshima, Nagasaki, and Chernobyl have taught us, and what scientists are saying about exposure to small amounts of radiation. Is it always harmful? Numerous images and diagrams enhance the text throughout. The more tricky terms are linked to a glossary, and there is a comprehensive bibliography of sources for further research.

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radiation biology

study of how living things are affected by radioactive (ionizing) emissions (see radioactivity) and by electromagnetic (nonionizing) radiation (electromagnetic waves). Both are potentially harmful and can cause mutations as well as leukaemia and other cancers; even low levels of radioactivity are very dangerous. Both, however, are used therapeutically, for example to treat cancer, when the radiation dose is very carefully controlled (radiotherapy or X-ray therapy).

Radioactive emissions are more harmful. Exposure to high levels produces radiation burns and radiation sickness, plus genetic damage (resulting in birth defects) and cancers in the longer term. Exposure to low-level ionizing radiation can also cause genetic damage and cancers, particularly leukaemia.

Electromagnetic radiation is usually harmful only if exposure is to high-energy emissions, for example close to powerful radio transmitters or near radar-wave sources. Such exposure can cause organ damage, cataracts, loss of hearing, leukaemia and other cancers, or premature ageing. It may also affect the nervous system and brain, distorting their electrical nerve signals and leading to depression, disorientiation, headaches, and other symptoms. Individual sensitivity varies and some people are affected by electrical equipment, such as televisions, computers, and refrigerators.

Background radiation is the natural radiation produced by cosmic rays and radioactive rocks such as granite, and this must be taken into account when calculating the effects of nuclear accidents or contamination from power stations.

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radiation sickness

sickness resulting from exposure to radiation, including X-rays, gamma rays, neutrons, and other nuclear radiation, as from weapons and fallout. Such radiation ionizes atoms in the body and causes nausea, vomiting, diarrhoea, and other symptoms. The body cells themselves may be damaged even by very small doses, causing leukaemia and other cancers.

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radiation units

units of measurement for radioactivity and radiation doses. In SI units, the activity of a radioactive source is measured in becquerels (symbol Bq), where one becquerel is equal to one nuclear disintegration per second (an older unit is the curie). The exposure is measured in coulombs per kilogram (C kg^{-1}); the amount of ionizing radiation (X-rays or gamma rays) that produces one coulomb of charge in one kilogram of dry air (replacing the roentgen). The absorbed dose of ionizing radiation is measured in grays (symbol Gy) where one gray is equal to one joule of energy being imparted to one kilogram of matter (the rad is the previously used unit). The dose equivalent, which is a measure of the effects of radiation on living organisms, is the absorbed dose multiplied by a suitable factor that depends upon the type of radiation. It is measured in sieverts (symbol Sv), where one sievert is a dose equivalent of one joule per kilogram (an older unit is the rem).

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radical

in chemistry, an atom or group of atoms carrying an unpaired electron, which is therefore highly reactive and often impossible to purify or keep for any length of time.

A radical can either recombine with another radical (creating an electron pair and thus a stable compound) or attack a stable molecule and thereby create a new radical and start a chain reaction. However, organic chemists can create reasonably stable radicals by surrounding the atom carrying the unpaired electron with bulky molecular groups that block or slow down its reaction.

Ozone is a radical, as are some of the chlorine compounds that are liberated from organic pollutants and start the chain reactions that ultimately damage the ozone shield.

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radicle

part of a plant embryo that develops into the primary root. Usually it emerges from the seed before the embryonic shoot, or plumule, its tip protected by a root cap, or calyptra, as it pushes through the soil. The radicle may form the basis of the entire root system, or it may be replaced by adventitious roots (positioned on the stem).

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radio

transmission and reception of radio waves. In radio transmission a microphone converts sound waves (pressure variations in the air) into a varying electric current, which is amplified and used to modulate a carrier wave which is transmitted as electromagnetic waves, which are then picked up by a receiving aerial, amplified, and fed to a loudspeaker, which converts them back into sound waves.

The theory of electromagnetic waves was first developed by Scottish physicist James Clerk Maxwell in 1864, given practical confirmation in the laboratory in 1888 by German physicist Heinrich Hertz, and put to practical use by Italian inventor Guglielmo Marconi, who in 1901 achieved reception of a signal in Newfoundland, Canada, transmitted from Cornwall, England.

To carry the transmitted electrical signal, an oscillator produces a carrier wave of high frequency; different stations are allocated different transmitting carrier frequencies. A modulator superimposes the audio-frequency signal on the carrier. There are two main ways of doing this: **amplitude modulation** (AM), used for long- and medium-wave broadcasts, in which the strength of the carrier is made to fluctuate in time with the audio signal; and **frequency modulation** (FM), as used for VHF broadcasts, in which the frequency of the carrier is made to fluctuate. The transmitting aerial emits the modulated electromagnetic waves, which travel outwards from it.

How Digital Radio Works

analogue signal

Conventional radio is broadcast as an analogue signal, using either amplitude modulation (AM) or frequency modulation (FM). The sound suffers interference from other stations and 'multipath' reflections from hills and buildings. If the signal is weak and the receiver is straining to pick it up, the sound is polluted with background hiss. If analogue sound is converted into digital code before transmission, as long as the signal is strong enough to decode, it is immune from interference and free from hiss. Less transmitter power is needed to cover the same area as an analogue signal. However, if reflections are as strong as the code, the receiver does not work at all. Also, when analogue sound is converted into digits, the raw code takes up more space on the airwaves than the analogue signal. There is more space in the satellite bands, and some broadcasters and music delivery services have transmitted CD-quality digital sound from space. But the satellite bands are now crowding. Also, the signals can only be received with a dish or plate aerial, mounted in a fixed position.

DAB

Digital Audio Broadcasting (DAB) lets a receiver work with a simple rod aerial, even when moving. It also reduces the number of digital bits needed so that the signal takes up less space than an analogue transmission. Although DAB signals can be transmitted from satellites, they will initially come from conventional terrestrial transmitters. Pan-European Eureka research team number 147 developed a DAB system, and this has been adopted as the standard for Europe. The only difference between countries is in the transmission frequencies to be used; high VHF in some and L band at 1,500 MHz in others.

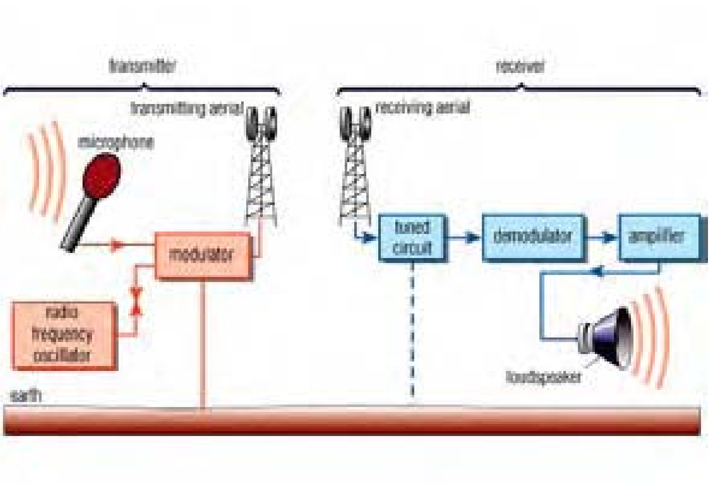
the Eureka system

The Eureka system combines two processes. Analogue sound is first converted into digital code and compressed by a system known as 'Musicam'. When there are two sounds of similar frequency, but different volume level, the 'Musicam' encoder ignores the quieter sound. This can reduce the number of bits by a factor of ten, without the ear noticing. The bitstream is then split into several hundred parallel channels, so that each carries only slow-moving bits of data. The many channels are broadcast simultaneously on closely neighbouring frequencies. The receiver recombines the channels and rebuilds the sound. Because the bits in each channel are travelling slowly and are quite widely spaced, the receiver can distinguish between wanted signals which arrive direct from the transmitter, and unwanted 'multipath' reflections which arrive later. The introduction of DAB does not take anything away from existing listeners, but a new radio is needed to listen to new digital broadcasts. These radios will often tune to all possible DAB bands, so that owners can use them anywhere in Europe.

IBOC technology

The Eureka system is on offer to other countries; Canada is using it and China is testing. The situation in the USA is still fluid, because rival systems use 'in-band, on-channel' (IBOC) technology. IBOC transmits digital code at very low level, underneath a conventional analogue radio broadcast. So conventional AM and FM radio analogue receivers should continue working as normal, while a new digital radio retrieves the low-level signal and decodes it to deliver high-quality sound. So new frequencies are not needed for IBOC, but critics say it may be susceptible to 'multipath' reflections and interference. There may be no single agreed standard for the USA, with open market competition left to create a *de facto* standard – like VHS versus Beta home video. Britain's BBC started regular Eureka DAB transmissions in September 1995, and the commercial stations soon followed, along with most other countries in Europe. At first the only receivers were bulky engineering test prototypes. Compact radios are now starting to appear, with prices falling to consumer levels.

radio



(Image © Research Machines plc)

Radio transmission and reception. The radio frequency oscillator generates rapidly varying electrical signals, which are sent to the transmitting aerial. In the aerial, the signals produce radio waves (the carrier wave), which spread out at the speed of light. The sound signal is added to the carrier wave by the modulator. When the radio waves fall on the receiving aerial, they induce an electrical current in the aerial. The electrical current is sent to the tuning circuit, which picks out the signal from the particular transmitting station desired. The demodulator separates the sound signal from the carrier wave and sends it, after amplification, to the loudspeaker.

Sony Radio Awards

These UK awards are given in recognition of excellence in radio broadcasting. They are presented in May for the previous year.

2005	
Award	**Winner**
Event Award	*The Drive Show: D-Day Anniversary* (BBC Radio Kent)
News Output Award	*The Beslan Siege* (BBC World Service)
News Programme Award	*Vote Friction* (BBC Radio 1)
Community Award	*The Stephen Nolan Show* (BBC Radio Ulster)
Feature Award	*Missing The Message* (BBC Radio 1)
'Music Special' Award	*Teenage Dreams So Hard To Beat* (BBC Radio 1)
Specialist Music Award	*Zane Lowe* (BBC Radio 1)
Entertainment Award	*Christian O'Connell's Breakfast Show* (Xfm)
Comedy Award	*The National Theatre Of Brent's Complete And Utter History Of The Mona Lisa* (BBC Radio 4)
Speech Award	*Beyond Belief - Islam and Women* (BBC Radio 4)
Sports Award	*City Till I Die* (BBC Radio York)
Drama Award	*Laughter In The Dark* (BBC Radio 3)
Station of the Year (audience up to 300,000)	BBC Radio Foyle
Station of the Year (audience 300,000 to 1 million)	BBC Three Counties Radio
Station of the Year (audience over 1 million)	Radio City 96.7
Station of the Year (UK audience)	BBC Radio 2
Station Sound Award	Kiss 100
Breakfast Music Award	*Christian O'Connell's Breakfast Show* (Xfm)
Speech Broadcaster Award	Jeremy Vine (BBC Radio 2)
Interactive Award	*Three Counties Breakfast* (BBC Three Counties Radio)
Short Form Award	*Blind Man's Beauty* (BBC Radio 4)
Competition Award	*Christian O'Connell's Rock School* (Xfm)
Music Broadcaster Award	Zane Lowe (BBC Radio 1)
News Broadcaster Award	Eddie Mair (BBC Radio 4)
News Story Award	*The Tsunami* (BBC Radio Five Live)
Information Award	Unhappy Hour (Viking FM)
Station Programmer of the Year	Richard Maddock (Radio City 96.7)
2004 Award	UK Radio Aid
Digital Terrestrial Station of the Year	Capital Disney
Gold Award	Steve Wright

Radio Days

Go to site

Part of a larger site that pays homage to the glory days of radio, this page features a number of audio clips from some of the most celebrated comedies, mysteries, private eye, and sci-fi radio programmes of the era. The programmes are arranged by genre, and each programme includes, in addition to the audio clips, a brief textual introduction and photograph.

Xtal Set Society

Go to site

All about crystal set radios. This site includes instructions on how to build a basic AM broadcast crystal set in a cereal box, plus information on how to join The Xtal Set Society.

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radioactive decay

process of disintegration undergone by the nuclei of radioactive elements, such as radium and various isotopes of uranium and the transuranic elements, in order to produce a more stable nucleus. The three most common forms of radioactive decay are alpha, beta, and gamma decay.

In **alpha decay** (the loss of a helium nucleus – two protons and two neutrons) the atomic number decreases by two and a new nucleus is formed, for example, an atom of uranium isotope of mass 238, on emitting an alpha particle, becomes an atom of thorium, mass 234. In **beta decay** the loss of an electron from an atom is accomplished by the transformation of a neutron into a proton, thus resulting in an increase in the atomic number of one. For example, the decay of the carbon-14 isotope results in the formation of an atom of nitrogen (mass 14, atomic number 7) and the emission of a high-energy electron. Gamma emission usually occurs as part of alpha or beta emission. In gamma emission high-speed electromagnetic radiation is emitted from the nucleus, making it more stable during the loss of an alpha or beta particle. Certain lighter, artificially-created isotopes also undergo radioactive decay. The associated radiation consists of alpha rays, beta rays, or gamma rays (or a combination of these), and it takes place at a constant rate expressed as a specific half-life, which is the time taken for half of any mass of that particular isotope to decay completely. Less commonly-occurring decay forms include heavy-ion emission, electron capture, and spontaneous fission (in each of these the atomic number decreases). The original nuclide is known as the parent substance, and the product is a daughter nuclide (which may or may not be radioactive). The final product in all modes of decay is a stable element.

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radioactive tracer

any of various radioactive isotopes added to fluids in order to monitor their flow and therefore identify leaks or blockages. See tracer.

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radioactive waste

any waste that emits radiation in excess of the background level. See nuclear waste.

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radioactivity

spontaneous change of the nuclei of atoms, accompanied by the emission of radiation. Such atoms are called radioactive. It is the property exhibited by the radioactive isotopes of stable elements and all isotopes of radioactive elements, and can be either natural or induced. See radioactive decay.

A radioactive material decays by releasing radiation, and transforms into a new substance. The energy is released in the form of alpha particles and beta particles or in the form of high-energy electromagnetic waves known as gamma radiation. Natural radioactive elements are those with an atomic number of 83 and higher. Artificial radioactive elements can also be formed.

Devices such as the Geiger-Muller tube, a photographic plate, or an electroscope can detect radioactivity. An electronic counter on the Geiger-Muller instrument displays a digital reading of the amount of radiation detected.

Cosmic Microwave Background Radiation

Go to site

Mainly text-based page that explains the occurrence of background radiation and provides reasons why the study of it is important. Other links lead to relevant topics, such as the expansion rate and age of the universe.

Decay: Radioactivity

Go to site

Beginning with the history of radioactivity, this page details the development of knowledge about radioactivity, and its impact on the understanding of physics. Further topics relating to decay are available from a menu.

Nuclear Physics Past Present and Future

Go to site

The site is divided into lessons covering nuclear technology, uses of nuclear energy, general applications and weapons and warfare. A very thorough site with difficult terms explained and colourful illustrations.

Particle Adventure

Go to site

Comprehensive site about particles. It covers many topics including what the world is made of, what holds it together, and decay and annihilations. The subject matter is difficult in places, but the introductions to each topic may be of use to GCSE pupils, and the site is of interest to all those who wish to stretch themselves.

Radiation and Radioactivity

Go to site

Lesson on radioactivity. It begins with a definition of radioactivity, and then covers the atom and types of radiation including alpha, beta, and gamma radiation and X-rays, plus the properties of each. A well-presented lesson with clear, helpful diagrams.

Radioactivity in Nature

Go to site

Detailed explanation of the different types of radiation found naturally on Earth and in its atmosphere, as well as those produced by humans. It includes tables of the breakdown of nuclides commonly found in soil, the oceans, the air, and even the human body.

Uses of Radiation

Go to site

Short introduction explaining how radiation can be dangerous. Two links are provided detailing medical and non-medical uses of radiation.

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radio astronomy

study of radio waves emitted naturally by objects in space, by means of a radio telescope. Radio emission comes from hot gases (**thermal radiation**); electrons spiralling in magnetic fields (**synchrotron radiation**); and specific wavelengths (**lines**) emitted by atoms and molecules in space, such as the 21-cm/8.3-in line emitted by hydrogen gas.

Radio astronomy began in 1932 when US astronomer Karl Jansky detected radio waves from the centre of our Galaxy, but the subject did not develop until after World War II. Radio astronomy has greatly improved our understanding of the evolution of stars, the structure of galaxies, and the origin of the universe. Astronomers have mapped the spiral structure of the Milky Way from the radio waves given out by interstellar gas, and they have detected many individual radio sources within our Galaxy and beyond.

Among radio sources in our Galaxy are the remains of supernova explosions, such as the Crab nebula and pulsars. Short-wavelength radio waves have been detected from complex molecules in dense clouds of gas where stars are forming. Searches have been undertaken for signals from other civilizations in the Galaxy, so far without success.

Strong sources of radio waves beyond our Galaxy include radio galaxies and quasars. Their existence far off in the universe demonstrates how the universe has evolved with time. Radio astronomers have also detected weak cosmic background radiation, thought to be from the Big Bang explosion that marked the birth of the universe.

Radio Astronomy: The Search for Extraterrestrials

the search for ET

In Steven Spielberg's film *ET*, an extraterrestrial landed on Earth and then tried to phone home. Perhaps he should have phoned Earth before setting out; radio communication is easier than interstellar travel. That is the thinking behind NASA's search for extraterrestrial intelligence, which started on 12 Oct 1992, the 500th anniversary of Columbus' arrival in America.

NASA's radio survey

NASA's survey uses two approaches. In an all-sky survey, radio telescopes will listen in all directions for signals at frequencies with least background noise, between 1,000 and 10,000 megahertz. The survey began with the 34 m/111 ft radio dish of NASA's Goldstone tracking station in California; the southern sky will be covered later by a similar dish at Canberra, Australia.

A targeted search will listen to a thousand stars like the Sun within 100 light-years' distance, using large radio telescopes worldwide. First observations were made with the world's largest radio dish, the 305 m/1,000 ft radio telescope at Arecibo, Puerto Rico.

The targeted search can pick up fainter signals, but might miss a transmission from some unexpected source, which the all-sky survey would pick up. The all-sky survey is less sensitive and might miss faint signals from a nearby star which the targeted search would hear. Sophisticated electronics have been developed to recognize a genuine alien message while filtering out terrestrial interference.

is there anybody there?

No previous attempt to pick up alien radio messages has been as comprehensive. 'In the first few minutes, more searching will be accomplished than in all previous searches combined,' said John Billingham at NASA's Ames Research Center in California.

If a seemingly artificial signal is detected, the searchers will notify other radio observatories worldwide to check the discovery. If it is genuine rather than a false alarm, the world will be told. No attempt will be made to answer except by international agreement.

If the search succeeds, says Carl Sagan, 'we will have transformed our civilization and our concept of ourselves forever'; if nothing is heard, that will reveal 'something about the rarity and preciousness of life on our planet'. The survey will probably continue for ten years at a total cost of around $100 million. By early next century, we may know whether or not we are alone.

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radio beacon

radio transmitter in a fixed location, used in marine and aerial navigation. Ships and aircraft pinpoint their positions by reference to continuous signals given out by two or more beacons. They have largely been superseded by more advanced technologies such as Loran and GPS.

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radiocarbon dating

or carbon dating

method of dating organic materials (for example, bone or wood), used in archaeology. Plants take up carbon dioxide gas from the atmosphere and incorporate it into their tissues, and some of that carbon dioxide contains the radioactive isotope carbon-14. As this decays at a known rate (half of it decays every 5,730 years), the time elapsed since the plant died can be measured in a laboratory. Animals take carbon-14 into their bodies from eating plant tissues and their remains can be similarly dated. After 120,000 years so little carbon-14 is left that no measure is possible (see half-life).

Radiocarbon dating was first developed in 1949 by the US chemist Willard Libby. The method yields reliable ages back to about 50,000 years, but its results require correction since Libby's assumption that the concentration of carbon-14 in the atmosphere was constant through time has subsequently been proved wrong. Discrepancies were noted between carbon-14 dates for Egyptian tomb artefacts and construction dates recorded in early local texts. Radiocarbon dates from tree rings (see dendrochronology) showed that material before 1000 BC had been exposed to greater concentrations of carbon-14. Now radiocarbon dates are calibrated against calendar dates obtained from tree rings, or, for earlier periods, against uranium/thorium dates obtained from coral. The carbon-14 content is determined by counting beta particles with either a proportional gas or a liquid scintillation counter for a period of time. A new advance, accelerator mass spectrometry, requires only tiny samples and counts the atoms of carbon-14 directly, disregarding their decay.

Radiocarbon WEB-info

Go to site

Information about radiocarbon dating that includes the basis of the method, its applications, and submission of samples for testing, plus links to related sites.

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radio, cellular

portable telephone system; see mobile phone.

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radiochemistry

chemical study of radioactive isotopes and their compounds (whether produced from naturally radioactive or irradiated materials) and their use in the study of other chemical processes.

When such isotopes are used in labelled compounds, they enable the biochemical and physiological functioning of parts of the living body to be observed. They can help in the testing of new drugs, showing where the drug goes in the body and how long it stays there. They are also useful in diagnosis – for example cancer, fetal abnormalities, and heart disease.

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radio frequencies and wavelengths

see electromagnetic waves.

radio galaxy

galaxy that is a strong source of electromagnetic waves of radio wavelengths. All galaxies, including our own, emit some radio waves, but radio galaxies are up to a million times more powerful.

In many cases the strongest radio emission comes not from the visible galaxy but from two clouds, invisible through an optical telescope, that can extend for millions of light years either side of the galaxy. This double structure at radio wavelengths is also shown by some quasars, suggesting a close relationship between the two types of object. In both cases, the source of energy is thought to be a massive black hole at the centre. Some radio galaxies are thought to result from two galaxies in collision or recently merged.

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radiography

branch of science concerned with the use of radiation (particularly X-rays) to produce images on photographic film or fluorescent screens. X-rays penetrate matter according to its nature, density, and thickness. In doing so they can cast shadows on photographic film, producing a radiograph. Radiography is widely used in medicine for examining bones and tissues and in industry for examining solid materials; for example, to check welded seams in pipelines. The field has been transformed by the technique of computed tomography, in which X-ray images produced in numerous scans are combined by computer to form a false-colour image of the three-dimensional structure of internal organs.

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radioisotope

or radioactive isotope

naturally occurring or synthetic radioactive form of an element. Most radioisotopes are made by bombarding a stable element with neutrons in the core of a nuclear reactor (see fission). The radiations given off by radioisotopes are easy to detect (hence their use as tracers), can in some instances penetrate substantial thicknesses of materials, and have profound effects (such as genetic mutation) on living matter.

Most natural isotopes of relative atomic mass below 208 are not radioactive. Those from 210 and up are all radioactive.

uses

Radioisotopes have many uses in medicine, for example in radiotherapy and radioisotope scanning. The use of radioactive isotopes in the diagnosis, investigation, and treatment of disease is called **nuclear medicine**.

radioisotope decay

The nucleus of a radioisotope is unstable and undergoes changes by breaking down into a more stable form. A radioisotope decays over a period of time into a new element. As it decays it emits radiation energy in the form of alpha and beta particles and gamma radiation. The time taken for half of the original atoms to decay is known as the half-life. The product of the radioactive decay is called a 'daughter' atom.

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radioisotope scanning

use of radioactive materials (radioisotopes or radionucleides) to pinpoint disease. It reveals the size and shape of the target organ and whether any part of it is failing to take up radioactive material, usually an indication of disease.

The speciality known as nuclear medicine makes use of the affinity of different chemical elements for certain parts of the body. Iodine, for instance, always makes its way to the thyroid gland. After being made radioactive, these materials can be given by mouth or injected, and then traced on scanners working on the Geiger-counter principle. The diagnostic record gained from radioisotope scanning is known as a **scintigram**.

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radiology

medical speciality concerned with the use of radiation, including X-rays, and radioactive materials in the diagnosis and treatment of injury and disease.

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radiometric dating

method of dating rock by assessing the amount of radioactive decay of naturally occurring isotopes. The dating of rocks may be based on the gradual decay of uranium into lead. The ratio of the amounts of 'parent' to 'daughter' isotopes in a sample gives a measure of the time it has been decaying, that is, of its age. Different elements and isotopes are used depending on the isotopes present and the age of the rocks to be dated. Once-living matter can often be dated by radiocarbon dating, employing the half-life of the isotope carbon-14, which is naturally present in organic tissue.

Radiometric methods have been applied to the decay of long-lived isotopes, such as potassium-40, rubidium-87, thorium-232, and uranium-238, which are found in rocks. These isotopes decay very slowly and this has enabled rocks as old as 3,800 million years to be dated accurately. Carbon dating can be used for material between 1,000 and 100,000 years old.
Potassium dating is used for material more than 100,000 years old, **rubidium** for rocks more than 10 million years old, and **uranium** and **thorium** dating is suitable for rocks older than 20 million years.

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radiosonde

balloon carrying a compact package of meteorological instruments and a radio transmitter, used to 'sound', or measure, conditions in the atmosphere. The instruments measure temperature, pressure, and humidity, and the information gathered is transmitted back to observers on the ground. A radar target is often attached, allowing the balloon to be tracked.

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radio telescope

instrument for detecting radio waves from the universe in radio astronomy. Radio telescopes usually consist of a metal bowl that collects and focuses radio waves the way a concave mirror collects and focuses light waves. Radio telescopes are much larger than optical telescopes, because the wavelengths they are detecting are much longer than the wavelength of light. The largest single dish is at Arecibo Observatory, Puerto Rico.

A large dish such as that at Jodrell Bank, Cheshire, England, can see the radio sky less clearly than a small optical telescope sees the visible sky.
Interferometry is a technique in which the output from two dishes is combined to give better resolution of detail than with a single dish.
Very long baseline interferometry (VBLI) uses radio telescopes spread across the world to resolve minute details of radio sources. The deep-space network (DSN) works in this way to track artificial satellites.

In **aperture synthesis**, several dishes are linked together to simulate the performance of a very large single dish. This technique was pioneered by English radio astronomer Martin Ryle at the Mullard Radio Astronomy Observatory, Cambridge, England, site of a radio telescope consisting of eight dishes in a 5-km/3-mi line. The Very Large Array in New Mexico consists of 27 dishes arranged in a Y-shape, which simulates the performance of a single dish 27 km/17 mi in diameter. Other radio telescopes are shaped like long troughs, and some consist of simple rod-shaped aerials.

National Radio Astronomy Observatory

Go to site

News of the research activities of the National Radio Astronomy Observatory. This large Web site has pages about principles and techniques in radio astronomy and an impressive image gallery.

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radiotherapy

treatment of disease by radiation from X-ray machines or radioactive sources. Radiation in the correct dosage can be used to kill cancerous cells and prevent their spreading.

Generally speaking, the rays of a diagnostic X-ray machine are not penetrating enough to be efficient in treatment, so for this purpose more powerful machines are required, operating at from 10,000 volts to over 30 million volts. The lower-voltage machines are similar to conventional X-ray machines. The higher-voltage ones may be of special design; for example, linear accelerators and betatrons. Modern radiotherapy is associated with fewer side effects than formerly, but radiotherapy to the head can cause temporary hair loss, and if the treatment involves the intestine, diarrhoea and vomiting may occur. Much radiation now comes from synthesized radioisotopes. Radioactive cobalt is the most useful, because it produces gamma rays, which are highly penetrating, and it is used instead of very high-energy X-rays.

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radio wave

electromagnetic wave possessing a long wavelength (ranging from about 10^{-3} to 10^{4} m) and a low frequency (from about 10^{5} to 10^{11} Hz) that travels at the speed of light. Included in the radio wave part of the spectrum are: microwaves, used for both communications and for cooking; ultra high- and very high-frequency waves, used for television and FM (frequency modulation) radio communications; and short, medium, and long waves, used for AM (amplitude modulation) radio communications. Radio waves that are used for communications have all been modulated (see modulation) to carry information. Certain astronomical objects emit radio waves, which may be detected and studied using radio telescopes.

There is a layer in the atmosphere, called the ionosphere, where gas molecules are separated from their electrons by radiation from the Sun. When radio waves reach the ionosphere, they produce movements or oscillations of the electrons. As the electrons oscillate they produce electromagnetic waves that are identical to the radio waves with which the electrons were stimulated. The radio waves are reflected back and can be detected by a receiver. It is important to note that the reflected radio waves come from the oscillating electrons in the ionosphere.

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radish

annual herb native to Europe and Asia, and cultivated for its fleshy, pungent, edible root, which is usually reddish but sometimes white or black; it is eaten raw in salads. (Genus *Raphanus sativus*, family Cruciferae.)

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radium

chemical symbol Ra

(Latin radius 'ray')

white, radioactive, metallic element, atomic number 88, relative atomic mass 226.02. It is one of the alkaline-earth metals, found in nature in pitchblende and other uranium ores. Of the 16 isotopes, the commonest, Ra-226, has a half-life of 1,620 years. The element was discovered and named in 1898 by Pierre and Marie Curie, who were investigating the residues of pitchblende.

Radium decays in successive steps to produce radon (a gas), polonium, and finally a stable isotope of lead. The isotope Ra-223 decays through the uncommon mode of heavy-ion emission, giving off carbon-14 and transmuting directly to lead. Because radium luminesces, it was formerly used in paints that glowed in the dark; when the hazards of radioactivity became known its use was abandoned, but factory and dump sites remain contaminated and many former workers and neighbours contracted fatal cancers.

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radius

in biology, one of the two bones in the lower forelimb of tetrapod (four-limbed) vertebrates.

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radius

straight line from the centre of a circle to its circumference, or from the centre to the surface of a sphere.

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radon

chemical symbol Rn

colourless, odourless, gaseous, radioactive, non-metallic element, atomic number 86, relative atomic mass 222. It is grouped with the noble gases (rare gases) and was formerly considered nonreactive, but is now known to form some compounds with fluorine. Of the 20 known isotopes, only three occur in nature; the longest half-life is 3.82 days (Rn-222).

discovery

Radon is the densest gas known and occurs in small amounts in spring water, streams, and the air, being formed from the natural radioactive decay of radium. Ernest Rutherford discovered the isotope Rn-220 in 1899, and Friedrich Dorn (1848–1916) in 1900; after several other chemists discovered additional isotopes, William Ramsay and R W Whytlaw-Gray isolated the element, which they named niton in 1908. The name radon was adopted in the 1920s.

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rafflesia

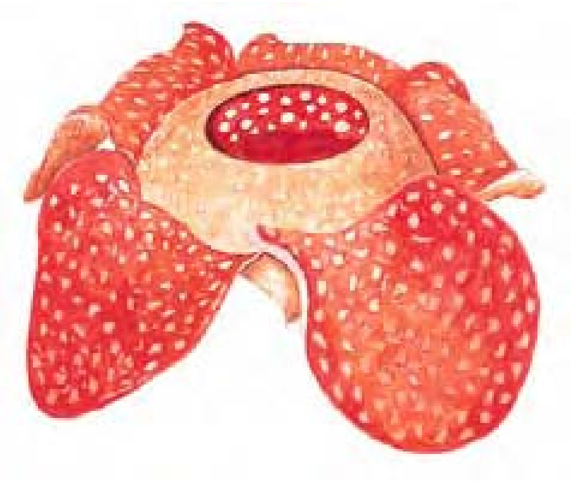
or stinking corpse lily

any of a group of parasitic plants without stems, native to Malaysia, Indonesia, and Thailand. There are 14 species, several of which are endangered by the destruction of the forests where they grow. The fruit is used locally for medicine. The largest flowers in the world are produced by *R. arnoldiana*. About 1 m/3 ft across, they exude a smell of rotting flesh, which attracts flies to pollinate them. (Genus *Rafflesia*, family Rafflesiaceae.)

rafflesia

The world's largest flower smells of rotting flesh. The flower of the parasitic *Rafflesia* has a diameter of up to 1 m/3.3 ft and attracts pollinating insects by mimicking the smell of decomposing corpses. It flowers only once every ten years.

rafflesia



(Image © Research Machines plc)

The rafflesia, or stinking corpse lily, is the largest known flower, about 1 m/3 ft across and weighing 7 kg/15 lb.

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ragworm

marine bristle-worm (polychaete), characterized by its prominent parapodia (lateral, paired 'paddles' found on each of its segments). Ragworms are usually well adapted to an active existence, with large muscle blocks and stout parapodia for swimming as well as crawling and burrowing, and a large head complete with complex sense organs. Some, such as *Nereis virens*, reach several metres in length, but most are 2-10 cm/1-4 in long.

Ragworms can be found on the seashore at low tide sheltering from dehydration and high temperatures under rocks, in crevices, or shallow burrows and are often brightly coloured. They are often scavengers feeding on general animal debris or are active predators possessing a large proboscis and stout jaws for feeding on other soft-bodied invertebrates; some feed on algae.

classification

The ragworm is in genus *Nereis*, a member of class Polychaeta in phylum Annelida.

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ragwort

any of several European perennial plants, usually with yellow flower heads; some are poisonous. (Genus *Senecio*, family Compositae.)

ragwort

The Oxford Ragwort *Senecio squalidus* was introduced into the city's Botanic Gardens from Sicily in 1794. In the 19th century, it escaped from the garden and established itself in the cinders of Oxford's railway, being similar to the volcanic soil of the plant's native Sicily. In Victorian times, the plant spread along the railway system, and is now common all over southern England.

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rail

any wading bird of the family Rallidae, including the rails proper (genus *Rallus*), coots, moorhens, and gallinules. Rails have dark plumage, a short neck and wings, and long legs. They are 10-45 cm/4-18 in long.

Many oceanic islands have their own species of rail, often flightless, such as the Guam rail *R. owstoni* and Auckland Island rail *R. muelleri*. Several of these species have declined sharply, usually because of introduced predators such as rats and cats.

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railway

method of transport in which trains convey passengers and goods along a twin rail track. Following the work of British steam pioneers such as the Scottish engineer James Watt, English engineers, such as George Stephenson, developed the steam locomotive and built the first railways; Stephenson built the first public steam railway, from Stockton to Darlington, England, in 1825. This heralded extensive railway building in Britain, continental Europe, and North America, providing a fast and economical means of transport and communication. After World War II, steam engines were replaced by electric and diesel engines. At the same time, the growth of road building, air services, and car ownership brought an end to the supremacy of the railways.

Railway

the whispering arrow

In March 1994 the German cabinet approved construction of Europe's first high-speed magnetic levitation train (maglev) route to link Berlin and Hamburg. Nicknamed Whispering Arrow, the 400 kmh/250 mph Transrapid magnetic hovertrain will reduce the time for the 177-mile journey from 3 hours to 53 minutes, matching air travel time. When the Transrapid enters service in 2002, it will challenge the short-hop air services in Europe. Costs of the project are estimated at £3.86 billion.

The Transrapid floats above the track, suspended by magnetic attraction between magnets in the train and track. The electrical current running along the track is switched on and off 100,000 times a second to produce horizontal motion. The train is so powerful that it can climb a 10% gradient, lessening the need for expensive tunnelling. The train is also more manoeuvrable than the French TGV or high-speed train. It can turn in a one-mile radius over twisting routes.

railway

(Image © Research Machines plc)

The great peaks of the Canadian Rockies, which rise along Alberta's southwestern boundary, are cut by the Canadian Pacific Railway. Completed in 1885, it is one of the most impressive engineering feats in the world.

Grand Central Station

(Image © Corel)

The Renaissance-style front of Grand Central Station in New York which was opened in 1913. The station concourse is one of the largest rooms in the world. Statues of Mercury, Athena, and Hercules surround the station clock.

railway

(Image © Research Machines plc)

A train in northern Mexico. Mexico has a wide variety of transportation systems. While some farmers still carry their goods to market on their heads or backs, all the major cities are connected by highways and railways, such as this one in northern Mexico.

railway

(Image © Research Machines plc)

Waterloo International train station in London, England. Waterloo station is one of London's major train stations. One of the most modern and advanced train stations in the world, it is now the principal link between London and the Channel Tunnel.

Railways: key dates

1500s	Tramways – wooden tracks along which trolleys run – are in use in European mines.
1785	English engineer William Jessop develops cast-iron rails upon which flanged wheels may run; cars are still horse-drawn.
1797	Some roads in Shropshire, England, are converted to iron railways along which horse-drawn trams may run.
1804	An English engineer, Richard Trevithick, builds the first steam locomotive and runs it on the track at the Pen-y-darren ironworks at Merthyr Tydfil, South Wales.
1820	An English inventor, John Birkinshaw, begins making rails out of wrought iron.
1825	The English engineer George Stephenson builds the first public railway to carry steam trains – the Stockton and Darlington line – using his engine *Locomotion*.
1829	Stephenson designs his locomotive *Rocket*.
1830	Stephenson completes the Liverpool and Manchester Railway, the first steam passenger line. The first US-built locomotive, *Best Friend of Charleston*, goes into service on the South Carolina Railroad.
1832	The German engineer Franz Anton von Gerstner designs the first railway passenger carriages.
1835	Germany pioneers steam railways in Europe, using *Der Adler*/*The Eagle*, a locomotive built by Stephenson.
1863	Scottish inventor Robert Fairlie patents a locomotive with pivoting driving bogies, allowing tight curves in the track (this is later applied in the Garratt locomotives). London opens the world's first underground railway, powered by steam.
1869	The first US transcontinental railway is completed at Promontory, Utah, when the Union Pacific and the Central Pacific railroads meet. George Westinghouse of the USA invents the compressed-air brake.
1879	German inventor Werner von Siemens demonstrates an electric train at an exhibition in Berlin.
1881	Siemens begins the world's first public electric streetcar service at Lichterfelde, Berlin, Germany.
1883	Volk's Electric Railway begins operating a public service along the Brighton seafront in England and is still in business at the start of the 21st century. French engineer Charles Lartique builds the first monorail, in Ireland. The Orient Express, a luxury steam train running from Paris, France, to Constantinople (later Istanbul), Turkey, enters service. It continues operation until 1977.

1885	The trans-Canada continental railway is completed, from Montréal in the east to Port Moody in the west.
1890	The first electric underground railway opens in London.
1891	Construction of the Trans-Siberian Railway begins. It is completed in 1904. A section of line built in 1916 around Lake Baikal allows passengers to make the journey from Moscow in the west to Vladivostok in the east without changing trains.
1901	The world's longest-established monorail, the Wuppertal Schwebebahn, goes into service in Germany.
1912	The first diesel locomotive takes to the rails in Germany.
1921	The 250 private railway companies that provide the UK's rail services are reorganized into four regional systems.
1938	The British steam locomotive *Mallard* sets a steam-rail speed record of 203 kph/126 mph.
1941	Swiss Federal Railways introduce a gas-turbine locomotive.
1948	A Labour government brings the UK railways into public ownership. The rail services are nationalized under the name British Railways. This name is changed to British Rail in 1965, three years after the setting up of the supervisory British Railways Board.
1955	Steam locomotives begin to be replaced by diesel trains in the UK.
1960s	Electric trains begin to come into regular service in the UK.
1963-65	Richard Beeching, head of the British Railways Board, implements most of the recommendations made in his government report to close down the loss-making parts of the UK rail network. He reduces it from 21,000 km/13,000 mi to 17,000 km/11,000 mi, shutting down many branch lines and closing more than 2,000 stations.
1964	Japan National Railways inaugurates the 515 km/320 mi New Tokaido line between Osaka and Tokyo, on which the 210 kph/130 mph 'bullet' trains run.
1973	British Rail's High Speed Train (HST) sets a diesel-rail speed record of 229 kph/142 mph.
1979	Japan National Railways' maglev test vehicle ML-500 attains a speed of 517 kph/321 mph.
1981	France's Train à Grande Vitesse (TGV) superfast trains begin operation between Paris and Lyons, regularly attaining a peak speed of 270 kph/168 mph.
1987	British Rail sets a new diesel-traction speed record of 238.9 kph/148.5 mph, on a test run between Darlington and York; France and the UK begin work on the Channel Tunnel, a railway link connecting the two countries, running beneath the English Channel.
1988	The West German Intercity Experimental train reaches 405 kph/252 mph on a test run between Würzburg and Fulda.
1990	A new rail-speed record of 515 kph/320 mph is established by a French TGV train, on a stretch of line between Tours and Paris.
1991	The British and French twin tunnels meet 23 km/14 mi out to sea to form the Channel Tunnel.
1993	British Rail privatization plans are announced, separating the management of the infrastructure from the provision of train services and placing the running of the rail system under a regulatory regime; government investment is further reduced.
1994	In the UK's newly privatized rail system, a new company called Railtrack takes over ownership and management of all 17,000 km/11,000 mi of railway lines, signalling, and other infrastructure. Rail services start through the Channel Tunnel.
1996	After being awarded franchises under the government's rail privatization programme, the first private companies to offer train services in the UK since 1948 begin operating. Railtrack is floated on the London Stock Exchange.
1998	A Labour government seeks greater regulatory powers over the private rail companies through its proposed Strategic Rail Authority (SRA). The SRA will have power to guide future planning for the UK rail industry, encourage greater rail travel, and penalize underperforming franchise-holders.
1999	The government passes legislation to establish the SRA by late 2000.
2000	Railtrack, with the service operator South West Trains, announces a feasibility study for the introduction of double-decker trains to cope with a 25% rise in commuter traffic using London's Waterloo station.
2001	Railtrack goes into administration. Network Rail is created to oversee the UK rail infrastructure.
2002	The magnetic levitation train between Shanghai and its airport makes its first test journey.
2003	Phase 1 of the Channel Tunnel Rail Link is completed, leading to a new record journey time of 2 hours 19 minutes from London to Paris.
December 2003	A Japanese train, using magnetic levitation, breaks the rail speed record, reaching 581 kph (360 mph).
2005	A new railway line across the Himalyas from Golmud in China to Lhasa in Tibet is completed by China.

European Railway Server

Go to site

Complete source of information about the railways of Europe. The needs of travellers, railway enthusiasts, and students of public transport are provided for. There are links to all of Europe's railway operators and information about real and model trains.

Iron Road

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *The American Experience*, this page tells the story of the construction of the first US railroad link connecting East and West. It includes information about the harsh conditions that labourers, mostly immigrants, endured during its construction. There is also a list of sources for further reading.

National Railway Museum, York

Go to site

Information for railway enthusiasts. In addition to information about the National Railway Museum and its exhibitions, there is news of railway matters from around the world. There is also a listing of other sites for train buffs.

Railways in the 19th Century

Go to site

Development of the railway system during the 19th century. This comprehensive site focuses on the individual entrepreneurs and their inventions, as well as the railway companies, stations, and the effect the railways had on towns and cities.

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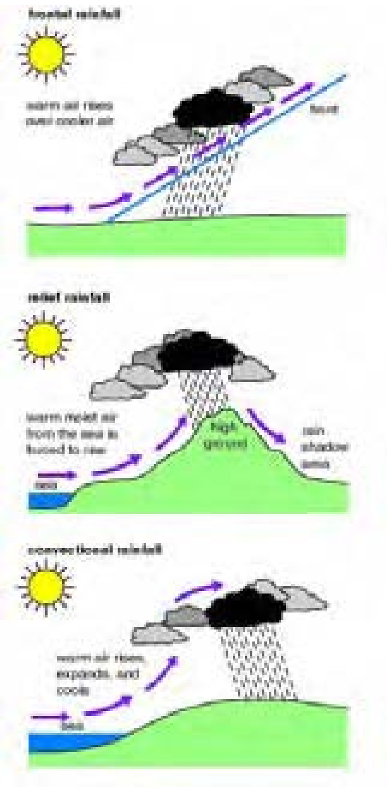
rain

form of precipitation in which separate drops of water fall to the Earth's surface from clouds. The drops are formed by the accumulation of fine droplets that condense from water vapour in the air. The condensation is usually brought about by rising and subsequent cooling of air.

Rain can form in three main ways: frontal (or cyclonic) rainfall, orographic (or relief) rainfall, and convectional rainfall.
Frontal rainfall takes place at the boundary, or front, between a mass of warm air from the tropics and a mass of cold air from the poles. The water vapour in the warm air is chilled and condenses to form clouds and rain.
Orographic rainfall occurs when an airstream is forced to rise over a mountain range. The air becomes cooled and precipitation takes place. In the UK, the Pennine hills, which extend southwards from Northumbria to Derbyshire in northern England, interrupt the path of the prevailing southwesterly winds, causing orographic rainfall. Their presence is partly responsible for the west of the UK being wetter than the east.
Convectional rainfall, associated with hot climates, is brought about by rising and abrupt cooling of air that has been warmed by the extreme heat of the ground surface. The water vapour carried by the air condenses, producing heavy rain. Convectional rainfall is usually accompanied by a thunderstorm, and it can be intensified over urban areas due to higher temperatures there.

rain


frontal rainfall
warm air rises over cooler air
front
relief rainfall
warm moist air from the sea is forced to rise
high ground
rain shadow area
sea
convectional rainfall
warm air rises, expands, and cools
sea

(Image © Research Machines plc)

The three patterns of rainfall. Frontal (or cyclonic) rain is caused by warm air rising over cold air in a low pressure area. Relief (or orthographic) rainfall occurs when warm, moist air cools as it is forced to rise over hills or mountains. Convectional rainfall is caused when the surface of the Earth has been warmed by the Sun and the air in contact with it rises and meets colder layers. It is usually accompanied by a thunderstorm and is common in tropical regions.

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rainbow

luminous arch in the sky displaying the colours of the spectrum formed by the refraction and reflection of the Sun's rays through rain or mist. Its cause was discovered by Theodoric of Freiburg in the 14th century.

rainforest

dense forest usually found on or near the Equator where the climate is hot and wet. Moist air brought by the converging trade winds rises because of the heat and produces heavy rainfall. More than half the tropical rainforests are in Central and South America, primarily the lower Amazon and the coasts of Ecuador and Columbia. The rest are in Southeast Asia (Malaysia, Indonesia, and New Guinea) and in West Africa and the Congo.

Tropical rainforests once covered 14% of the Earth's land surface, but are now being destroyed at an increasing rate as their valuable timber is harvested and the land cleared for agriculture, causing problems of deforestation. Although by 1991 over 50% of the world's rainforests had been removed, they still comprise about 50% of all growing wood on the planet, and harbour at least 40% of the Earth's species (plants and animals).

The vegetation in tropical rainforests typically includes an area of dense forest called **selva**; a **canopy** formed by high branches of tall trees providing shade for lower layers; an intermediate layer of shorter trees and tree roots; lianas; and a ground cover of mosses and ferns. The lack of **seasonal rhythm** causes adjacent plants to flower and shed leaves simultaneously. Chemical weathering and leaching take place in the iron-rich soil due to the high temperatures and humidity.

Rainforests comprise some of the most complex and diverse ecosystems on the planet, deriving their energy from the Sun and photosynthesis. In a hectare (10,000 sq m/107,640 sq ft) of rainforest there are an estimated 200-300 tree species compared with 20-30 species in a hectare of temperate forest. The trees are the main **producers**. Herbivores such as insects, caterpillars, and monkeys feed on the plants and trees and in turn are eaten by the carnivores, such as ocelots and puma. Fungi and bacteria, the primary **decomposers**, break down the dead material from the plants, herbivores, and carnivores with the help of heat and humidity. This decomposed material provides the **nutrients** for the plants and trees.

The rainforest ecosystem helps to regulate global weather patterns - especially by taking up CO_2 (carbon dioxide) from the atmosphere - and stabilizes the soil. Rainforests provide most of the oxygen needed for plant and animal respiration. When deforestation occurs, the microclimate of the mature forest disappears; soil erosion and flooding become major problems since rainforests protect the deep tropical soils. Once an area is cleared it is very difficult for shrubs and bushes to re-establish because soils are poor in nutrients. This causes problems for plans to convert rainforests into agricultural land - after two or three years the crops fail and the land is left bare. Clearing of the rainforests may lead to global warming of the atmosphere, and contribute to the greenhouse effect.

The Fate of the Rainforests

rainforests: the richest natural habitat

The English naturalist Charles Darwin, who went on to devise the theory of evolution, was greatly impressed by his first sight of the Brazilian rainforest in 1832:

'The elegance of the grasses, the novelty of the parasitical plants, the beauty of the flowers, the glossy green of the foliage, but above all the general luxuriance of the vegetation, filled me with admiration) The noise from the insects is so loud, that it may be heard even in a vessel anchored several hundred yards from the shore.'

Today, you can still see what Darwin saw. But it is getting more difficult. We are as likely to agonize about the rainforests as admire them. These richest of all natural habitats are the focus of intense conflicts between developers and conservationists, international agencies and local inhabitants. And their continual erosion concerns people around the world interested in biodiversity and climate change.

no ordinary forest

What Darwin saw was tropical rainforest, the richest kind, which grows in a belt four degrees either side of the Earth's equator. It flourishes where it is hottest and wettest, needing mean monthly temperatures of 20-28°C/68-82°F and annual rainfall of 1.5-10 m/5-33 ft, spread evenly through the year. This happens in 30 different countries, mainly in South America, the islands of the Malay Archipelago in Asia, and the Congo basin in Africa. The country with the largest area of tropical rainforest is Brazil, with Indonesia second.

Visitors, like Darwin, have always found the rainforest fascinating. The tallest trees soar 45-55 m/150-180 ft aloft. Beneath them, several other layers of trees and plants vie for a share of food and energy. Although the tropical sun beats down on the canopy, only 1-3% of its light ever reaches the forest floor. Most of the biological activity takes place well above the ground.

The combination of high rainfall and humidity, high temperatures and abundant energy from sunlight sustains a profusion of competing plant and animal species unlike any other **ecosystem**. Scientists don't really know how many species there are on the planet. However, the best estimates suggest that around half of them are found in tropical rainforests, even though they only cover 7% of the land area.

This is true for all types of living things. Whatever you sample, the chances are there are more kinds in the rainforest than anywhere else, especially trees, of course. The temperate forests of Northern Europe have only 50 native tree species. North America has 171. A single 50-hectare plot of Malayan rainforest yielded 830 species. Tropical trees and plants in turn support thousands of different creatures. Insects are the most varied by far. A single tree at Tambopata, Peru, hosted 43 different species of ants. You would have to survey the whole of the British Isles to find as many. The plants and insects support many birds and animals. One survey at Maraca in Brazil recorded 450 different species of birds and 45 kinds of bats. Further up the evolutionary scale, rainforest dwellers include 90% of all non-human primates. At the other end of the scale, there may be as many as one and a half million kinds of fungi.

past and future harvest

This vast natural hothouse has yielded many plants vital to humans. In the past, these included rice, potatoes, cassava, tomatoes, peanuts, and bananas for food. We also use bamboo, rubber, coffee, and cocoa.

New edible plants may yet be cultivated, although tropical forests are more likely to yield genetic variants of existing crops that have greater resistance to pests or disease. It is also possible that some plants not yet tested by scientists will contain compounds useful in medicine. Plants were the original source for many valuable drugs, including digitoxin, used to treat heart disease, and quinine, which has antimalarial properties. Many forest peoples, like the Penan in Sarawak, Malaysia, use dozens of medicinal plants.

felling the forest

Human use of the forest lands is changing. Some indigenous peoples, notably groups of American Indians and central African Pygmies, still live as hunter-gatherers, much as they have done for thousands of years. For them, the forest is a kind of natural supermarket. The Chacabo Indians of Bolivia use 82% of the plant species that are known to grow in their foraging grounds.

The supermarket has limited stocks, though, and supports relatively small populations. Most forest dwellers are farmers, who cultivate the shallow soils in cleared patches of forest, then move on. This so-called shifting cultivation often goes along with planting useful crops in the forest itself, which may even increase its diversity. All this leaves its traces. Around 12% of the vast Amazonian rainforest in Brazil shows signs of past human occupation, such as the relative abundance of particular trees.

But this is nothing compared to the imprint left by modern exploitation. Growing populations, and improved technologies for road-building and for cutting and processing the giant trees, have encouraged incursions into the rainforest. Shifting cultivation is only sustainable when population densities are relatively low, and migrations along new roads increase clearance. Larger agricultural clearances for ranching and commercial logging are also eating into tropical forests wherever they flourish. Add mining, dams for hydroelectric power, and oil prospecting, and the reasons for taking a piece out of the forest multiply.

In many countries, the rainforests are already considerably reduced. In Costa Rica, for example, primary forest cover fell from 67% of the land area to a mere 17% between 1940 and 1983. Losses in other, larger countries are typically less startling. But the largest forest tract of all, in Amazonia, has already shrunk by around 15%.

In some ways, this fits an historical pattern. Early 20th-century ecologists saw the rainforest as a stable system, carrying on unchanged for tens of thousands of years. But later studies reveal a more dynamic picture, with widespread traces of damage by volcanoes, storms, droughts, and, most importantly, fires. It is not so long, in geological terms, 12,000–18,000 years, since ice-age climates limited most of the lands where rainforests can grow now to seasonal savannah grasslands.

The other effects we now see in the tropics are not really new either. The temperate forests which once covered much of Europe and China were mostly felled by humans thousands of years ago. European colonists then set about the trees of North and South America and Australia. But perhaps rainforests are different. Their remarkable biodiversity, their little-understood effects on atmosphere and climate, to say nothing of their beauty, may mean there is a greater global interest in conserving more of the tropical forest than ever occurred to earlier generations of forest-fellers. For example, there is evidence that rainforests grow faster as atmospheric carbon dioxide increases, which might just slow down global warming.

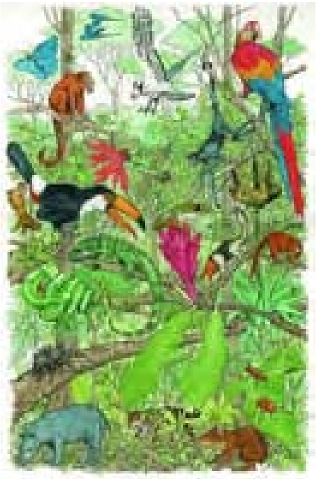
a future for rainforests?

Whatever the case for preservation, there is no doubt that contemporary rainforests are under threat. The most recent estimates from the United Nations Food and Agriculture Organization, based on a combination of ground-based surveys and remote sensing from space, show a net loss of 65.1 million hectares of forest in developing countries between 1990 and 1995. This is a smaller number than in the decade 1980–90 (13.7 million hectares per year compared with 15.5 million per year). The net result is that total forestation in the developing world, much of it rainforest, declined by just over 9% between 1980 and 1995.

More local studies show why concern about the future of the forests does not translate easily into successful conservation. Outside activists have often focused on logging for export, for example, but more than three quarters of Amazon timber is used in Brazil. Estimates based on satellite images indicate that 1.7 million hectares of Amazon forest were lost in 1999. Although government regulations are tightening, and this is slightly smaller than the loss registered the previous year, much illegal felling still takes place.

In central Africa, where an estimated four million hectares a year of forest are succumbing to chainsaws, the Worldwide Fund for Nature has teamed up with the World Bank to try and press governments to grant logging concessions to companies that will use known techniques to improve the chances of forest regeneration. A 'forest summit' in Yaoundé, capital of Cameroon, in 2000 saw the presidents of five central African countries pledge to protect remaining forests and harvest timber sustainably. However, such measures reduce production in the short term, and local people are asked to risk their own and their children's livelihood for the sake of biodiversity. Telling them that they are saving hundreds of species of birds or 1,200 species of termites, is not persuasive. They need other sources of income, other ways to buy food. If outsiders want to help preserve the forest, they will probably need to find some way to pay for it. Tourism may be one answer, but it has a long way to go to compete with the wood trade.

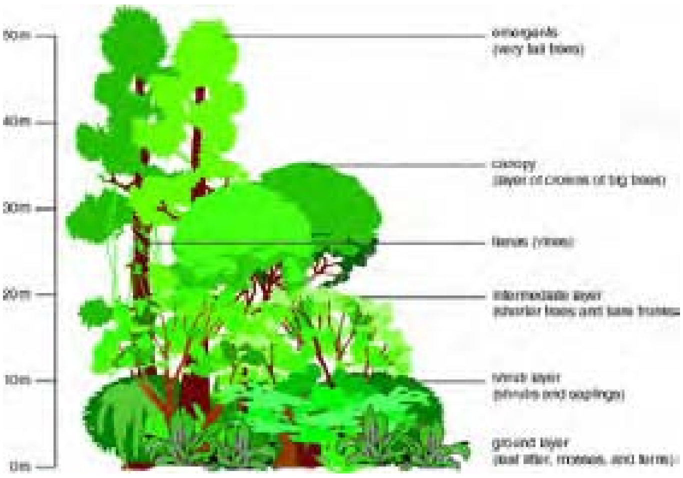
rainforest



(Image © Research Machines plc)

Cross section of a South American rainforest, showing the different horizontal layers of vegetation that make up the rainforest, and the animals and plants found in each layer. To a certain extent the separate layers provide unique microhabitats, with animals and plants found only in one stratum and being adapted to life there, so for example the tapir occupies only the forest floor and some butterfly species always fly at specific heights. Other animals and plants move across strata, for example many of the monkeys and birds.

rainforest


50m
40m
30m
20m
10m
0m
emergents
(very tall trees)
canopy
(layer of crowns of big trees)
lianas (vines)
intermediate layer
(shorter trees and bare trunks
shrub layer
(shrubs and saplings)
ground layer
(leaf litter, mosses, and ferns)

(Image © Research Machines plc)

The different layers of vegetation in a typical rainforest. The dense canopy of leaves shades the lower layers from the sun. Lianas are woody vines that grow around, and hang from, the trees. Ferns and mosses grow at ground level where the conditions are dark, damp, and humid.

Exploring the Tropics

Go to site

Missouri Botanical Garden guide to tropical rainforests, covering issues such as 'Are all tropical forests, rain forests?', 'Effects of elevation on climate and vegetation', and 'Causes of destruction'.

Rainforests of the World

Go to site

Resource that explores many aspects of this type of vegetation. The site includes detail on 'Climate', 'Homeland for Forest Peoples', and 'Rainforest Facts'.

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raisin

dried grape, for eating as a fruit and also used in baking and confectionery. The chief kinds are the seedless raisin, the sultana, and the currant. The main producers are the Mediterranean area, California, Mexico, and Australia.

Grapes may be dried in the sun or artificially, using hot air. The dark colour of the dried fruit comes from the caramelization of natural sugars during the drying process. Drying reduces grapes to 25% of their original weight, while retaining almost all the nutritional value of the fresh fruit.

RAM

acronym for random-access memory

in computing, a memory device in the form of a collection of integrated circuits (chips), frequently used in microcomputers. Unlike ROM (read-only memory) chips, RAM chips can be both read from and written to by the computer, but their contents are lost when the power is switched off.

Many modern commercial programs require a great deal of RAM to work efficiently. By 2004, most PCs were supplied with 512 megabytes (MB) of RAM.

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ramjet

simple jet engine (see under jet propulsion) used in some guided missiles. It only comes into operation at high speeds. Air is then 'rammed' into the combustion chamber, into which fuel is sprayed and ignited.

Ramsay, William (1852-1916)

Scottish chemist who, with Lord Rayleigh, discovered argon in 1894. In 1895 Ramsay produced helium and in 1898, in cooperation with Morris Travers, identified neon, krypton, and xenon. In 1903, with Frederick Soddy, he noted the transmutation of radium into helium, which led to the discovery of the density and relative atomic mass of radium. He was awarded the Nobel Prize for Chemistry in 1904 for his discovery of noble gases (rare gases) in air and their locations in the periodic table. He was made a KCB in 1902.

In his book *The Gases of the Atmosphere* (1896), Ramsay repeated a suspicion he had stated in 1892 that there was an eighth group of new elements at the end of the periodic table. During the next decade Ramsay and Travers sought the remaining noble gases by the fractional distillation of liquid air.

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ranching

commercial form of pastoral farming that involves extensive use of large areas of land (extensive agriculture) for grazing cattle or sheep.

Ranches may be very large, especially where the soil quality is poor; for example, the estancias on the Pampas grasslands in Argentina. Cattle have in the past been allowed to graze freely but more are now enclosed. In the Amazon some deforested areas have been given over to beef-cattle ranching.

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random access

in computing, an alternative term for direct access.

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random number

one of a series of numbers having no detectable pattern. Random numbers are used in computer simulation and computer games. It is impossible for an ordinary computer to generate true random numbers, but various techniques are available for obtaining pseudo-random numbers - close enough to true randomness for most purposes.

Random Number Generator

Go to site

Internet resource that delivers genuine random numbers, generated by radioactive decay.

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rangefinder

instrument for determining the range or distance of an object from the observer; used to focus a camera or to sight a gun accurately. A **rangefinder camera** has a rotating mirror or prism that alters the image seen through the viewfinder, and a secondary window. When the two images are brought together into one, the lens is sharply focused.

Raoult, François Marie (1830-1901)

French chemist. In 1882, while working at the University of Grenoble, Raoult formulated one of the basic laws of chemistry.
Raoult's law enables the relative molecular mass of a substance to be determined by noting how much of it is required to depress the freezing point of a solvent by a certain amount.

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rape

in botany, either of two plant species of the mustard family grown for their seeds, which yield a pungent edible oil. The common turnip is a variety of *B. rapa* and the swede turnip is a variety of of *B. napus*. (Genus *Brassica rapa* and *B. napus*, family Cruciferae.)

Oilseed rape, or canola, is the world's third most important oilseed crop. Plant breeders developed it from the 'weed' rapeseed (*B. napus oleifera*). The first variety was marketed 1974, and the bright yellow fields of oilseed rape in flower are now a familiar sight in the countryside.

Rape methyl ester provides a renewable replacement for diesel fuel that gives off fewer sooty particles and none of the sulphur dioxide that causes acid rain.

oilseed rape fields

(Image © Corel)

Farm and oilseed rape field, Alberta, Canada. The most westerly of the prairie provinces, Alberta's agricultural industry is a mainstay of its economy.

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rare-earth element

alternative name for lanthanide.

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rarefaction

in medicine, the reduction in bone density due to the depletion of calcium stores, due to an infection of the bone, for example.

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rare gas

alternative name for noble gas.

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rash

in medicine, eruption on the surface of the skin. It is usually raised and red or it may contain vesicles filled with fluid. It may also be scaly or crusty. Characteristic rashes are produced by infectious diseases, such as chickenpox, measles, German measles, and scarlet fever. The severity of the rash usually reflects the severity of the disease. Rashes are also produced as an allergic response to stings from insects and plants. These are often alleviated by antihistamines and they usually resolve within a few days.

Chronic rashes are present in patients with some skin diseases, such as eczema and psoriasis.

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raspberry

any of a group of prickly cane plants native to Europe, Asia, and North America, and widely cultivated. They have white flowers followed by hollow red composite fruits, which are eaten fresh as a delicacy and used for making jam and wine. (Genus *Rubus*, family Rosaceae.)

raster graphics

computer graphics that are stored in the computer memory by using a map to record data (such as colour and intensity) for every pixel that makes up the image. When transformed (enlarged, rotated, stretched, and so on), raster graphics become ragged and suffer loss of picture resolution, unlike vector graphics. Raster graphics are typically used for painting applications, which allow the user to create artwork on a computer screen much as if they were painting on paper or canvas.

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rat

any of numerous long-tailed rodents (especially of the families Muridae and Cricetidae) larger than mice and usually with scaly, naked tails. The genus *Rattus* in the family Muridae includes the rats found in human housing.

The **brown rat** *Rattus norvegicus* is about 20 cm/8 in long with a tail of almost equal length. It is believed to have originated in central Asia, and is now found worldwide after being transported from Europe by ships. Female brown rats become sexually receptive at the age of 8–12 weeks. If food is plentiful, litters of up to 12 are born every few months. The **black rat** *R. rattus*, responsible for the plague, is smaller than the brown rat, but has larger ears and a longer, more pointed snout. It does not interbreed with brown rats. The **pack rat** or **wood rat**, genus *Neotoma*, is common throughout North America and there are seven different species. Their dens, made of partly eaten plants, dung, and miscellaneous objects, are known as middens and can be up to 2 m/6.5 ft across and 20–30 cm/8–12 in high. The rats' crystallized urine preserves the midden, in some cases for up to 40,000 years.

rat

Rats emit chirps and whistles beyond the range of human hearing when they are tickled or when playing together when young, leading US psychologists to conclude in 1998 that rats have a sense of fun and are capable of laughter.

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rate of reaction

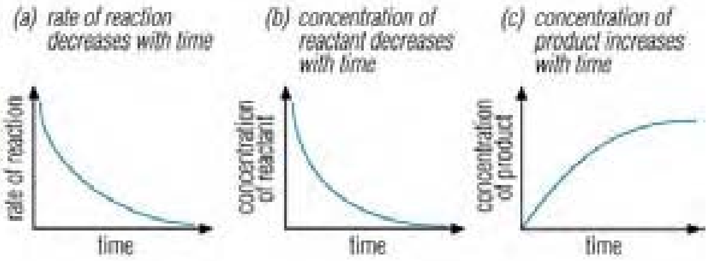
speed at which a chemical reaction proceeds. It is usually expressed in terms of the concentration (usually in moles per litre) of a reactant consumed, or product formed, in unit time; so the units would be moles per litre per second ($mol\ l^{-1}\ s^{-1}$). The rate of a reaction may be affected by the concentration of the reactants, the temperature of the reactants (or the amount of light in the case of a photochemical reaction), and the presence of a catalyst. If the reaction is entirely in the gas state, the rate is affected by pressure, and, where one of the reactants is a solid, it is affected by the particle size.

During a reaction at constant temperature the concentration of the reactants decreases and so the rate of reaction gradually slows down. These changes can be represented by drawing graphs.

For an endothermic reaction (one that absorbs heat) increasing the temperature may produce large increases in the rate of reaction. A 10°C rise can double the rate while a 40°C rise can produce a 50- to 100-fold increase in the rate.

Collision theory is used to explain these effects. Increasing the concentration or the pressure of a gas means there are more particles per unit volume, therefore there are more collisions and more successful collisions. Increasing the temperature makes the particles move much faster, resulting in more collisions per unit time and more successful collisions; consequently the rate increases.

rate of reaction



(Image © Research Machines plc)

The rate of reaction decreases with time while the concentration of product increases.

ratio

measure of the relative size of two quantities or of two measurements (in similar units), expressed as a proportion. For example, the ratio of vowels to consonants in the alphabet is 5:21. As a fraction 5/26 of the letters are vowels. The ratio of 500 m to 2 km is 500:2,000, or in its simplest integer form 1:4 (dividing both sides of the ratio by 500).

Ratios are normally expressed as whole numbers, so 2:3.5 would become 4:7 (the ratio remains the same provided both parts of the ratio are multiplied or divided by the same number).

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rational number

in mathematics, any number that can be expressed as an exact fraction (with a denominator not equal to 0), that is, as $a \div b$ where a and b are integers; or an exact decimal. For example, 2/1, 1/4, 15/4, -3/5 are all rational numbers, whereas π (which represents the constant 3.141592 ...) is not. Numbers such as π are called irrational numbers.

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ratite

flightless bird that has a breastbone without the keel to which flight muscles are attached. Examples are ostrich, rhea, emu, cassowary, and kiwi.

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rat-tail

or grenadier

any fish of the family Macrouridae of deep-sea bony fishes. They have stout heads and bodies, and long tapering tails. They are common in deep waters on the continental slopes. Some species have a light-emitting organ in front of the anus.

Also known as rat-tails are some of the chimaeras.

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rattlesnake

any of various New World pit vipers of the genera *Crotalus* and *Sistrurus* (the massasaugas and pygmy rattlers), distinguished by horny flat segments of the tail, which rattle when vibrated as a warning to attackers. They can grow to 2.5 m/8 ft long. The venom injected by some rattlesnakes can be fatal.

There are 31 species distributed from southern Canada to central South America. The eastern diamondback *C. adamanteus* 0.9-2.5 m/2.8-8 ft long, is found in the flat pinelands of the southern USA.

Raunkiaer system

method of classification devised by the Danish ecologist Christen Raunkiaer (1860-1938) whereby plants are divided into groups according to the position of their perennating (overwintering) buds in relation to the soil surface. For example, plants in cold areas, such as the tundra, generally have their buds protected below ground, whereas in hot, tropical areas they are above ground and freely exposed. This scheme is useful for comparing vegetation types in different parts of the world.

The main divisions are **phanerophytes** with buds situated well above the ground; **chamaephytes** with buds borne within 25 cm/10 in of the soil surface; **hemicryptophytes** with buds at or immediately below the soil surface; and **cryptophytes** with their buds either beneath the soil (**geophyte**) or below water (**hydrophyte**).

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raven

any of several large crows, genus *Corvus*, of the Corvidae family, order Passeriformes. The common raven *C. corax* is about 60 cm/2 ft long with a wingspan of nearly 1 m/3 ft, and has black, lustrous plumage; the beak and mouth, tongue, legs, and feet are also black. It is a scavenger and is found only in the northern hemisphere.

The nest is built in cliffs or in the fork of a tall tree, and is a bulky structure. In it are laid four or five pale-green eggs spotted with brown. Incubation by the female lasts about 21 days.

Ravens are traditionally associated with death, probably from their practice of gathering in large numbers around a carcass, despite being by habit a solitary species.

---

ray

any of several orders (especially Ragiformes) of cartilaginous fishes with a flattened body, winglike pectoral fins, and a whiplike tail.

Species include the stingray, for example the Southern stingray *Dasyatis americana*, which has a serrated, poisonous spine on the tail, and the torpedo fish.

Ray, John (1627-1705)

English naturalist who devised a classification system accounting for some 18,000 plant species. It was the first system to divide flowering plants into monocotyledons and dicotyledons, with additional divisions made on the basis of leaf and flower characters and fruit types.

In *Methodus plantarum nova* (1682), Ray first set out his system. He also established the species as the fundamental unit of classification. Ray believed that fossils are the petrified remains of dead animals and plants. This concept, which appeared in his theological writings, did not gain general acceptance until the late 18th century.

Ray, Man (1890-1976)

adopted name of Emmanuel Rabinovich Rudnitsky

US photographer, painter, and sculptor. He was active mainly in France and was associated with the Dada movement and then surrealism. One of his best-known sculptures is *Gift* (1921), a surrealist ready-made consisting of an iron on to which a row of nails has been glued.

Man Ray was born in Philadelphia, but lived mostly in Paris from 1921. He began as a painter and took up photography in 1915, the year he met the Dada artist Marcel Duchamp in New York. In 1922 he invented the **rayograph**, a black-and-white image obtained without a camera by placing objects on sensitized photographic paper and exposing them to light. He also used the technique of **solarization** (partly reversing the tones on a photograph). Among his photographs is *Le Violon d'Ingres* (1924), a nude woman viewed from the back so as to suggest a violin. His photographs include portraits of many artists and writers.

His autobiography, *Self Portrait*, apppeared in 1963.

Ray, Man

Go to site

Contains an article by the photographer Man Ray entitled 'Photography can be Art'. There are also reproductions of Ray's photographs each with a brief amount of information.

Rayleigh, John William Strutt (1842-1919)

3rd Baron Rayleigh

English physicist who wrote the standard treatise *The Theory of Sound* (1877-78), experimented in optics and microscopy, and, with William Ramsay, discovered argon. He was awarded the Nobel Prize for Physics in 1904 for his work on the densities of gases and the discovery of argon. He was created a baron in 1873.

Raynaud's disease

chronic condition in which the blood supply to the extremities is reduced by periodic spasm of the blood vessels on exposure to cold. It is most often seen in young women.

Attacks are usually brought on by cold or by emotional factors. Typically, the hands and/or feet take on a corpselike pallor, changing to blue as the circulation begins to return; initial numbness is replaced by a tingling or burning sensation. Drugs may be necessary to control the condition, which in severe cases can give rise to ulceration or gangrene.

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rayon

synthetic fibre derived from cellulose that has been regenerated, by treating wood pulp and/or cotton linters (very short fibres) with chemicals to produce a syrupy, yellowish solution. The solution is then pressed through very small holes and the resulting filaments (long fibres) are solidified. There are many different types of rayon and these include viscose and cuprammonium. They all have different characteristics, but because they are derived from cellulose (like cotton), many of these are similar to those of natural fibres. Rayon can be given properties which make it look similar to silk, cotton, or wool. It absorbs moisture, does not shrink, is cool to wear, can be mixed other fibres, and is cheaper to produce than natural fibres.

---

razorbill

North Atlantic sea bird *Alca torda* of the auk family, order Charadriiformes, which breeds on cliffs and migrates south in winter. It is about 40 cm/16 in long, has a large curved beak, and is black above and white below. It uses its wings as paddles when diving. Razorbills make no nest; the female lays a single egg, which is white with brown markings. They are common off Newfoundland.

---

reactance

property of an alternating current circuit that together with any resistance makes up the impedance (the total opposition of the circuit to the passage of a current).

The reactance to an alternating current of frequency f of an inductance L is $2\pi fL$ and that of a capacitance C is $1/2\pi fC$. Reactance is measured in ohms.

---

reaction

in chemistry, the coming together, or interaction, of two or more atoms, ions, or molecules with the result that a chemical change takes place and a new substance is formed, with a different chemical composition. The nature of the reaction is described by a chemical equation. For example, in the chemical reaction that occurs when magnesium burns in oxygen, a new substance, magnesium oxide is made:

$$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$$

Chemical equations show the reactants and products of a chemical reaction by using chemical symbols and formulae. State symbols and the energy symbol (ΔH) can be used to show whether reactants and products are solids (s), liquids (l), gases (g), or are in solution (aq); and whether energy has been released or absorbed during the reaction.

Enzymes

Go to site

Part of a section dealing with rates of reaction, this page considers the role of enzymes in chemical processes. The processes of making beer and bread are used as examples of the enzyme yeast. Key words are highlighted in either red or blue.

Mass Conservation

Go to site

Insightful page on the conservation of mass within chemical reactions. An extremely short history behind the principles precedes a detailed explanation involving the formation of water, and an example of how to calculate the mass of oxygen that has reacted with a metal to form rust.

Rates of Reaction

Go to site

Colourful text-based site that covers all of the topics under the 'Rates of reaction' heading, which is necessary for numerous parts of chemistry. Key words and concepts are highlighted in either red or blue.

ScienceNet: Chemistry

Go to site

Set up as an answer to a student's question, this site covers what endothermic and exothermic reactions are. Along with helpful explanations are some examples, expressed in equation form, as well as a section at the end, which explains the normal occurrence of exothermic and endothermic reactions in the real world.

---

reaction force

in physics, the equal and opposite force described by Newton's third law of motion that arises whenever one object applies a force (**action force**) to another. For example, if a magnet attracts a piece of iron, then that piece of iron will also attract the magnet with a force that is equal in magnitude but opposite in direction. When any object rests on the ground the downwards contact force applied to the ground always produces an equal, upwards reaction force.

---

reactivity series

chemical series produced by arranging the metals in order of their ease of reaction with reagents such as oxygen, water, and acids. An example of such an arrangement, starting with the most reactive, is: potassium, sodium, calcium, magnesium, aluminium, zinc, iron, tin, lead, copper, silver, gold. This arrangement aids the understanding of the properties of metals, helps to explain differences between them, and enables predictions to be made about a metal's behaviour, based on a knowledge of its position or properties. It also allows prediction of the relative stability of the compounds formed by an element: the more reactive the metal, the more stable its compounds are likely to be.

The position of a metal in the series determines the reactions of the metal with various reagents, the displacement of one metal from its compound by another metal, and the method of extraction of a metal from its ore.

---

real number

in mathematics, any of the rational numbers (which include the integers) or irrational numbers. Real numbers exclude imaginary numbers, found in complex numbers of the general form $a + b\mathrm{i}$ where $\mathrm{i} = \sqrt{-1}$, although these do include a real component a.

---

real-time system

in computing, a program that responds to events in the world as they happen. For example, an automatic-pilot program in an aircraft must respond instantly in order to correct deviations from its course. Process control, robotics, games, and many military applications are examples of real-time systems.

---

receptacle

the enlarged end of a flower stalk to which the floral parts are attached. Normally the receptacle is rounded, but in some plants it is flattened or cup-shaped. The term is also used for the region on that part of some seaweeds which becomes swollen at certain times of the year and bears the reproductive organs.

---

receptor

in biology, receptors are discrete areas of cell membranes or areas within cells with which neurotransmitters, hormones, and drugs interact. Such interactions control the activities of the body. For example, adrenaline transmits nervous impulses to receptors in the sympathetic nervous system, which initiates the characteristic response to excitement and fear in an individual.

Other types of receptors, such as the proprioceptors, are located in muscles, tendons, and joints. They relay information on the position of the body and the state of muscle contraction to the brain.

---

recessive gene

allele (alternative form of a gene) that will show in the (phenotype observed characteristics of an organism) only if its partner allele on the paired chromosome is similarly recessive. Such an allele will not show if its partner is dominant, that is if the organism is heterozygous for a particular characteristic. Alleles for blue eyes in humans and for shortness in pea plants are recessive. Most mutant alleles are recessive and therefore are only rarely expressed (see haemophilia).

For every characteristic of a plant or animal that is inherited, there are two genes present in the cells determining this characteristic in all but a few examples. By 'characteristic' is meant 'height' or 'eye colour' or 'ability to make a particular enzyme'. If the two genes are identical (homozygous state) the characteristic seen in the organism is determined by the two genes. However, one gene may be different from the other (heterozygous state). If so, the two genes are alleles - contrasting genes for a characteristic. In this case it is possible that one of them determines the characteristic seen and the other does not. The characteristic seen in this case is said to be dominant. The other allele not expressed in this case will only be expressed when present in the homozygous state. This characteristic is said to be recessive. Sometimes the allele that produces the dominant characteristic is described as being a dominant allele and the one that tends to produce the recessive characteristic as being the recessive allele. This is not really the correct use of the terms dominant and recessive. An allele is one of two or more alternative forms of a gene. This is best explained with examples. A gene which tends to produce blue eyes in a person will have an alternative allele that tends to produce brown eye colour. In a plant that may be found in tall and short forms may have an allele that tends to produce tall plants though its alternative allele produces short plants.

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reciprocal

result of dividing a given quantity into 1. Thus the reciprocal of 2 is 1/2; the reciprocal of 2/3 is 3/2; and the reciprocal of x^2 is $1/x^2$ or x^{-2}. Reciprocals are used to replace division by multiplication, since multiplying by the reciprocal of a number is the same as dividing by that number.

On a calculator, the reciprocals of all numbers except 0 are obtained by using the button marked $1/x$.

---

recombinant DNA

in genetic engineering, DNA formed by splicing together genes from different sources into new combinations.

recombination

in genetics, any process that recombines, or 'shuffles', the genetic material, thus increasing genetic variation in the offspring. The two main processes of recombination both occur during meiosis (reduction division of cells). One is **crossing over**, in which chromosome pairs exchange segments; the other is the random reassortment of chromosomes that occurs when each gamete (sperm or egg) receives only one of each chromosome pair.

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recording

any of a variety of techniques used to capture, store, and reproduce music, speech, and other information carried by sound waves. A microphone first converts the sound waves into an electrical signal that varies in proportion to the loudness of the sound. The signal can be stored in digital or analogue form, or on magnetic tape.

analogue recording

In an analogue recording, the pattern of the signal is copied into another form. In a **vinyl** gramophone record, for example, a continuous spiral groove is cut into a plastic disc by a vibrating needle. The recording is replayed by a stylus that follows the track of the groove, and so reproduces the vibrations that are amplified and turned back into sound. In a **magnetic tape** recording, the signal is recorded as a pattern of magnetization on a plastic tape coated with a magnetic powder. When the tape is played back, the magnetic patterns create an electrical signal that, as with the gramophone record, is used to recreate the original sound. All analogue recording techniques suffer from background noise and the quality of reproduction gradually degrades as the format changes and the disc or tape wears out.

digital recording

In digital recording, the signals picked up by the microphone are converted into a stream of numbers that can then be stored in several ways. The most well-known of these is the compact disc, in which numbers are coded as a string of tiny pits pressed into a 12 cm/4.7 in plastic disk. When the recording is played back, using a laser, the exact values are retrieved and converted into a varying electrical signal and then back into sound. Digital recording is relatively free from noise and interference and gives a very high quality of reproduction. It is also suitable for storing information to be processed by computers.

---

record player

device for reproducing recorded sound stored as a spiral groove on a vinyl disc. A motor-driven turntable rotates the record at a constant speed, and a stylus or needle on the head of a pick-up is made to vibrate by the undulations in the record groove. These vibrations are then converted to electrical signals by a transducer in the head (often a piezoelectric crystal). After amplification, the signals pass to one or more loudspeakers, which convert them into sound. The vinyl disc has been almost wholly superseded by the compact disc. Alternative sound-recording formats include magnetic tape recording and the hard discs and memory cards found in computers and in personal music players.

The pioneers of the record player were Thomas Edison, with his phonograph playing recordings on cylinders, and Emile Berliner (1851-1929), who invented the predecessor of the vinyl record 1896.

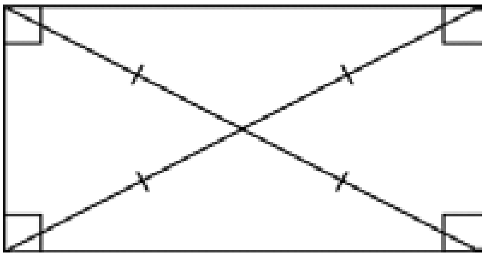
---

rectangle

quadrilateral (four-sided plane figure) with opposite sides equal and parallel and with each interior angle a right angle (90°). Its area A is the product of the length l and height h; that is, $A = l \times h$. A rectangle with all four sides equal is a square.

A rectangle is a special case of a parallelogram. The diagonals of a rectangle are equal and bisect each other.

rectangle



(Image © Research Machines plc)

A rectangle (or oblong) has four sides, with the opposite sides being parallel and of equal length. Its four angles are all right angles. Its diagonals are of equal length.

---

rectifier

device for obtaining one-directional current (DC) from an alternating source of supply (AC). (The process is necessary because almost all electrical power is generated, transmitted, and supplied as alternating current, but many devices, from television sets to electric motors, require direct current.) Types include plate rectifiers, thermionic diodes, and semiconductor diodes.

rectum

lowest part of the large intestine of animals, which stores faeces prior to elimination (defecation).

recursion

in computing and mathematics, a technique whereby a function or procedure calls itself into use in order to enable a complex problem to be broken down into simpler steps. For example, a function that finds the factorial of a number *n* (calculates the product of all the whole numbers between 1 and *n*) would obtain its result by multiplying *n* by the factorial of *n* - 1.

recycling

processing of industrial and household waste (such as paper, glass, and some metals and plastics) so that the materials can be reused. This saves expenditure on scarce raw materials, slows down the depletion of non-renewable resources, and helps to reduce pollution. Aluminium is frequently recycled because of its value and special properties that allow it to be melted down and re-pressed without loss of quality, unlike paper and glass, which deteriorate when recycled.

The USA recycles only around 25% of its waste (1998), compared with around 33% in Japan. However, all US states encourage or require local recycling programmes to be set up. It was estimated in 1992 that 4,000 cities collected waste from 71 million people for recycling. Most of these programmes were set up 1989-92. Around 33% of newspapers, 22% of office paper, 64% of aluminium cans, 3% of plastic containers, and 20% of all glass bottles and jars were recycled.

Recycle City

Go to site

Child-friendly site of the US Environmental Protection Agency designed to help people to live more ecologically. The site includes games and activities to encourage children to think about waste disposal issues.

Zero Waste America

Go to site

Site dedicated to the elimination (not reduction) of waste and pollution. The Zero Waste America organization explains its drastic aim of banning garbage. It provides ideas for action by local campaigning groups, and sets out a domestic strategy for composting, recycling and re-using everything the household consumes. This huge resource provides legal reports and a database of political and scientific information relevant to the zero waste ideal.

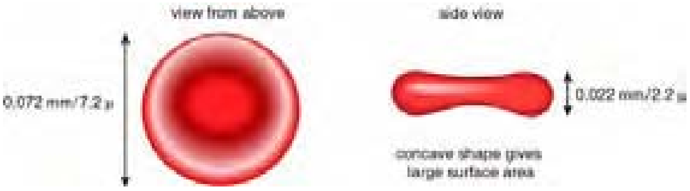
red blood cell

or erythrocyte

most common type of blood cell, and responsible for transporting oxygen around the body. They contain haemoglobin, a red protein, which combines with oxygen from the lungs to form oxyhaemoglobin. When transported to the tissues the oxyhaemoglobin splits into its original constituents, and the cells are able to release the oxygen. There are about 6 million red cells in every cubic centimetre of blood.

The red cell is a highly specialized cell with a distinctive shape. In mammals they are in the shape of a disc with a depression in the face of the disc and lose their nucleus before they work as oxygen transporters in order to make maximum space for haemoglobin. In other vertebrates they are oval and nucleated. They are manufactured in the bone marrow. In humans, red cells last for only four months before being destroyed in the liver. Haemoglobin contains iron, which is why this mineral must be included as part of a balanced diet. However, the liver can store and re-use iron from old red cells.

red blood cell



(Image © Research Machines plc)

The structure of a human red blood cell. Their concave surfaces give them a large surface area for the transportation of haemoglobin.

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red deer

large deer widely distributed throughout Europe, Asia and North Africa. A full-grown male (stag or hart) stands 1.2 m/4 ft at the withers, and typical antlers measure about 80 cm/31 in in length with a spread of about the same. During the breeding season the colour is a rich brown, turning grey at the approach of winter. The young are spotted with white.

The antlers are shed in April or May, and a few days afterwards the new growth shows. While the new antlers are developing they are covered with a thick velvet, and while in this condition are very sensitive. They are full-grown in about 12 weeks, and the 'velvet' is then rubbed off. Hornless stags sometimes occur.

classification

The red deer *Cervus elaphus* is in family Cervidae, order Artiodactyla.

---

red dwarf

any star that is cool, faint, and small (about one-tenth the mass and diameter of the Sun). Red dwarfs burn slowly, and have estimated lifetimes of 100 billion years. They may be the most abundant type of star, but are difficult to see because they are so faint. Two of the closest stars to the Sun, Proxima Centauri and Barnard's Star, are red dwarfs.

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red giant

any large bright star with a cool surface. It is thought to represent a late stage in the evolution of a star like the Sun, as it runs out of hydrogen fuel at its centre and begins to burn heavier elements, such as helium, carbon, and silicon. Because of more complex nuclear reactions that then occur in the red giant's interior, it eventually becomes gravitationally unstable and begins to collapse and heat up. The result is either explosion of the star as a supernova, leaving behind a neutron star, or loss of mass by more gradual means to produce a white dwarf.

Red giants have diameters between 10 and 100 times that of the Sun. They are very bright because they are so large, although their surface temperature is lower than that of the Sun, about 2,000-3,000 K (1,700-2,700°C/3,000-5,000°F). See also red supergiants.

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red-hot poker

any of a group of perennial plants native to Africa, in particular *K. uvaria*, with a flame-coloured spike of flowers. (Genus *Kniphofia*, family Liliaceae.)

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redox reaction

chemical change where one reactant is reduced and the other reactant oxidized. The reaction can only occur if both reactants are present and each changes simultaneously. For example, hydrogen reduces copper(II) oxide to copper while it is itself oxidized to water. The corrosion of iron and the reactions taking place in electric and electrolytic cells are just a few examples of redox reactions.

Oxidation and Reduction

Go to site

Introduction to these key electrochemical concepts from the student-created 'ThinkQuest' site. Using tables, equations, and easily understood text, this page explains how oxidation-reduction or redox reactions produce the current that drives batteries. Click forward to access useful pages on other electrochemistry topics such as electrodes and Faraday's constant.

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red setter

breed of dog. See setter.

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redshank

wading bird *Tringa totanus* of northern Europe and Asia, a type of sandpiper. It nests in swampy areas, rarely in Europe, since most redshanks winter in the south. It is greyish and speckled black, and has long red legs.

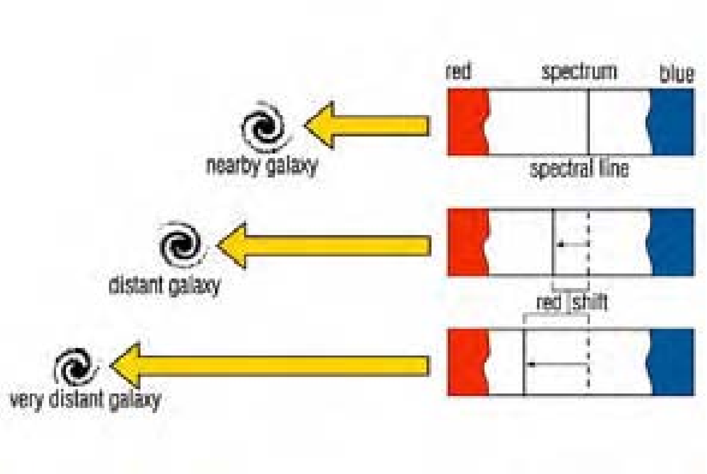
---

red shift

in astronomy, lengthening of the wavelengths of light from an object as a result of the object's motion away from us. It is an example of the Doppler effect. The red shift in light from galaxies is evidence that the universe is expanding.

Lengthening of wavelengths causes the light to move or shift towards the red end of the spectrum, hence the name. The amount of red shift can be measured by the displacement of lines in an object's spectrum. By measuring the amount of red shift in light from stars and galaxies, astronomers can tell how quickly these objects are moving away from us. A strong gravitational field can also produce a red shift in light; this is termed **gravitational red shift**.

red shift



(Image © Research Machines plc)

The red shift causes lines in the spectra of galaxies to be shifted towards the red end of the spectrum. More distant galaxies have greater red shifts than closer galaxies. The red shift indicates that distant galaxies are moving apart rapidly, as the universe expands.

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redstart

any of several New World wood warblers (family Parulidae), especially the American redstart *Setophaga ruticulla*.

The male is black and orange with white underparts. Old World redstarts are small thrushes with a reddish tail, belonging to the genus *Phoenicurus*.

Redstone rocket

short-range US military missile, modified for use as a space launcher. Redstone rockets launched the first two flights of the *Mercury* project. A modified Redstone, Juno 1, launched the first US satellite, Explorer 1, in 1958.

The rocket was developed at Redstone Arsenal in Huntsville, Alabama, by a team headed by German rocket engineer Wernher von Braun.

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reduction

in chemistry, the gain of electrons, loss of oxygen, or gain of hydrogen by an atom, ion, or molecule during a chemical reaction.

Reduction may be brought about by reaction with another compound, which is simultaneously oxidized (reducing agent), or electrically at the cathode (negative electrode) of an electric cell. Examples include the reduction of iron(III) oxide to iron by carbon monoxide:

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

the hydrogenation of ethene to ethane:

$CH_2{=}CH_2 + H_2 \rightarrow CH_3{-}CH_3$

and the reduction of a sodium ion to sodium:

$Na^+ + e^- \rightarrow Na$

redwing

type of thrush *Turdus iliacus*, family Muscicapidae, order Passeriformes. It is smaller than the song thrush, with reddish wing and body markings, and there is a distinct white line over the eye. It breeds in the north of Europe and Asia, flying south in winter.

redwood

giant coniferous tree, one of the two types of sequoia.

reed

any of various perennial tall, slender grasses found growing in wet or marshy environments; also the hollow, jointed stalks of any of these plants. The common reed (*P. australis*) reaches a height of 3 m/10 ft, having stiff, upright leaves and straight stems with a plume of purplish flowers at the top. (Especially species of the genera *Phragmites* and *Arundo*, family Gramineae.)

reflecting telescope

telescope in which light is collected and brought to a focus by a concave mirror. Cassegrain and Newtonian telescopes are examples.

refining

any process that purifies or converts something into a more useful form. Metals usually need refining after they have been extracted from their ores by such processes as smelting. Petroleum, or crude oil, needs refining before it can be used; the process involves fractional distillation, the separation of the substance into separate components or 'fractions'.

Electrolytic metal-refining methods use the principle of electrolysis to obtain pure metals. When refining petroleum, or crude oil, further refinery processes after fractionation convert the heavier fractions into more useful lighter products. The most important of these processes is cracking; others include polymerization, hydrogenation, and reforming.

reflection

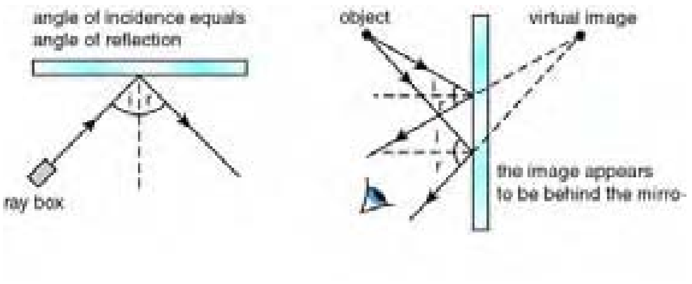
throwing back or deflection of waves, such as light or sound waves, when they hit a surface. Reflection occurs whenever light falls on an object. The **law of reflection** states that the angle of incidence (the angle between the ray and a perpendicular line drawn to the surface) is equal to the angle of reflection (the angle between the reflected ray and a perpendicular to the surface).

Looking at an image on the surface of the water in a lake is an example of light rays reflecting towards the observer. Reflection of light takes place from all materials. Some materials absorb a small amount of light and reflect most of it back; for example, a shiny, silvery surface. Other materials absorb most of the light and reflect only a small amount back; for example, a dark, dull surface. Reflected light gives objects their visible texture and colour.

Light reflected from a surface can be either regular (plane), where the surface is flat and smooth and light rays are reflected without any scattering; or scattered, where the surface is irregular (in effect, many different surfaces). The colour of the sky is due to scattering of sunlight by particles in the atmosphere, such as dust and gas particles, water droplets, or ice crystals. On a clear day the sky appears blue due to the scattering of shorter wavelength light.

When light passes from a dense medium to a less dense medium, such as from water to air, both refraction and reflection can occur. If the angle of incidence is small, the reflection will be relatively weak compared to the refraction. But as the angle of incidence increases the relative degree of reflection will increase. At some **critical angle of incidence** the angle of refraction is 90°. Since refraction cannot occur above 90°, the light is totally reflected at angles above this critical angle of incidence. This condition is known as **total internal reflection**. Total internal reflection is used in fibre optics to transmit data over long distances, without the need of amplification.

reflection



(Image © Research Machines plc)

Light rays reflected from a regular (plane) mirror. The angle of incidence is the angle between the ray and a perpendicular line drawn to the surface and the angle of reflection is the angle between the reflected ray and a perpendicular to the surface. The image of an object in a plane mirror is described as virtual or imaginary because it appears to be the position from which the rays are formed.

---

reflex

in animals, a very rapid involuntary response to a particular stimulus. It is controlled by the nervous system. A reflex involves only a few nerve cells, unlike the slower but more complex responses produced by the many processing nerve cells of the brain.

A **simple reflex** is entirely automatic and involves no learning. Examples of such reflexes include the sudden withdrawal of a hand in response to a painful stimulus, or the jerking of a leg when the kneecap is tapped. Sensory cells (receptors) in the knee send signals to the spinal cord along a sensory nerve cell. Within the spine a **reflex arc** switches the signals straight back to the muscles of the leg (effectors) via an intermediate nerve cell and then a motor nerve cell; contraction of the leg occurs, and the leg kicks upwards. Only three nerve cells are involved, and the brain is only aware of the response after it has taken place. Such reflex arcs are particularly common in lower animals, and have a high survival value, enabling organisms to take rapid action to avoid potential danger. In higher animals (those with a well-developed central nervous system) the simple reflex can be modified by the involvement of the brain - for instance, humans can override the automatic reflex to withdraw a hand from a source of pain.

A **conditioned reflex** involves the modification of a reflex action in response to experience (learning). A stimulus that produces a simple reflex response becomes linked with another, possibly unrelated, stimulus. For example, a dog may salivate (a reflex action) when it sees its owner remove a tin-opener from a drawer because it has learned to associate that stimulus with the stimulus of being fed.

Integration and Control: How Nervous Systems Work

Go to site

Text-based page on the nervous system from the University of Maryland. The page describes concepts such as the reflex arc and explains the main differences between the nervous systems of vertebrate and invertebrate species.

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reflex angle

angle greater than 180° but less than 360°.

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reflex camera

camera that uses a mirror and prisms to reflect light passing through the lens into the viewfinder, showing the photographer the exact scene that is being shot. When the shutter button is released the mirror springs out of the way, allowing light to reach the film. The most common type is the single-lens reflex (SLR) camera. The twin-lens reflex (TLR) camera has two lenses: one has a mirror for viewing, the other is used for exposing the film.

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reflexology

in alternative medicine, manipulation and massage of the feet to ascertain and treat disease or dysfunction elsewhere in the body. It is based on the belief that each part of the foot is a mirror site for a part of the body. Reflexologists consider themselves to be holistic medicine practitioners, not foot doctors, as they believe that the whole body is represented in the feet.

Correspondence between reflex points on the feet and remote organic and physical functions were discovered in the West early in the 20th century by US physician William Fitzgerald, who also found that pressure and massage applied to these reflex points beneficially affect the related organ or function. He published his work in *Zone Therapy* in 1917. In the 1930s, Eunice Ingham (1889-1974) simplified Fitzgerald's teachings, concentrating on the energy zones in the feet, and called the result reflexology.

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refraction

bending of a wave when it passes from one medium into another. It is the effect of the different speeds of wave propagation in two substances that have different densities. For example, when light passes from air (less dense) into glass (more dense) it slows down (from 300 million to 200 million metres per second) and is refracted. The amount of refraction depends on the densities of the media, the angle at which the wave strikes the surface of the second medium, and the amount of bending and change of velocity corresponding to the wave's frequency (dispersion). Refraction occurs with all types of progressive waves – electromagnetic waves, sound waves, and water waves – and differs from reflection, which involves no change in velocity.

refraction of light

The degree of refraction depends in part on the angle at which the light hits the surface of a material. A line perpendicular to that surface is called the **normal**. The angle between the incoming light ray and the normal to the surface is called the **angle of incidence**. The angle between the refracted ray and the normal is called the **angle of refraction**. The angle of refraction cannot exceed 90°. An example of refraction is light hitting a glass pane. When light in air enters the denser medium, it is bent toward the normal. When light passes out of the glass into the air, which is less dense, it is bent away from the normal. The incident light will be parallel to the emerging light because the two faces of the glass are parallel. However, if the two faces are not parallel, as with a prism, the emerging light will not be parallel to the incident light. The angle between the incident ray and the emerging ray is called the **angle of deviation**. The amount of bending and change in velocity of the refracted wave is due to the amount of dispersion corresponding to the wave's frequency, and the **refractive index** of the material. When light hits the denser material, its frequency remains constant, but its velocity decreases due to the influence of electrons in the denser medium. Constant frequency means that the same number of light waves must pass by in the same amount of time. If the waves are slowing down, wavelength must also decrease to maintain the constant frequency. The waves become more closely spaced, bending toward the normal as if they are being dragged. The refractive index of a material indicates by how much a wave is bent. It is found by dividing the velocity of the wave in the first medium by the velocity of the wave in the second medium. The **absolute refractive index** of a material is the velocity of light in that material relative to the velocity of light in a vacuum. See also apparent depth.

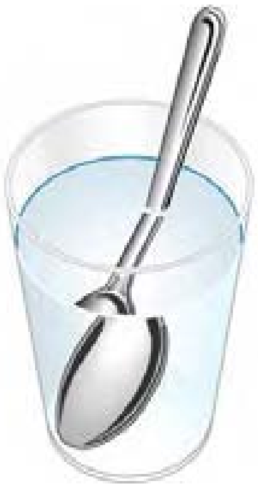
refraction of sound

Sound waves, unlike light waves, travel faster in denser materials, such as solids and liquids, than they travel in air. When sound waves enter a solid, their velocity and wavelength *increase* and they are bent away from the normal to the surface of the solid.

water waves

Water waves are refracted when their velocity decreases. Water waves slow down as water becomes shallower. A good example of this is a wavefront approaching a shore that is shallower in one place and deeper in another. When the wavefront approaches, the part of the wave in shallower water will slow down and its wavelength will decrease, causing it to lag behind the part of the wave in the deeper water.

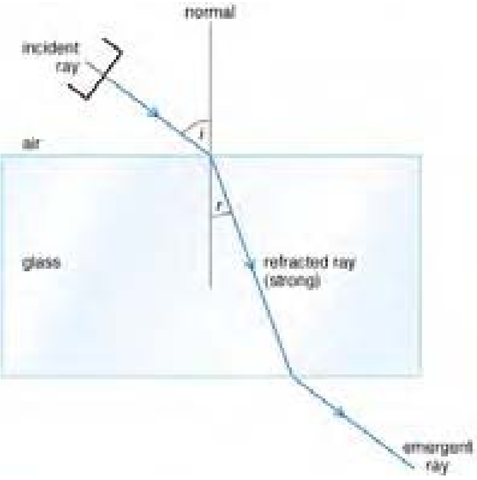
refraction



(Image © Research Machines plc)

Refraction is the bending of a light beam when it passes from one transparent medium to another. This is why a spoon appears bent when standing in a glass of water and pools of water appear shallower than they really are. The quantity sin *i*/sin *r* has a constant value, for each material, called the refractive index.

refraction



(Image © Research Machines plc)

The refraction of light through glass. When the light ray strikes the glass (a denser medium than the air) it is bent towards the normal. When it leaves the glass and re-enters the less dense medium it is bent away from the normal.

---

refractive index

measure of the refraction of a ray of light as it passes from one transparent medium to another. If the angle of incidence is *i* and the angle of refraction is *r*, the ratio of the two refractive indices is given by $n_1/n_2 = \sin i/\sin r$. It is also equal to the speed of light in the first medium divided by the speed of light in the second, and it varies with the wavelength of the light.

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refractor

in astronomy, telescope in which light is collected and brought to a focus by a convex lens (the object lens or objective).

---

refractory

(of a material) able to resist high temperature, for example ceramics made from clay, minerals, or other earthy materials. Furnaces are lined with refractory materials such as silica and dolomite.

Alumina (aluminium oxide) is an excellent refractory, often used for the bodies of spark plugs. Titanium and tungsten are often called refractory metals because they are temperature resistant. Cermets are refractory materials made up of ceramics and metals.

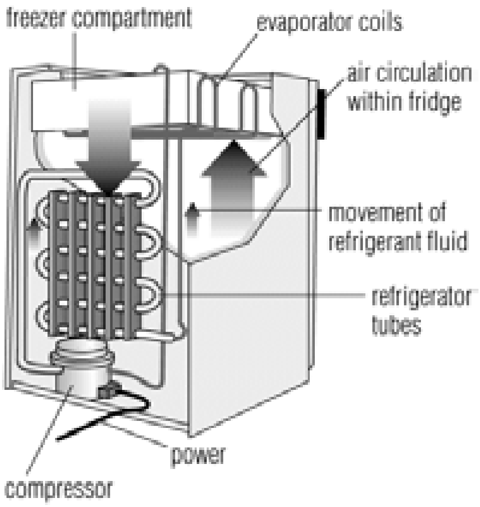
---

refrigeration

use of technology to transfer heat from cold to warm, against the normal temperature gradient, so that an object can remain substantially colder than its surroundings. Refrigeration equipment is used for the chilling and deep-freezing of food in food technology, and in air conditioners and industrial processes.

Refrigeration is commonly achieved by a vapour-compression cycle, in which a suitable chemical (the refrigerant) travels through a long circuit of tubing, during which it changes from a vapour to a liquid and back again. A compression chamber makes it condense, and thus give out heat. In another part of the circuit, called the evaporator coils, the pressure is much lower, so the refrigerant evaporates, absorbing heat as it does so. The evaporation process takes place near the central part of the refrigerator, which therefore becomes colder, while the compression process takes place near a ventilation grille, transferring the heat to the air outside. The most commonly used refrigerants in modern systems were chlorofluorocarbons (CFCs), but these are now being replaced by coolants that do not damage the ozone layer.

refrigeration



(Image © Research Machines plc)

The constituent parts of a refrigerator and the flow of air and refrigerant fluid around the system.

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regelation

phenomenon in which water refreezes to ice after it has been melted by pressure at a temperature below the normal freezing point of water. Pressure makes an ice skate, for example, form a film of water that freezes once again after the skater has passed.

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register

in computing, a memory location that can be accessed rapidly; it is often built into the computer's central processing unit.

Some registers are reserved for special tasks – for example, an **instruction register** is used to hold the machine-code command that the computer is currently executing, while a **sequence-control register** keeps track of the next command to be executed. Other registers are used for holding frequently used data and for storing intermediate results.

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regolith

surface layer of loose material that covers most bedrock. It consists of eroded rocky material, volcanic ash, river alluvium, vegetable matter, or a mixture of these known as soil.

---

regular

describing geometric figures having all angles and sides equal. Also, of solids, having bases comprised of regular polygons.

Regulus

or Alpha Leonis

brightest star in the constellation Leo, and the 21st brightest star in the sky. First-magnitude Regulus has a true luminosity 100 times that of the Sun, and is 85 light years from Earth.

Regulus was one of the four royal stars of ancient Persia marking the approximate positions of the Sun at the equinoxes and solstices. The other three were Aldebaran, Antares, and Fomalhaut.

---

regurgitation

in medicine, the return of food that has already been swallowed from the oesophagus or the stomach to the mouth.

Regurgitation of blood in the heart results from defective heart valves. These inhibit the passage of blood from the atria to the ventricles or from the ventricles to the arteries.

---

rehabilitation

in medicine, the period required to restore general health and the capacity to work following recovery from the immediate effects of disease, mental illness, or addiction.

Reich, Wilhelm (1897-1957)

Austrian physician who emigrated to the USA in 1939. He combined Marxism and psychoanalysis to advocate the positive effects of directed sexual energies and sexual freedom. His works include *Die Sexuelle Revolution/The Sexual Revolution* (1936-45) and *Die Funktion des Orgasmus/The Function of the Orgasm* (1948).

Reichstein, Tadeus (1897-1996)

Swiss biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1950 for work on the structure and biological effects of hormones of the adrenal cortex. By 1946 Reichstein had identified a large number of steroids secreted by the adrenal cortex, some of which would later be used in the treatment of Addison's disease. Reichstein shared the prize with Edward Kendall and Philip Hench.

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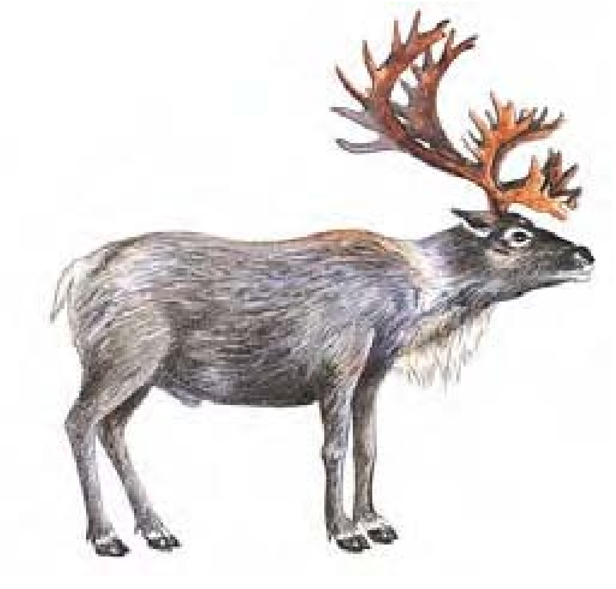
reindeer

or caribou

deer *Rangifer tarandus* of Arctic and subarctic regions, common to North America and Eurasia. About 1.2 m/4 ft at the shoulder, it has a thick, brownish coat and broad hooves well adapted to travel over snow. It is the only deer in which both sexes have antlers; these can grow to 1.5 m/5 ft long, and are shed in winter.

The Old World reindeer have been domesticated by the Lapps of Scandinavia for centuries. There are two types of North American caribou: the large woodland caribou of the more southerly regions, and the barren-ground caribou of the far north. Reindeer migrate south in winter, moving in large herds. They eat grass, small plants, and lichens.

reindeer



(Image © Research Machines plc)

The reindeer ranges over the tundra of Northern Europe and Asia, Alaska, Canada, and Greenland. It is a social animal, living in large herds containing thousands of individuals. Some herds migrate hundreds of kilometres from their breeding grounds on the tundra to their winter feeding grounds farther south.

reindeer

(Image © Corel)

Male reindeer *Rangifer tarandus* with a full set of antlers. The animals use their antlers to uncover edible vegetation buried by snow. Their large hooves are adapted to spread for balance when they walk on snow or soft ground.

reindeer migration

(Image © Corel)

Reindeer *Rangifer tarandus* migrate in herds over vast distances between their summer and winter feeding grounds. They are adapted to both tundra and woodland environments.

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relational database

database in which data are viewed as a collection of linked tables. It is the most popular of the three basic database models, the others being **network** and **hierarchical**. Its theoretical concepts were developed by E F Codd (1924-2003) in the early 1970s.

---

relative

in computing (of a value), variable and calculated from a base value. For example, a **relative address** is a memory location that is found by adding a variable to a base (fixed) address, and a **relative cell reference** locates a cell in a spreadsheet by its position relative to a base cell - perhaps directly to the left of the base cell or three columns to the right of the base cell. The opposite of relative is absolute.

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relative density

density (at 20°C/68°F) of a solid or liquid relative to (divided by) the maximum density of water (at 4°C/39.2°F). The relative density of a gas is its density divided by the density of hydrogen (or sometimes dry air) at the same temperature and pressure.

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relative humidity

concentration of water vapour in the air. It is expressed as the ratio of the partial pressure of the water vapour to its saturated vapour pressure at the same temperature. The higher the temperature, the higher the saturated vapour pressure.

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relativity

in physics, theory of the relative rather than absolute character of mass, time, and space, and their interdependence, as developed by German-born US physicist Albert Einstein in two phases:

special theory of relativity (1905)

Starting with the premises that (1) the laws of nature are the same for all observers in unaccelerated motion and (2) the speed of light is independent of the motion of its source, Einstein arrived at some rather unexpected consequences. Intuitively familiar concepts, like mass, length, and time, had to be modified. For example, an object moving rapidly past the observer will appear to be both shorter and more massive than when it is at rest (that is, at rest relative to the observer), and a clock moving rapidly past the observer will appear to be running slower than when it is at rest. These predictions of relativity theory seem to be foreign to everyday experience merely because the changes are quite negligible at speeds less than about 1,500 kps/930 mps and only become appreciable at speeds approaching the speed of light.

general theory of relativity (1915)

The geometrical properties of space-time were to be conceived as modified locally by the presence of a body with mass. A planet's orbit around the Sun (as observed in three-dimensional space) arises from its natural trajectory in modified space-time. Einstein's general theory accounts for a peculiarity in the behaviour of the motion of the perihelion of the orbit of the planet Mercury that cannot be explained in Newton's theory. The new theory also said that light rays should bend when they pass by a massive object. The predicted bending of starlight was observed during the eclipse of the Sun in 1919. A third corroboration is found in the shift towards the red in the spectra of the Sun and, in particular, of stars of great density - white dwarfs such as the companion of Sirius.

Einstein showed that, for consistency with the above premises (1) and (2), the principles of dynamics as established by Newton needed modification; the most celebrated new result was the equation $E = mc^2$, which expresses an equivalence between mass (m) and energy (E), c being the speed of light in a vacuum. In 'relativistic mechanics', conservation of mass is replaced by the new concept of conservation of 'mass-energy'. General relativity is central to modern astrophysics and cosmology; it predicts, for example, the possibility of black holes. General relativity theory was inspired by the simple idea that it is impossible in a small region to distinguish between acceleration and gravitation effects (as in a lift one feels heavier when the lift accelerates upwards), but the mathematical development of the idea is formidable. Such is not the case for the special theory, which a non-expert can follow up to $E = mc^2$ and beyond.

Cambridge Relativity

Go to site

Discussion of quantum gravity, strings, black holes, inflation, and cosmology, on Cambridge's relativity pages. The site also has information on COSMOS, the national cosmology supercomputer, and links to English physicist Stephen Hawking's pages.

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relaxation therapy

development of regular and conscious control of physiological processes and their related emotional and mental states, and of muscular tensions in the body, as a way of relieving stress and its results. Meditation, hypnotherapy, autogenics, and biofeedback are techniques commonly employed.

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relaxin

hormone produced naturally by women during pregnancy that assists childbirth. It widens the pelvic opening by relaxing the ligaments, inhibits uterine contractility, so preventing premature labour, and causes dilation of the cervix. A synthetic form was pioneered by the Howard Florey Institute in Australia, and this drug has possible importance in helping the birth process and avoiding surgery or forceps delivery.

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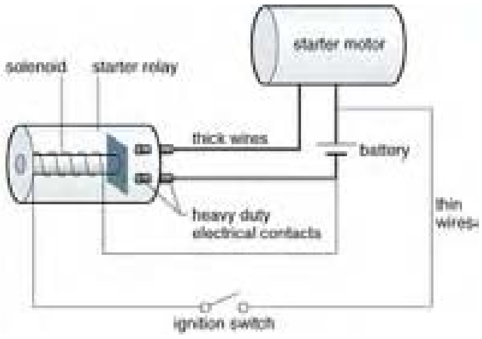
relay

in electrical engineering, an electromagnetic switch. A small current passing through a coil of wire wound around an iron core attracts an armature whose movement closes a pair of sprung contacts to complete a secondary circuit, which may carry a large current or activate other devices. The solid-state equivalent is a thyristor switching device.

relay



(Image © Research Machines plc)

A relay is a device that allows a small amount of electrical current to control a large amount of current. A car starter motor uses a relay to solve the problem that a car has in needing a large amount of current to start the engine. A starter relay is installed in series between the battery and the starter. Some cars use a starter solenoid (as shown here) to accomplish the same purpose of allowing a small amount of current from the ignition switch to control a high current flow from the battery to the starter.

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rem

acronym for roentgen equivalent man

unit of radiation dose equivalent.

Remington, Philo (1816-1889)

US inventor and businessman. He designed the breech-loading rifle that bears his name. He began manufacturing typewriters in 1873, using the patent of Christopher Sholes, and made improvements that resulted five years later in the first machine with a shift key, thus providing lower-case letters as well as capital letters.

The Remington rifle and carbine, which had a falling block breech and a tubular magazine, were developed in collaboration with his father Eliphalet Remington.

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remission

in medicine, temporary disappearance of symptoms during the course of a disease.

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remora

any of a family of warm-water fishes that have an adhesive disc on the head, by which they attach themselves to whales, sharks, and turtles. These provide the remora with shelter and transport, as well as food in the form of parasites on the host's skin.

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remote sensing

gathering and recording information from a distance. Aircraft and satellites can observe a planetary surface or atmosphere, and space probes have sent back photographs and data about planets as distant as Neptune. Remote sensing usually refers to gathering data of the electromagnetic spectrum (such as visible light, ultraviolet light, and infrared light). In archaeology, surface survey techniques provide information without disturbing subsurface deposits.

Remote sensing is most commonly taken to refer to the process of photographing the Earth's surface with orbiting satellites. Satellites such as *Landsat* have surveyed all of the Earth's surface from orbit. Computer processing of data obtained by their scanning instruments, and the application of so-called false colours (generated by computer), have made it possible to reveal surface features invisible in ordinary light. This has proved valuable in agriculture, forestry, and urban planning, and has led to the discovery of new deposits of minerals.

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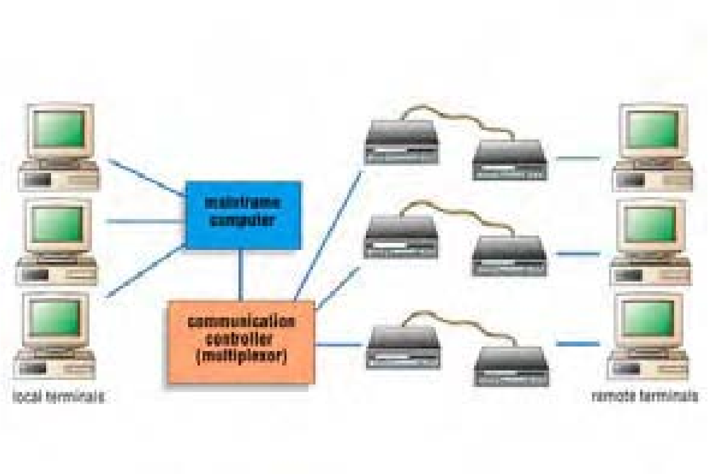
remote terminal

in computing, a terminal that communicates with a computer via a modem (or acoustic coupler) and a telephone line.

remote terminal



(Image © Research Machines plc)

Remote computer terminals communicate with the central mainframe via modems and telephone lines. The controller allocates computer time to the terminals according to predetermined priority rules. The multiplexer allows more than one terminal to use the same communications link at the same time (multiplexing).

REM sleep

acronym for rapid-eye-movement sleep

phase of sleep that recurs several times nightly in humans and is associated with dreaming. The eyes flicker quickly beneath closed lids.

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renal

pertaining to the kidneys.

Renault

France's largest motor-vehicle manufacturer, founded in 1898. In November 1994 the French government began to implement plans to privatize the company, which had been nationalized from 1944.

Louis Renault (1877–1944) formed the company with his brothers Fernand and Marcel. In 1899 they began motor racing, which boosted the sales of their cars, and by 1908 they were producing 5,000 cars a year. The company produced tanks for the French army in both world wars.

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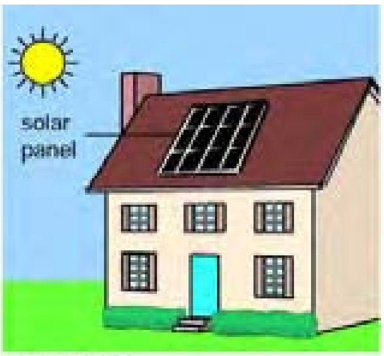
renewable energy

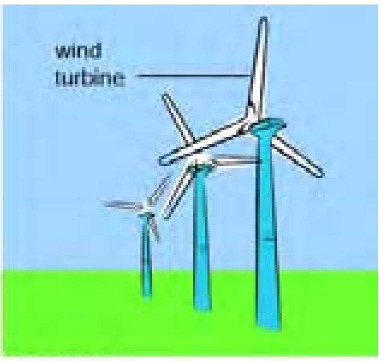
power from any source that can be replenished. Most renewable systems rely on solar energy directly or through the weather cycle as wave power, hydroelectric power, wind power via wind turbines, or solar energy collected by plants (alcohol fuels, for example). In addition, the gravitational force of the Moon can be harnessed through tidal power stations, and the heat trapped in the centre of the Earth is used via geothermal energy systems. Other examples are energy from biofuel and fuel cells. Renewable energy resources have the advantage of being non-polluting. However, some (such as wind energy) can be unreliable and therefore lose their effectiveness in providing a constant supply of energy.

Despite inherent problems with the technology behind renewable energy sources, increasing environmental pressure is forcing development at an increasing pace. By the end of 2002, worldwide wind-power generation had exceeded 30 megawatts and had reached an annual growth rate of 25%.

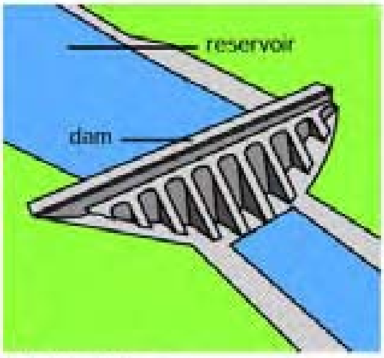
renewable energy



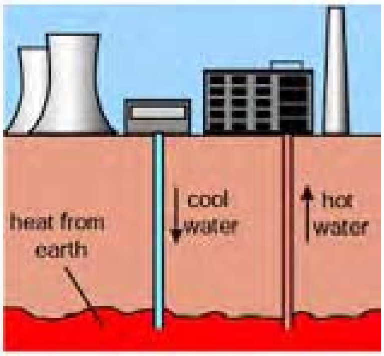
solar power



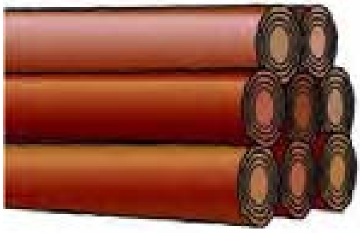
wind power



hydroelectric power



geothermal energy



biomass

(Image © Research Machines plc)

Some examples of renewable energy. Panels of solar cells can be used to convert the light of the Sun into electrical energy. Wind turbines are connected to generators and turn to generate electricity. In a typical hydroelectric plant, water is stored in a reservoir. The water's potential energy is converted to kinetic energy as it is piped into turbines that are connected to generators. Geothermal energy harnesses the heat of the Earth to provide heating and electricity. Biomass is organic matter that can be converted to provide heat or electricity.

---

renewable resource

natural resource that is replaced by natural processes in a reasonable amount of time. Soil, water, forests, plants, and animals are all renewable resources as long as they are properly conserved. Solar, wind, wave, and geothermal energies are based on renewable resources.

Hydroelectric Power

Go to site

Insight and introduction to how hydroelectric power (HEP) works. The site provides an animated diagram, which allows the path of the water to be traced through a HEP plant, and shows how electricity is generated from it. Further relevant links to resources dealing with other aspects of HEP are provided.

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rennet

extract, traditionally obtained from a calf's stomach, that contains the enzyme rennin, used to coagulate milk in the cheesemaking process. The enzyme can now be chemically produced.

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rennin

or chymase

enzyme found in the gastric juice of young mammals, used in the digestion of milk.

---

repellent

anything whose smell, taste, or other properties discourages nearby creatures.
Insect repellent is usually a chemical substance that keeps, for example, mosquitoes at bay; natural substances include citronella, lavender oil, and eucalyptus oils. A device that emits ultrasound waves is also claimed to repel insects and small mammals.

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repetitive strain injury

RSI

generic term for various kinds of work-related musculoskeletal injuries, such as carpal tunnel syndrome and tendonitis. Symptoms of RSI include inflammation of tendon sheaths, mainly in the hands and wrists, which may be disabling. It is found predominantly in factory workers involved in constant repetitive movements, and in those who work with computer keyboards. The symptoms include aching muscles, weak wrists, tingling fingers, and in severe cases, pain and paralysis. Some victims have successfully sued their employers for damages.

In many RSI cases, there is no actual sign of tissue damage and some researchers are beginning to believe that the origin of the pain may be due to a problem in the brain rather than the tissues, with the brain rewiring its neurones to cope with continual repetitive movements until it loses awareness of which finger is which.

Focal hand dystonia, commonly known as writer's or musician's cramp, one of the most disabling forms of RSI, is characterized by spasms of the fingers and wrist causing uncontrollable hand movements. It has proved notoriously difficult to treat but responds well to a form of sensory retraining therapy (pioneered by US physical therapist Nancy Byl), where patients slowly relearn sensory distinctions by performing structured delicate tasks while blindfolded.

Repetitive Strain Injury

Go to site

Unofficial, but informative and extensively-linked, site produced by a sufferer of RSI. It includes a section on the symptoms, as well as diagrams and photos of how to type without straining your back or hands. The site is largely focused upon prevention rather than cure.

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replication

in biology, production of copies of the genetic material DNA; it occurs during cell division (mitosis and meiosis). Most mutations are caused by mistakes during replication.

During replication the paired strands of DNA separate, exposing the bases. Nucleotides floating in the cell matrix pair with the exposed bases, adenine pairing with thymine, and cytosine with guanine.

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repression

in psychology, a mental process that ejects and excludes from consciousness ideas, impulses, or memories that would otherwise threaten emotional stability.

In the Austrian psychiatrist Sigmund Freud's early writing, repression is controlled by the censor, a hypothetical mechanism or agency that allows ideas, memories, and so on from the unconscious to emerge into consciousness only if distorted or disguised, as for example in dreams.

---

reproduction

in biology, the process by which a living organism produces other organisms more or less similar to itself. The ways in which species reproduce differ, but the two main methods are by asexual reproduction and sexual reproduction. Asexual reproduction involves only one parent without the formation of gametes: the parent's cells divide by mitosis to produce new cells with the same number and kind of chromosomes as its own. Thus offspring produced asexually are clones of the parent and there is no variation.
Sexual reproduction involves two parents, one male and one female. The parents' sex cells divide by meiosis producing gametes, which contain only half the number of chromosomes of the parent cell. In this way, when two sets of chromosomes combine during fertilization, a new combination of genes is produced. Hence the new organism will differ from both parents, and variation is introduced. The ability to reproduce is considered one of the fundamental attributes of living things.

sexual reproductive systems

The plant organs concerned with sexual reproduction are found in the flowers. These consist of the stamens (male organ) and carpels (female organ). In male mammals the reproductive system consists of the testes, which produce sperm, epididymis, sperm duct, and penis, and in the females the ovaries, which produce eggs, Fallopian tubes, and uterus.

hermaphrodites

These are bisexual organisms, such as earthworms, that have both male and female reproductive organs, or plants whose flowers contain both stamens and carpels. This is the normal arrangement in most plants. Some plant species, such as maize and birch, which have separate male and female flowers on the same plants are described as **monoeious**; in **dioecious** species, such as willow and holly, the male and female flowers are on separate plants.

reptile

any member of a class (Reptilia) of vertebrates. Unlike amphibians, reptiles have hard-shelled, yolk-filled eggs that are laid on land and from which fully formed young are born. Some snakes and lizards retain their eggs and give birth to live young. Reptiles are cold-blooded, and their skin is usually covered with scales. The metabolism is slow, and in some cases (certain large snakes) intervals between meals may be months. Reptiles date back over 300 million years.

Many extinct forms are known, including the orders Pterosauria, Plesiosauria, Ichthyosauria, and Dinosauria. The chief living orders are the Chelonia (tortoises and turtles), Crocodilia (alligators and crocodiles), and Squamata, divided into three suborders: Lacertilia (lizards), Ophidia or Serpentes (snakes), and Amphisbaenia (worm lizards). The order Rhynchocephalia has one surviving species, the lizardlike tuatara of New Zealand.

A four-year study of rainforest in eastern Madagascar revealed 26 new reptile species in 1995.

Classification of reptiles

Suborder	Number of species	Examples
Amphisbaenia	160	worm lizards
Crocodilia	23	alligators, caymans, crocodiles, gavial
Cryptodira	220	terrapins, tortoises, turtles
Ophidia	3,000	snakes: anaconda, boa, cobras, pythons, vipers
Pleurodira	70	sideneck turtles
Rhynchocephalia	2	tuatara
Sauria	4,500	lizards: gecko, gila monster, iguanas, skinks

research

the primary activity in science, a combination of theory and experimentation directed towards finding scientific explanations of phenomena. It is commonly classified into two types: **pure research**, involving theories with little apparent relevance to human concerns; and **applied research**, concerned with finding solutions to problems of social or commercial importance - for instance in medicine and engineering. The two types are linked in that theories developed from pure research may eventually be found to be of great value to society.

financing research

Scientific research is most often funded by government and industry, so a nation's wealth and priorities are likely to have a strong influence on the kind of work undertaken.

In 1989 the European Community (now the European Union) Council adopted a revised programme on research and technological development for the period 1990-94, requiring a total EC finance of 5,700 million euros, to be apportioned as follows: information and communications technology 2,221 million; industrial and materials technologies 888 million; life sciences and technologies 741 million; energy 814 million; human capacity and mobility 518 million; environment 518 million.

reservoir

natural or artificial lake that collects and stores water for community water supplies and for irrigation (see dam).

residue

in chemistry, a substance or mixture of substances remaining after the removal of one or more components by a separation process.

The nonvolatile substance left in a container after evaporation of liquid, the solid left behind after removal of liquid by filtration, and the substances left in a distillation flask after removal of components by distillation, are all residues.

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resin

substance exuded from pines, firs, and other trees in gummy drops that harden in air. Varnishes are common products of the hard resins, and ointments come from the soft resins.

Rosin is the solid residue of distilled turpentine, a soft resin. The name 'resin' is also given to many synthetic products manufactured by polymerization; they are used in adhesives, plastics, and varnishes.

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resistance

in physics, that property of a conductor that restricts the flow of electricity through it, associated with the conversion of electrical energy to heat; also the magnitude of this property.

Materials that are good conductors of electricity have electrons held loosely in the outer shells of their atoms. Current can flow easily and these materials have low resistance. In poor conductors of electricity, the electrons in the outer shells of their atoms are more strongly attracted by the positively-charged nucleus. Such materials restrict the flow of electrons and have a high resistance. Resistance (*R*) is related to current (*I*) and voltage (*V*) by the formula: $R = V/I$. The statement that current is proportional to voltage (resistance is constant) at constant temperature is known as Ohm's law. It is approximately true for many materials that are accordingly described as 'ohmic'.

Resistance depends on many factors, such as the nature of the material; its temperature; its length and cross-sectional area; the nature and state of illumination of the surface; and the frequency and magnitude of the current.

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resistivity

in physics, a measure of the ability of a material to resist the flow of an electric current. It is numerically equal to the resistance of a sample of unit length and unit cross-sectional area, and its unit is the ohm metre (symbol Ωm). A good conductor has a low resistivity (1.7×10^{-8} Ωm for copper); an insulator has a very high resistivity (10^{15} Ωm for polyethane).

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resistor

in physics, any component in an electrical circuit used to introduce resistance to a current by restricting the flow of electrons. Resistors are often made from wire-wound coils (higher resistance) or pieces of carbon (lower resistance). Rheostats and potentiometers are variable resistors.

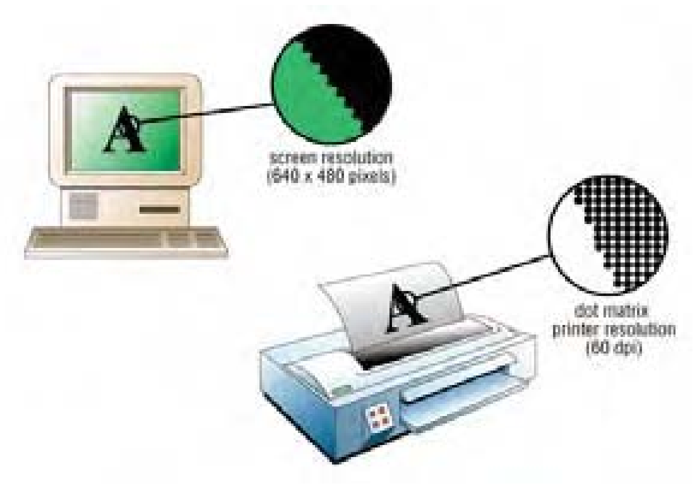
When resistors R_1, R_2, R_3,... are connected in a series circuit, the total resistance of the circuit is $R_1 + R_2 + R_3 + \ldots$. When resistors R_1, R_2, R_3,... are connected in a parallel circuit, the total resistance of the circuit is R, given by $1/R = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$.

---

resolution

in computing, the number of dots per unit length in which an image can be reproduced on a screen or printer. A typical screen resolution for colour monitors is 72-96 dpi (dots per inch). A laser printer will typically have a printing resolution of 600 dpi, ink-jet printers have a minimum of 300 dpi, and dot matrix printers typically have resolutions from 60 to 180 dpi. Photographs in books and magazines have a resolution of 1,200 dpi or 2,400 dpi.

resolution



(Image © Research Machines plc)

An example of typical resolutions of screens and printers. The resolution of a screen image when printed can only be as high as the resolution supported by the printer itself.

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resonance

rapid amplification of a vibration when the vibrating object is subject to a force varying at its natural frequency. In a trombone, for example, the length of the air column in the instrument is adjusted until it resonates with the note being sounded. Resonance effects are also produced by many electrical circuits. Tuning a radio, for example, is done by adjusting the natural frequency of the receiver circuit until it coincides with the frequency of the radio waves falling on the aerial.

Resonance has many physical applications. Children use it to increase the size of the movement on a swing, by giving a push at the same point during each swing. Soldiers marching across a bridge in step could cause the bridge to vibrate violently if the frequency of their steps coincided with its natural frequency.

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resources

materials that can be used to satisfy human needs. Because human needs are varied and extend from basic physical requirements, such as food and shelter, to spiritual and emotional needs that are hard to define, resources cover a vast range of items. The intellectual resources of a society – its ideas and technologies – determine which aspects of the environment meet that society's needs, and therefore become resources. For example, in the 19th century uranium was used only in the manufacture of coloured glass. Today, with the development of nuclear technology, it is a military and energy resource. Resources are often divided into **human resources**, such as labour, supplies, and skills, and **natural resources**, such as climate, fossil fuels, and water. Natural resources are divided into non-renewable resources and renewable resources.

Non-renewable resources include minerals such as coal, copper ores, and diamonds, which exist in strictly-limited quantities. Once consumed they will not be replenished within the time-span of human history. In contrast, water supplies, timber, food crops, and similar resources can, if managed properly, provide a steady yield virtually forever; they are therefore replenishable or renewable resources. Inappropriate use of renewable resources can lead to their destruction, as for example the cutting down of rainforests, with secondary effects, such as the decrease in oxygen and the increase in carbon dioxide and the resulting greenhouse effect. Some renewable resources, such as wind or solar energy, are continuous; supply is largely independent of people's actions.

Demands for resources made by rich nations are causing concern that the present and future demands of industrial societies cannot be sustained for more than a century or two, and that this will be at the expense of the developing world and the global environment. Other authorities believe that new technologies will be developed, enabling resources that are now of little importance to replace those being used up.

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respiration

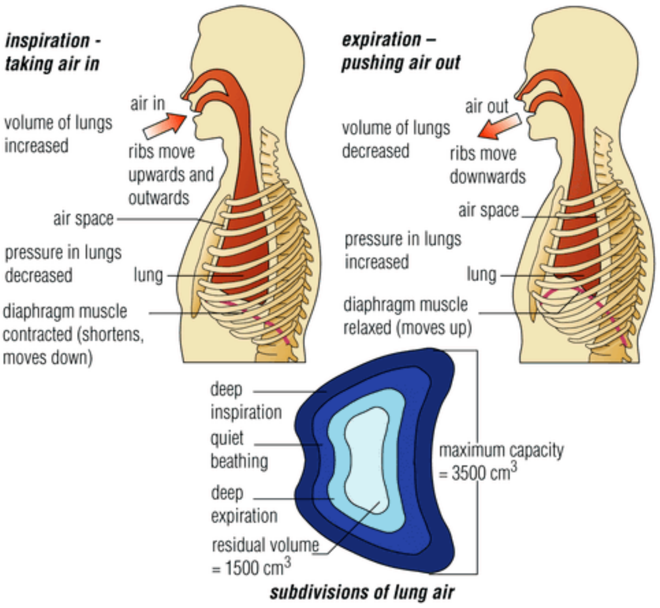
process that occurs inside cells in which carbohydrate, particularly glucose, is broken down to release energy that the cell can use. This energy is used for many different processes, but in all of them energy transfer occurs. The processes range from muscle contraction to the manufacture of protein for new cells. Respiration is a key feature of life and is carried out by all living cells. There are two kinds of respiration in organisms – aerobic and anaerobic respiration. Aerobic respiration is a complex process of chemical reactions in which oxygen is used to break down glucose into carbon dioxide and water. This releases energy in the form of energy-carrying molecules (ATP). Respiration sometimes occurs without oxygen, and this is called anaerobic respiration. In this case, glucose is only partially broken down, and the end products are energy and either lactic acid or ethanol (alcohol) and carbon dioxide; this process is termed fermentation.

The word 'respiration' should not be used to refer to the air movements in the air passageways. These air movements are called ventilation (breathing).

The starting and finishing points of aerobic respiration would be the same if glucose was burned. During burning the energy that is released is all in the form of heat. In aerobic respiration, however, the energy is released in a controlled way and less is released as heat. Most of the released energy is used to drive various processes in the cell, such as growth or movement.

In humans, anaerobic respiration can only carry on for a short time. The muscles producing lactic acid will stop working as it builds up. However, many micro-organisms can respire anaerobically for long periods of time or all the time. Yeast respires aerobically if oxygen is present, but, if there is no oxygen, it respires anaerobically. In anaerobic respiration it produces alcohol.

respiration


inspiration - taking air in
air in
volume of lungs increased
ribs move upwards and outwards
air space
pressure in lungs decreased
lung
diaphragm muscle contracted (shortens, moves down)
expiration – pushing air out
air out
volume of lungs decreased
ribs move downwards
air space
pressure in lungs increased
lung
diaphragm muscle relaxed (moves up)
deep inspiration
quiet beathing
deep expiration
residual volume = 1500 cm^3
maximum capacity = 3500 cm^3
subdivisions of lung air

(Image © Research Machines plc)

The two phases of the process of respiration. Gas exchange occurs in the alveoli, tiny air tubes in the lungs.

Respiration

Go to site

Outlines the process of respiration, focusing on three main areas of 'Tissue Respiration', 'Ventilation of the Lung', and 'Gaseous Exchange'. Key points are highlighted to help revision, and there are further links to a page with tips on remembering the equation for respiration.

Respiratory System

Go to site

Detailed description of how respiration occurs in humans. The text is accompanied by useful graphics.

Structure of the Human Respiratory System

Go to site

Short guide to the human respiratory system, including explanations of the functions of the major structures such as the nose and what happens to their effectiveness when they are exposed to tobacco smoke. It is divided into two main sections: 'Gas exchange in humans' and 'Other factors involved with respiration'.

The Respiratory System

Go to site

Explanation of the respiratory systems of different organisms, from single-celled organisms, flatworms, and jellyfish to larger animals, including humans. Includes a hyperlinked illustrated glossary of key terms.

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respiratory distress syndrome

RDS; formerly hyaline membrane disease

condition in which a newborn baby's lungs are insufficiently expanded to permit adequate oxygenation. Premature babies are most at risk. Such babies survive with the aid of intravenous fluids and oxygen, sometimes with mechanically assisted ventilation.

Normal inflation of the lungs requires the presence of a substance called surfactant to reduce the surface tension of the alveoli (air sacs) in the lungs. In premature babies, surfactant is deficient and the lungs become hard and glassy. As a result, the breathing is rapid, laboured, and shallow, and there is the likelihood of asphyxia. Artificial surfactant is administered to babies at risk.

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respiratory surface

area used by an organism for the exchange of gases, for example the lungs, gills or, in plants, the leaf interior. The gases oxygen and carbon dioxide are both usually involved in respiration and photosynthesis. Although organisms have evolved different types of respiratory surface according to need, there are certain features in common. These include thinness and moistness, so that the gas can dissolve in a membrane and then diffuse into the body of the organism. In many animals the gas is then transported away from the surface and towards interior cells by the blood system.

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response time

in computing, the delay between entering a command and seeing its effect.

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rest mass

in physics, the mass of a body when its velocity is zero or considerably below that of light. According to the theory of relativity, at very high velocities, there is a relativistic effect that increases the mass of the particle.

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restriction enzyme

or endonuclease

bacterial enzyme that breaks a chain of DNA into two pieces at a specific point; used in genetic engineering. The point along the DNA chain at which the enzyme can work is restricted to places where a specific sequence of base pairs occurs. Different restriction enzymes will break a DNA chain at different points. The overlap between the fragments is used in determining the sequence of base pairs in the DNA chain.

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resuscitation

steps taken to revive anyone on the brink of death. The most successful technique for life-threatening emergencies, such as electrocution, near-drowning, or heart attack, is mouth-to-mouth resuscitation. Medical and paramedical staff are trained in cardiopulmonary resuscitation (CPR): the use of specialized equipment and techniques to attempt to restart the breathing and/or heartbeat and stabilize the patient long enough for more definitive treatment. CPR has a success rate of less than 30%.

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retina

light-sensitive area at the back of the eye connected to the brain by the optic nerve. It has several layers and in humans contains over a million rods and cones, sensory cells capable of converting light into nervous messages that pass down the optic nerve to the brain.

The **rod cells**, about 120 million in each eye, are distributed throughout the retina. They are sensitive to low levels of light, but do not provide detailed or sharp images, nor can they detect colour. The **cone cells**, about 6 million in number, are mostly concentrated in a central region of the retina called the **fovea**, and provide both detailed and colour vision. The cones of the human eye contain three visual pigments, each of which responds to a different primary colour (red, green, or blue). The brain can interpret the varying signal levels from the three types of cone as any of the different colours of the visible spectrum.

The image actually falling on the retina is highly distorted; research into the eye and the optic centres within the brain has shown that this poor quality image is processed to improve its quality. The retina can become separated from the wall of the eyeball as a result of a trauma, such as a boxing injury. It can be reattached by being 'welded' into place by a laser.

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retinol

or vitamin A

fat-soluble chemical derived from β-carotene and found in milk, butter, cheese, egg yolk, and liver. Lack of retinol in the diet leads to the eye disease **xerophthalmia**.

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retinopathy

in medicine, a general term to describe diseases of the retina. Such diseases are often complications of other diseases, such as hypertensive retinopathy, which occurs in people with high blood pressure and diabetic retinopathy, which occurs in patients with diabetes mellitus. The underlying condition needs to be treated to prevent the progress of the retinopathy.

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retriever

any of several breeds of hunting dogs, often used as guide dogs for the blind. The commonest breeds are the **Labrador retriever**, large, smooth-coated, and usually black or yellow; and the **golden retriever**, with either flat or wavy coat. They can grow to 60 cm/2 ft high and weigh 40 kg/90 lb.

Retrievers were originally developed for retrieving birds and other small game. Their gentle, even-tempered nature makes them popular companion dogs, and Labradors are also used in police work.

Golden Retriever Club of America

Go to site

Information about the history of the breed, the breed standard, shows, veterinary advice, and many tips for owners. There is a listing of other Golden Retriever sites across the world and many photos.

Labrador Retriever Club

Go to site

Information about the history of the breed, the breed standard, shows, veterinary advice, and many tips for owners. There is a listing of other Labrador sites across the world and many photos. The home page, however, is not particularly user-friendly. You need to click on 'Library' to access general information on Labradors rather than club affairs.

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retrograde

in astronomy, describing the orbit or rotation of a planet or satellite if the sense of rotation is opposite to the general sense of rotation of the Solar System. On the celestial sphere, it refers to motion from east to west against the background of stars.

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retrovirus

any of a family of viruses (Retroviridae) that contain RNA as genetic material and are able to produce DNA copies of their RNA genes, which they incorporate into the host genome.

The retrovirus is able to transcribe RNA into DNA with the help of an enzyme encoded in its genome, known as the reverse transcriptase (since the transfer of genetic information from DNA to RNA is known as transcription, and retroviruses do the reverse of this). Retroviruses were seen as a rare and exotic exception to the rules of biology, until in the late 1980s the agents causing AIDS and some forms of leukaemia were recognized to be retroviruses.

Retroviruses are used as vectors in genetic engineering, but they cannot be used to target specific sites on the chromosome. Instead they incorporate their genes at random sites.

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reuse

multiple use of a product (often a form of packaging), by returning it to the manufacturer or processor each time. Many such returnable items are sold with a deposit which is reimbursed if the item is returned. Reuse is usually more energy- and resource-efficient than recycling unless there are large transport or cleaning costs.

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reverberation

in acoustics, the multiple reflections, or echoes, of sounds inside a building that merge and persist a short time (up to a few seconds) before fading away. At each reflection some of the sound energy is absorbed, causing the amplitude of the sound wave and the intensity of the sound to reduce a little.

Too much reverberation causes sounds to become confused and indistinct, and this is particularly noticeable in empty rooms and halls, and such buildings as churches and cathedrals where the hard, unfurnished surfaces do not absorb sound energy well. Where walls and surfaces absorb sound energy very efficiently, too little reverberation may cause a room or hall to sound dull or 'dead'. Reverberation is a key factor in the design of theatres and concert halls, and can be controlled by lining ceilings and walls with materials possessing specific sound-absorbing properties.

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reverse osmosis

movement of solvent (liquid) through a semipermeable membrane from a more concentrated solution to a more dilute solution. The solvent's direction of movement is opposite to that which it would experience during osmosis, and is achieved by applying an external pressure to the solution on the more concentrated side of the membrane. The technique is used in desalination plants, when water (the solvent) passes from brine (a salt solution) into fresh water via a semipermeable filtering device.

reverse video

alternative term for **inverse video**.

reversible reaction

chemical reaction that proceeds in both directions at the same time, as the product decomposes back into reactants as it is being produced. Such reactions do not run to completion, provided that no substance leaves the system. Examples include the manufacture of ammonia from hydrogen and nitrogen, and the oxidation of sulphur dioxide to sulphur trioxide.

Reye's syndrome

rare disorder of the metabolism causing fatty infiltration of the liver and encephalitis. It occurs mainly in children and has been linked with aspirin therapy, although its cause is still uncertain. The mortality rate is 50%.

Childhood Infections - Reye's Syndrome

Go to site

Useful information about Reye's syndrome. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

Reynolds number

number used in fluid mechanics to determine whether fluid flow in a particular situation (through a pipe or around an aircraft body or a fixed structure in the sea) will be turbulent or smooth. The Reynolds number is calculated using the flow velocity, density, and viscosity of the fluid, and the dimensions of the flow channel. It is named after Irish engineer Osborne Reynolds.

The Reynolds number for the wing of a Boeing 747 is 7×10^7 and that for a nuclear submarine is 10^9.

RGB

abbreviation of red-green-blue

method of connecting a colour screen to a computer, involving three separate signals: red, green, and blue. All the colours displayed by the screen can be made up from these three component colours.

rhe

unit of fluidity equal to the reciprocal of the poise.

rhea

one of two flightless birds of the family Rheidae, order Rheiformes. The common rhea *Rhea americana* is 1.5 m/5 ft high and is distributed widely in South America. The smaller Darwin's rhea *Pterocnemia pennata* occurs only in the south of South America and has shorter, feathered legs, and mottled plumage. Rheas differ from the ostrich in their smaller size and in having a feathered neck and head, three-toed feet, and no plumelike tail feathers.

rhenium

chemical symbol Re

(Latin Rhenus 'Rhine')

heavy, silver-white, metallic element, atomic number 75, relative atomic mass 186.2. It has chemical properties similar to those of manganese and a very high melting point (3,180°C/5,756°F), which makes it valuable as an ingredient in alloys.

It was identified and named in 1925 by German chemists Walter Noddack (1893-1960), Ida Tacke, and Otto Berg from the Latin name for the River Rhine.

rheostat

variable resistor, usually consisting of a high-resistance wire-wound coil with a sliding contact. It is used to vary electrical resistance without interrupting the current (for example, when dimming lights). The circular type, which can be used, for example, as the volume control of an amplifier, is also known as a potentiometer.

rhesus factor

group of antigens on the surface of red blood cells of humans which characterize the rhesus blood group system. Most individuals possess the main rhesus factor (Rh+), but those without this factor (Rh-) produce antibodies if they come into contact with it. The name comes from rhesus monkeys, in whose blood rhesus factors were first found.

If an Rh- mother carries an Rh+ fetus, she may produce antibodies if fetal blood crosses the placenta. This is not normally a problem with the first infant because antibodies are only produced slowly. However, the antibodies continue to build up after birth, and a second Rh+ child may be attacked by antibodies passing from mother to fetus, causing the child to contract anaemia, heart failure, or brain damage. In such cases, the blood of the infant has to be changed for Rh- blood; a badly affected fetus may be treated in the womb (see fetal therapy). The problem can be circumvented by giving the mother anti-Rh globulin just after the first pregnancy, preventing the formation of antibodies.

rhesus monkey

macaque monkey *Macaca mulatta* found in northern India and Southeast Asia. It has a pinkish face, red buttocks, and long, straight, brown-grey hair. It can grow up to 60 cm/2 ft long, with a 20 cm/8 in tail.

rheumatic fever

or acute rheumatism

acute or chronic illness characterized by fever and painful swelling of joints. Some victims also experience involuntary movements of the limbs and head, a form of chorea. It is now rare in the developed world.

Rheumatic fever, which strikes mainly children and young adults, is always preceded by a streptococcal infection such as scarlet fever or a severe sore throat, usually occurring a couple of weeks beforehand. It is treated with bed rest, antibiotics, and painkillers. The most important complication of rheumatic fever is damage to the heart and its valves, producing rheumatic heart disease many years later, which may lead to disability and death.

rheumatism

nontechnical term for a variety of ailments associated with inflammation and stiffness of the joints and muscles.

rheumatoid arthritis

inflammation of the joints; a chronic progressive disease, it begins with pain and stiffness in the small joints of the hands and feet and spreads to involve other joints, often with severe disability and disfigurement. There may also be damage to the eyes, nervous system, and other organs. The disease is treated with a range of drugs and with surgery, possibly including replacement of major joints.

Rheumatoid arthritis most often develops between the ages of 30 and 40, and is three times more common in women than men. It is an autoimmune disease and new hope has come for sufferers with the announcement in 1994 of an experimental drug which deactivates part of the immune system responsible for tissue damage. The drug, a monoclonal antibody, has performed well in preliminary trials, reducing pain and stiffness and improving mobility.

In the West it affects 2-3% of women and nearly 1% of men; an estimated 165 million people worldwide suffered from rheumatoid arthritis in 1995. In children rheumatoid arthritis is known as Still's disease.

rhim

or sand gazelle

smallish gazelle *Gazella leptocerus* that has already disappeared over most of its former range of north Africa. Populations are fragmented and often isolated. It is one of several highly threatened gazelle species in northern Africa and the Sahara.

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rhinoceros

large grazing mammal with one or more horns on its snout. Rhinoceroses have thick, loose skin with little hair, stumpy, powerful legs with three toes on each foot. The largest species (the one-horned Indian rhinoceros) can grow up to 2 m/6 ft high at the shoulder and weigh 2,300–4,000 kg/5,060–8,800 lb. Rhinoceroses eat grass, leafy twigs, and shrubs, and are solitary. They have poor eyesight but excellent hearing and smell. Although they look clumsy, rhinos can reach speeds of 56 kph/35 mph. In the wild they are thought to live for about 25 years, and up to 47 in captivity. There are five species: three Asian and two African, all in danger of extinction.

species

The largest rhinoceros is the **one-horned Indian rhinoceros** *Rhinoceros unicornis*, which has a rough skin, folded into shieldlike pieces; the African rhinoceroses are smooth-skinned and two-horned. The African **black rhinoceros** *Diceros bicornis* is 1.5 m/5 ft high, with a prehensile (grasping) upper lip for feeding on shrubs, and sometimes a smaller third horn. The **broad-lipped ('white') rhinoceros** *Ceratotherium simum* is actually slaty-grey, with a squarish mouth for browsing grass. The **Javan rhinoceros** *R. sondaicus* is near extinction, as is the **two-horned Sumatran rhinoceros** *Dicerorhinus sumatrensis*.

in danger

The Javan rhino is now one of the world's rarest mammals, and is included on the CITES list of endangered species. In 1998 there were 50-60 Javan rhino *Rhinoceros sondaicus sondaicus* in Ujing Kulon National Park, Java, and an estimated five of the subspecies *R. s. annamiticus* in Vietnam. The total population of Indian rhinoceroses (1995) consists of about 2,000 animals.

huge ancestor

An extinct hornless species, the baluchithere (genus *Baluchitherium*), reached 4.5 m/15 ft high.

classification

Rhinoceroses belong to the phylum Chordata, subphylum Vertebrata, class Mammalia (mammal), order Perissodactyla (odd-toed ungulates), suborder Ceratomorpha, family Rhinocerotidae. Today there are four genera with five remaining species: the great Indian rhinoceros (*Rhinoceros unicornis*), the Javan or lesser one-horned rhinoceros (*R. sondaicus*), the Sumatran or Asiatic two-horned or hairy rhinoceros (*Dicerorhinus sumatrensis*), the African black rhinoceros (*Diceros bicornis*) and the African white rhinoceros (*Ceratotherium simum*).

rhinoceros

The white rhino is not white, but a dirty grey. The name is a mistranslation of the Afrikaans word *weit*, which means 'wide'. The white rhino has a wider face and body than the more common black rhino.

Black Rhinoceros

Go to site

Illustrated guide to the black rhinoceros including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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rhinoplasty

in medicine, operation to repair the nose or modify its shape. It is usually performed for cosmetic reasons. The operation may involve alteration of the bony skeleton of the nose or of the septum.

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rhizoid

hairlike outgrowth found on the gametophyte generation of ferns, mosses, and liverworts. Rhizoids anchor the plant to the substrate and can absorb water and nutrients.

They may be composed of many cells, as in mosses, where they are usually brownish, or may be unicellular, as in liverworts, where they are usually colourless. Rhizoids fulfil the same functions as the roots of higher plants but are simpler in construction.

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rhizome

or rootstock

horizontal underground plant stem. It is a perennating organ in some species, where it is generally thick and fleshy, while in other species it is mainly a means of vegetative reproduction, and is therefore long and slender, with buds all along it that send up new plants. The potato is a rhizome that has two distinct parts, the tuber being the swollen end of a long, cordlike rhizome.

rhm

abbreviation of roentgen-hour-metre

the unit of effective strength of a radioactive source that produces gamma rays. It is used for substances for which it is difficult to establish radioactive disintegration rates.

rhodium

chemical symbol Rh

(Greek rhodon 'rose')

hard, silver-white, metallic element, atomic number 45, relative atomic mass 102.905. It is one of the so-called platinum group of metals and is resistant to tarnish, corrosion, and acid. It occurs as a free metal in the natural alloy osmiridium and is used in jewellery, electroplating, and thermocouples.

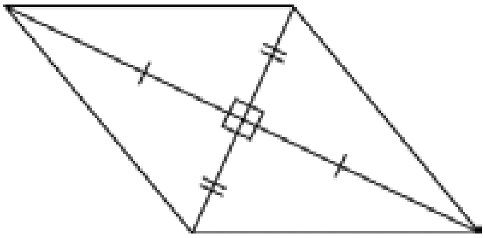
rhododendron

any of numerous, mostly evergreen shrubs belonging to the heath family. The leaves are usually dark and leathery, and the large funnel-shaped flowers, which grow in tight clusters, occur in all colours except blue. They thrive on acid soils. Azaleas belong to the same genus. (Genus *Rhododendron*, family Ericaceae.)

rhombus

equilateral (all sides equal) parallelogram. As with a parallelogram, the rhombus has diagonally opposed angles of equal size. Its diagonals bisect each other at right angles, and its area is half the product of the lengths of the two diagonals. The shape is sometimes called a diamond. A rhombus whose internal angles are 90° is called a square.

rhombus



(Image © Research Machines plc)

A rhombus is a parallelogram with sides of equal length. Its opposite angles are equal and they bisect each other at right angles. The shape of a rhombus is sometimes known as a diamond, although a rhombus with angles of 90° would be a square.

rhubarb

perennial plant grown for its pink edible leaf stalks. The large leaves contain oxalic acid, and are poisonous. There are also wild rhubarbs native to Europe and Asia. (Genus *Rheum rhaponticum*, family Polygonaceae.)

Rhubarb Compendium

Go to site

Pictures, history, recipes: the list of information included at this site goes on an on; it even includes a section on rhubarb being a possible key to CFC (chlorofluorocarbon) control. It is impossible to believe you would need to know something about rhubarb that this site doesn't tell you.

rhyolite

igneous rock, the fine-grained volcanic (extrusive) equivalent of granite.

rhythm method

method of natural contraception that relies on refraining from intercourse during ovulation.

The time of ovulation can be worked out by the calendar (counting days from the last period), by temperature changes, or by inspection of the cervical mucus. All these methods are unreliable because it is possible for ovulation to occur at any stage of the menstrual cycle.

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ria

long narrow sea inlet, usually branching and surrounded by hills. A ria is deeper and wider towards its mouth, unlike a fjord. It is formed by the flooding of a river valley due to either a rise in sea level or a lowering of a landmass.

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rib

long, usually curved bone that extends laterally from the spine in vertebrates. Most fishes and many reptiles have ribs along most of the spine, but in mammals they are found only in the chest area. In humans, there are 12 pairs of ribs. The ribs protect the lungs and heart, and allow the chest to expand and contract easily.

At the rear, each pair is joined to one of the vertebrae of the spine. The upper seven ('true' or vertebro-sternal ribs) are joined by cartilage directly to the breast bone (sternum). The next three ('false' or vertebro-costal ribs) are joined by cartilage to the end of the rib above. The last two ('floating ribs') are not attached at the front. The diaphragm and muscles between adjacent ribs are responsible for the respiratory movements which fill the lungs with air.

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ribbonfish

member of a family of marine fish. They have elongated and compressed bodies which have a ribbonlike appearance. They are pelagic (open sea) fishes.

There is no anal fin, but the dorsal fin is as long as the body, and the ventral fins have from one long ray to nine smaller ones. Ribbonfish are seldom found alive, and are usually seen floating dead on the surface of the ocean.

The **dealfish** *Trachypterus arcticus*, occurs in the north Atlantic. The oarfish also belongs to this family.

classification

Ribbonfish are in the family Trachypteridae, order Lampridiformes, class Osteichthyes.

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ribbon lake

long, narrow lake found on the floor of a glacial trough. A ribbon lake will often form in an elongated hollow carved out by a glacier, perhaps where it came across a weaker band of rock. Ribbon lakes can also form when water ponds up behind a terminal moraine or a landslide. The English Lake District is named after its many ribbon lakes, such as Lake Windermere and Coniston Water.

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riboflavin

or vitamin B_2

vitamin of the B complex important in cell respiration. It is obtained from eggs, liver, and milk. A deficiency in the diet causes stunted growth.

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ribosome

protein-making machinery of the cell. Active ribosomes are either located on the endoplasmic reticulum (ER) of eukaryotic cells or dissolved in the cytoplasm (of any kind of cell), and are made of proteins and a special type of RNA, ribosomal RNA. They receive messenger RNA (copied from the DNA) and amino acids, and 'translate' the messenger RNA by using its chemically coded instructions to link amino acids in a specific order, to make a strand of a particular protein.

When they are not busy, ribosomes dissociate into a larger and a smaller subunit. X-ray crystallography has revealed that the functional centre in the large subunit, which catalyzes the formation of the new peptide bond, is made up exclusively of RNA. Thus, the ribosome is also an example of a ribozyme or RNA enzyme. This finding lends strong support to the hypothesis that the early evolution of life on Earth involved an RNA world stage.

rice

principal cereal (*Oryza sativa*) of the wet regions of the tropics, derived from wild grasses probably native to India and Southeast Asia. Rice is unique among cereal crops in that it is grown standing in water. The yield is very large, and

rice is the staple food of one-third of the world's population.

cultivation

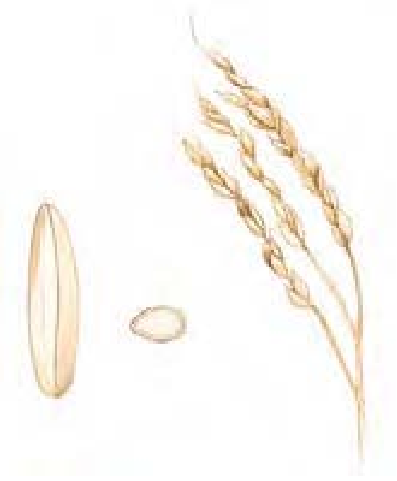
Rice has been cultivated for thousands of years in Asia. Grains of rice discovered at an excavation in South Korea in 2003 proved to be the earliest known domesticated rice: carbon dating showed the grains to be around 15,000 years old – 3,000 years earlier than the previously accepted date for the origin of rice cultivation in China around 12,000 years ago.

Rice takes 150–200 days to mature in warm, wet conditions. During its growing period, it needs to be flooded either by the heavy monsoon rains or by irrigation. This restricts the cultivation of swamp rice, the usual kind, to level land and terraces. Outside Asia, centres of rice production include the Po Valley in Italy, and Louisiana, the Carolinas, and California in the USA.

rice

It takes 1,900 l /3,300 pt of water to produce 1 kg/2.2 lb of rice.

rice



(Image © Research Machines plc)

The rice plant is unique among cereal crops in that it is grown standing in water. The rice stem is adapted to allow oxygen to pass downwards to the waterlogged roots. The grain is usually white, but there are red, brown, and black varieties. The thin skin of the grain is rich in oils, minerals, and vitamins.

rice

(Image © Research Machines plc)

Rice being harvested in Guilin, China. Rice is the staple food of one third of the world's population.

rice

(Image © Research Machines plc)

Rice harvest in Nepal. Rice is the most important cereal crop in Nepal's mainly agricultural economy.

rice

(Image © Research Machines plc)

Rice harvesting, Nepal. Agricultural smallholdings provide the livelihood of over 80% of the population. The introduction of small-scale mechanization and improved agricultural practices in recent years has helped to lessen the burden on farmers and their families.

rice paddies, Kanglung

(Image © Corel)

Terraced rice paddies, in Kanglung, eastern Bhutan. Villagers in this mountainous country make widespread use of this method of agriculture, and rice is the staple food.

rice

(Image © Garret Nagle)

A maturing rice plant. Rice requires a large amount of water and plenty of heat, in order to grow, and therefore it is generally only found in warm wet locations. It is cultivated intensively and has a high yield. Rice is a cereal that can easily support large populations and so is favoured in areas with high population pressures.

rice

(Image © Research Machines plc)

Rice terraces in Bali, Indonesia. Around 60% of the population of Bali works in agriculture, and rice farming is an integral part of everyday life.

Richter, Charles Francis (1900-1985)

US seismologist, deviser of the Richter scale used to indicate the strength of the waves from earthquakes.

Richter scale

quantitative scale of earthquake magnitude based on the measurement of seismic waves, used to indicate the magnitude of an earthquake at its epicentre. The Richter scale is logarithmic, so an earthquake of 6.0 is ten times greater than one of 5.0. The magnitude of an earthquake differs from its intensity, measured by the Mercalli scale, which is qualitative and varies from place to place for the same earthquake. The scale is named after US seismologist Charles Richter.

An earthquake's magnitude is a function of the total amount of energy released, and each point on the Richter scale represents a thirtyfold increase in energy over the previous point. One of the greatest earthquakes ever recorded, in 1920 in Gansu, China, measured 8.6 on the Richter scale.

Richter scale

The Richter scale is based on measurement of seismic waves, used to determine the magnitude of an earthquake at its epicentre. The magnitude of an earthquake differs from its intensity, measured by the Mercalli scale, which is subjective and varies from place to place for the same earthquake. The Richter scale was named after US seismologist Charles Richter (1900-1985). The relative amount of energy released indicates the ratio of energy between earthquakes of different magnitude.

Magnitude	Relative amount of energy released	Examples	Year
1	1		
2	31		
3	960		
4	30,000	Carlisle, England (4.7)	1979
5	920,000	Wrexham, Wales (5.1)	1990
6	29,000,000	San Fernando (CA), USA (6.5)	1971
		northern Armenia (6.8)	1988
7	890,000,000	Loma Prieta (CA), USA (7.1)	1989
		Kobe, Japan (7.2)	1995
		Izmit, Turkey (7.4)	1999
		Taichung and Nantou counties, Taiwan (7.6)	1999
		Rasht, Iran (7.7)	1990
		San Francisco (CA), USA (7.7-7.9)[1]	1906
8	28,000,000,000	Tangshan, China (8.0)	1976
		Gansu, China (8.6)	1920
		Lisbon, Portugal (8.7)	1755
9	850,000,000,000	Prince William Sound (AK), USA (9.2)	1964

[1] Richter's original estimate of a magnitude of 8.3 was revised by two studies carried out by the California Institute of Technology and the US Geological Survey.

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ricin

extremely poisonous extract from the seeds of the castor-oil plant. When incorporated into monoclonal antibodies, ricin can attack cancer cells, particularly in the treatment of lymphoma and leukaemia.

---

rickets

defective growth of bone in children due to an insufficiency of calcium deposits. The bones, which do not harden adequately, are bent out of shape. It is usually caused by a lack of vitamin D and insufficient exposure to sunlight. Renal rickets, also a condition of malformed bone, is associated with kidney disease.

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ridge of high pressure

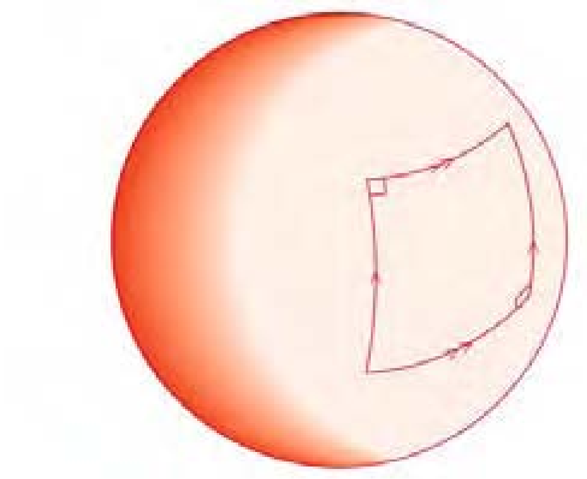
elongated area of high atmospheric pressure extending from an anticyclone. On a synoptic weather chart it is shown as a pattern of lengthened isobars. The weather under a ridge of high pressure is the same as that under an anticyclone.

Riemann, Georg Friedrich Bernhard (1826-1866)

German mathematician whose system of non-Euclidean geometry, thought at the time to be a mere mathematical curiosity, was used by Albert Einstein to develop his general theory of relativity. Riemann made a breakthrough in conceptual understanding within several other areas of mathematics: the theory of functions, vector analysis, projective and differential geometry, and topology.

Riemann took into account the possible interaction between space and the bodies placed in it; until then, space had been treated as an entity in itself, and this new point of view was to become a central concept of 20th-century physics.

Riemann



(Image © Research Machines plc)

Georg Riemann showed that in spherical geometry (a form of non-Euclidean geometry), although a parallelogram may have two opposite angles of 90°, it does not necessarily follow that the other two angles are also 90°.

Riemann, Georg Friedrich Bernhard

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of Georg Riemann. In addition to biographical information, you will find a list of references about Riemann and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Riemann. There is also an image of him, which can be enlarged, and a map of his birthplace.

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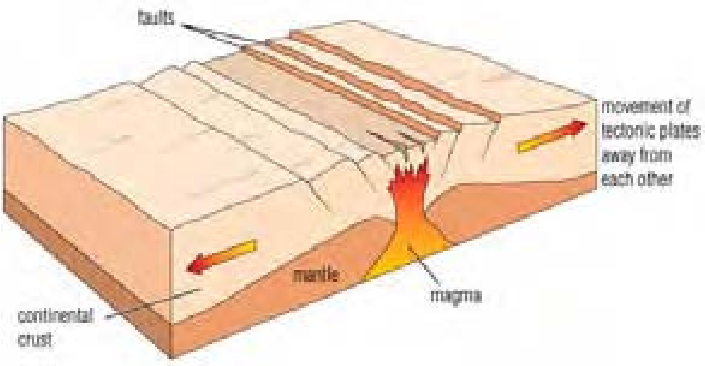
rift valley

valley formed by the subsidence of a block of the Earth's crust between two or more parallel faults. Rift valleys are steep-sided and form where the crust is being pulled apart, as at mid-ocean ridges, or in the Great Rift Valley of East Africa. In cross-section they can appear like a widened gorge with steep sides and a wide floor.

rift valley



(Image © Research Machines plc)

The subsidence of rock resulting from two or more parallel rocks moving apart is known as a graben. When this happens on a large scale, with tectonic plates moving apart, a rift valley is created.

rift valley

(Image © Garret Nagle)

A steep rift-valley wall at Thingvellir, Iceland. Rift valleys are created when tectonic plates pull apart, and part of the Earth's crust subsides. The Mid-Atlantic Ridge can be seen in action here at Thingvellir, where the North American plate is pulling away from the European plate.

rift valley

(Image © Garret Nagle)

A river runs through a steep-sided rift valley. This valley was formed as a result of the movement of tectonic plates on the Mid-Atlantic Ridge at Thingvellir, Iceland.

Rigel

or Beta Orionis

brightest star in the constellation Orion. It is a blue-white supergiant, with an estimated diameter 50 times that of the Sun. It is 910 light years from Earth, and is intrinsically the brightest of the first-magnitude stars, its true luminosity being about 40,000 times that of the Sun. It is the seventh-brightest star in the night sky.

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right ascension

in astronomy, coordinate on the celestial sphere that corresponds to longitude on the surface of the Earth. It is measured in hours, minutes, and seconds eastwards from one of the two points where the Sun's path, the ecliptic, intersects the celestial equator; this point is called the **vernal (spring) equinox**, because the Sun crosses it in the northern hemisphere spring, when apparently moving northward in the sky.

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right triangle

triangle in which one of the angles is a right angle (90°). It is the basic form of triangle for defining trigonometrical ratios (for example, sine, cosine, and tangent) and for which the Pythagorean theorem holds true. The longest side of a right triangle is called the hypotenuse; its area is equal to half the product of the lengths of the two shorter sides.

A triangle constructed with its hypotenuse as the diameter of a circle with its opposite vertex (corner) on the circumference is a right triangle. This is a fundamental theorem in geometry, first credited to the Greek mathematician Thales about 580 BC.

Rigil Kent

or Alpha Centauri

brightest star in the constellation Centaurus and the third-brightest star in the night sky. It is actually a triple star (see binary star); the two brighter stars orbit each other every 80 years, and the third, Proxima Centauri, is the closest star to the Sun, 4.2 light years away, 0.1 light years closer than the other two.

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rigor

medical term for shivering or rigidity.
Rigor mortis is the stiffness that ensues in a corpse soon after death, owing to chemical changes in muscle tissue.

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rinderpest

acute viral disease of cattle (sometimes also of sheep and goats) characterized by fever and bloody diarrhoea, due to inflammation of the intestines. It can be fatal. Almost eliminated in the 1960s, it revived in Africa in the 1980s.

Rinderpest belongs to the Paramyxoviridae virus family and has a mortality rate of 95%. Its highest incidence is in the Horn of Africa where it kills 50-80% of cattle.

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ring circuit

household electrical circuit in which appliances are connected in series to form a ring with each end of the ring connected to the power supply. It superseded the radial circuit.

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ringworm

any of various contagious skin infections due to related kinds of fungus, usually resulting in circular, itchy, discoloured patches covered with scales or blisters. The scalp and feet (athlete's foot) are generally involved. Treatment is with antifungal preparations.

Childhood Infections - Ringworm

Go to site

Useful information about ringworm. There is a detailed, illustrated description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

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ripple tank

in physics, shallow water-filled tray used to demonstrate various properties of waves, such as reflection, refraction, diffraction, and interference.

As light waves are not visible, waves produced in a ripple tank can be used to demonstrate their properties. Water waves are produced using an electric motor to vibrate either a straight bar dipped into the water to produce straight waves or a circular ball to produce circular waves. A stroboscope is used to study the water waves by 'freezing' their motion.

If a small piece of polystyrene is placed in a ripple tank while straight water waves are produced, then, viewed from the side, as the ripples move up and down (forming a pattern of crests and troughs) the polystyrene remains in its original position as the water waves travel along. This shows that waves transfer energy from one place to another without transferring matter.

RISC

acronym for Reduced Instruction-Set Computer

in computing, a microprocessor (processor on a single chip) that carries out fewer instructions than other (CISC) microprocessors in common use in the 1990s. Because of the low number and the regularity of machine code instructions, the processor carries out those instructions very quickly.

---

ritualization

in ethology, a stereotype that occurs in certain behaviour patterns when these are incorporated into displays. For example, the exaggerated and stylized head toss of the goldeneye drake during courtship is a ritualization of the bathing movement used to wet the feathers; its duration and form have become fixed. Ritualization may make displays clearly recognizable, so ensuring that individuals mate only with members of their own species.

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river

large body of water that flows down a slope along a channel restricted by adjacent banks and levees. A river starts at a point called its **source**, and enters a sea or lake at its **mouth**. Along its length it may be joined by smaller rivers called **tributaries**; a river and its tributaries are contained within a drainage basin. The point at which two rivers join is called the confluence.

Rivers are formed and moulded over time chiefly by the processes of erosion, and by the **transport** and **deposition** of sediment. Rivers are able to work on the landscape through erosion, transport, and deposition. The amount of potential energy available to a river is proportional to its initial height above sea level. A river follows the path of least resistance downhill, and deepens, widens and lengthens its channel by erosion. Up to 95% of a river's potential energy is used to overcome friction.

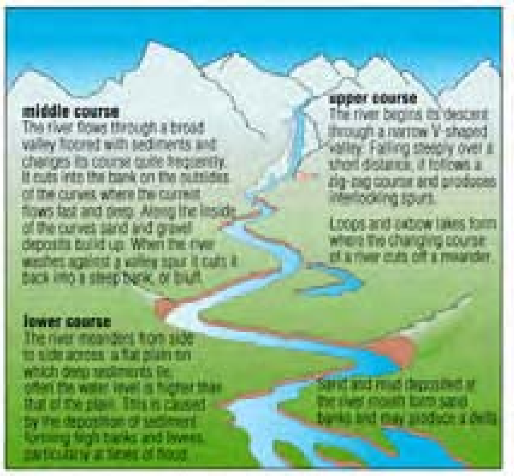
One way of classifying rivers is by their stage of development. An upper course is typified by a narrow V-shaped valley with numerous waterfalls, lakes, and rapids. Because of the steep gradient of the topography and the river's height above sea level, the rate of erosion is greater than the rate of deposition, and downcutting occurs by **vertical corrasion** (erosion or abrasion of the bed or bank caused by the load carried by the river).

In the middle course of a river, the topography has been eroded over time and the river's course has a shallow gradient. Such a river is said to be graded. Erosion and deposition are delicately balanced as the river meanders (gently curves back and forth) across the extensive flood plain.
Horizontal corrasion is the main process of erosion. The flood plain is an area of periodic flooding along the course of a river valley where fine silty material called alluvium is deposited by the flood water. Features of a mature river (or the **lower course** of a river) include extensive meanders, oxbow lakes, and braiding.

Many important flood plains, such as the Nile flood plain in Egypt, occur in arid areas where their exceptional fertility is very important to the local economy. However, using flood plains as the site of towns and villages involves a certain risk, and it is safer to use flood plains for other uses, such as agriculture and parks. Water engineers can predict when flooding is likely and take action to prevent it by studying hydrographs, which show how the discharge of a river varies with time.

Major rivers of the world include the Ganges, the Mississippi, and the Nile, the world's longest river.

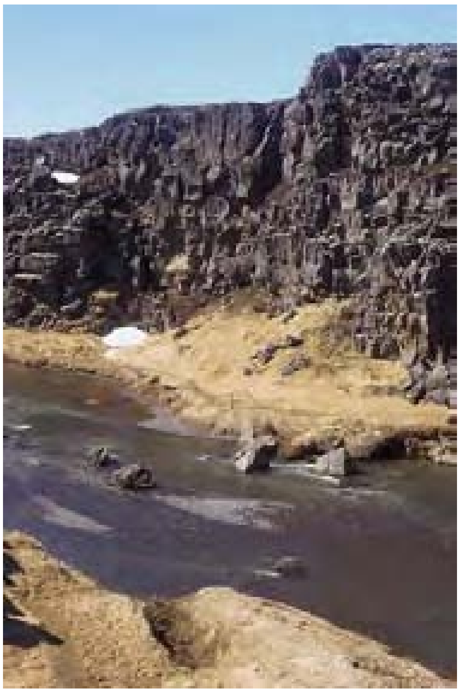
river


middle course
The river flows through a broad valley floored with sediments and changes its course quite frequently. It cuts into the bank on the outsides of the curves where the current flows fast and deep. Along the inside of the curves sand and gravel deposits build up. When the river washes against a valley spur it cuts it back into a steep bank, or bluff.
upper course
The river begins its descent through a narrow V-shaped valley. Falling steeply over a short distance, it follows a zig-zag course and produces interlocking spurs.
Loops and oxbow lakes form where the changing course of a river cuts off a meander.
lower course
The river meanders from side to side across a flat plain on which deep sediments lie, often the water level is higher than that of the plain. This is caused by the deposition of sediment forming high banks and levees, particularly at times of flood.
Sand and mud deposited at the river mouth form sand banks and may produce a delta

(Image © Research Machines plc)

The course of a river from its source of a spring or melting glacier, through to maturity where it flows into the sea.

river



(Image © Garret Nagle)

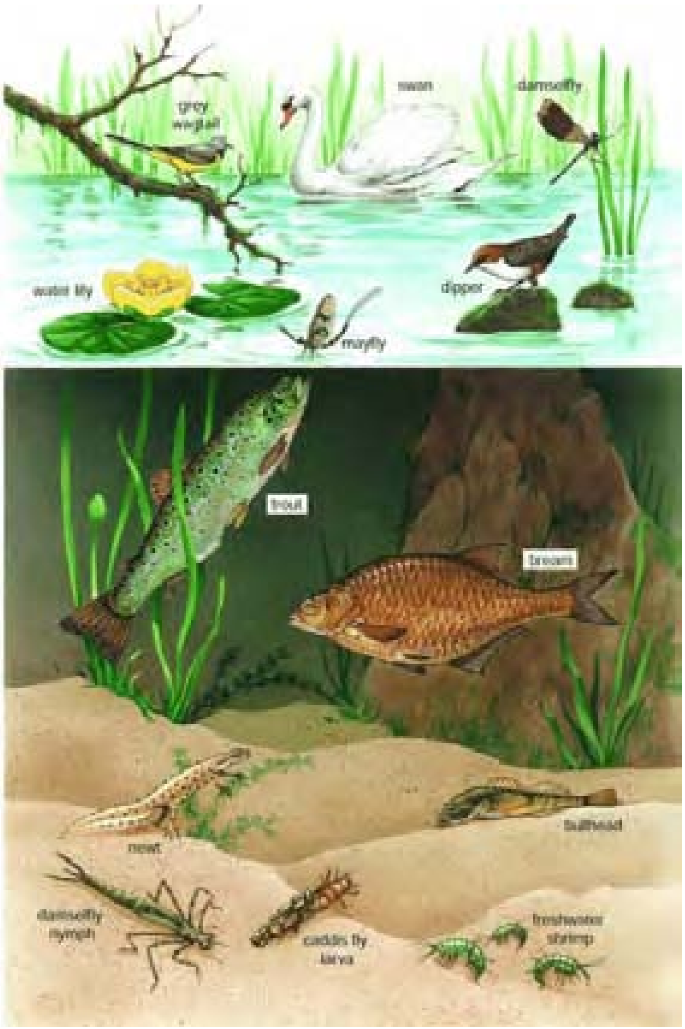
A river runs through a steep-sided rift valley at Thingvellir, in Iceland. In this area, the North American plate is pulling away from the European plate at an annual rate of 2 cm/0.8 in. It is part of the Mid-Atlantic Ridge, a constructive plate boundary where new material is formed by the cooling of lava.

river

(Image © Garret Nagle)

An urban river, the River Wandle, which flows through southwest London, England. In most developed countries natural rivers are now rare. Many lowland rivers have been significantly altered by engineering. Rivers have been straightened, widened, and deepened, and their banks have been built up. This is to protect urban residents and businesses from flooding. They do this by removing the water from the urban area as quickly as possible. Wider, deeper rivers can remove more water than small, narrow ones.

river


grey wagtail
swan
damselfly
water lily
mayfly
dipper
trout
bream
newt
bullhead
damselfly nymph
caddis fly larva
freshwater shrimp

(Image © Research Machines plc)

Some of the animals and plants that are likely to be found in a slow-moving British river.

Longest rivers in the world

River	Location	Approximate length	
		km	mi
Nile	Africa	6,695	4,160
Amazon	South America	6,570	4,083
Chang Jiang (Yangtze)	China	6,300	3,915
Mississippi-Missouri-Red Rock	USA	6,020	3,741
Huang He (Yellow River)	China	5,464	3,395
Ob-Irtysh	China/Kazakhstan/Russian Federation	5,410	3,362
Amur-Shilka	Asia	4,416	2,744
Lena	Russian Federation	4,400	2,734
Congo	Africa	4,374	2,718
Mackenzie-Peace-Finlay	Canada	4,241	2,635
Mekong	Asia	4,180	2,597
Niger	Africa	4,100	2,548
Yenisei	Russian Federation	4,100	2,548
Paraná	Brazil	3,943	2,450
Mississippi	USA	3,779	2,348
Murray-Darling	Australia	3,751	2,331
Missouri	USA	3,726	2,315
Volga	Russian Federation	3,685	2,290
Madeira	Brazil	3,241	2,014
Purus	Brazil	3,211	1,995
São Francisco	Brazil	3,199	1,988
Yukon	USA/Canada	3,185	1,979
Rio Grande	USA/Mexico	3,058	1,900
Indus	Tibet/Pakistan	2,897	1,800
Danube	central and eastern Europe	2,858	1,776

Japura	Brazil	2,816	1,750
Salween	Myanmar/China	2,800	1,740
Brahmaputra	Asia	2,736	1,700
Euphrates	Iraq	2,736	1,700
Tocantins	Brazil	2,699	1,677
Zambezi	Africa	2,650	1,647
Orinoco	Venezuela	2,559	1,590
Paraguay	Paraguay	2,549	1,584
Amu Darya	Tajikistan/Turkmenistan/Uzbekistan	2,540	1,578
Ural	Russian Federation/Kazakhstan	2,535	1,575
Kolyma	Russian Federation	2,513	1,562
Ganges	India/Bangladesh	2,510	1,560
Arkansas	USA	2,344	1,459
Colorado	USA	2,333	1,450
Dnieper	Russian Federation/Belarus/Ukraine	2,285	1,420
Syr Darya	Asia	2,205	1,370
Irrawaddy	Myanmar	2,152	1,337
Orange	South Africa	2,092	1,300

Hydrology of the Bryant Watershed

Go to site

Accessible page on the hydrology of the Bryant Watershed, in the Ozark Plateau of Missouri. The text traces the progress of Bryant Creek and describes the components of a stream including the watershed, the floodplain, and the stream corridor.

River Systems

Go to site

The site begins by defining the major characteristics of a river stream and then classifies an extensive list of concepts including information on drainage patterns, stream flow, and erosion into clearly organized tables and key points to note. A very thorough site, this would make a useful aid to revision.

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river blindness

another name for onchocerciasis, a disease prevalent in some countries of the developing world.

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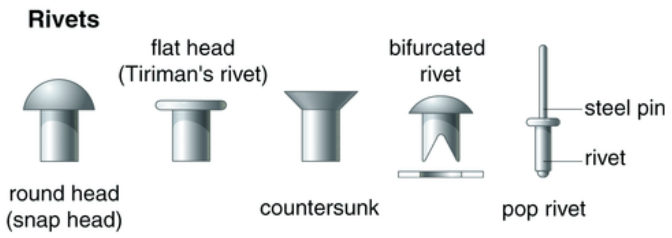
riveting

method of joining metal plates. A hot metal pin called a rivet, which has a head at one end, is inserted into matching holes in two overlapping plates, then the other end is struck and formed into another head, holding the plates tight. Riveting is used in building construction, boilermaking, and shipbuilding.

rivet



(Image © Research Machines plc)

Rivets are a quick method of permanently joining metal sheets together. Pop rivets are useful as they enable riveting from just one side.

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roach

any freshwater fish of the Eurasian genus *Rutilus*, of the carp family, especially *R. rutilus* of northern Europe. It is dark green above, whitish below, with reddish lower fins; it grows to 35 cm/1.2 ft.

road

specially constructed route for wheeled vehicles to travel on. Reinforced tracks became necessary with the invention of wheeled vehicles in about 3000 BC and most ancient civilizations had some form of road network.

early history

The first major road was the Persian Royal Road from the Gulf to the Aegean Sea, more than 2,800 km/4,480 mi long, used from 3500 BC. Ancient China also had an extensive road network. The Romans developed engineering techniques that were not equalled for another 1,400 years. Roman roads were usually straight, and composed of large flat stones, topped with a layer of gravel and a hard surface. During the Middle Ages, the quality of roads deteriorated. By the late 18th century most European roads were haphazardly maintained, making winter travel difficult. In England the Statute for Mending the Highways (1555) required all members of the parish to spend four days a year working on mending the roads, but the work was poorly done or not done at all, and travellers complained of ruts, mud, accidents, and highwaymen. Roads were particularly impracticable for heavy or bulk transport, and iron-rimmed wagon wheels broke up the road surface, despite legislation to try to increase the width of wheels.

improvements after 1700

General George Wade, commander of the English army in Scotland, improved many of the roads in the Highlands between 1726 and 1737, so that troops could be moved to areas of disturbance more quickly. In the 18th century in the UK, the increasing pace of trade required a corresponding improvement in the roads. The turnpike road system of collecting tolls created some improvement (although the turnpikes met with some opposition, notably the Rebecca Riots in South Wales 1842–44). The Scottish engineers Thomas Telford and John McAdam introduced sophisticated construction methods in the late 18th and early 19th century. The years from around 1750 to 1835 have been called 'the Coaching Age', as improved road transport allowed reduced journey times, stagecoaches, coaching inns, haulage firms, and a national postal service. The advent of the railways, however, drove most coaching firms into bankruptcy.

modern roads

The bicycling craze of the late 19th century and the development of the internal combustion engine and motor car led to the improvement of road systems after 1900. Road builders began to use asphalt to create a smooth, durable surface that would not create dust. The first motorway was completed in Italy in 1924, and Hitler initiated a system of autobahns in Germany in the 1930s.

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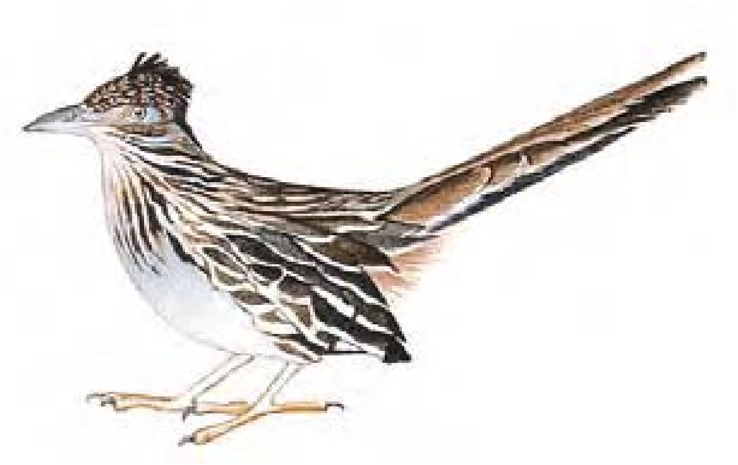
roadrunner

crested North American ground-dwelling bird *Geococcyx californianus* of the cuckoo family, found in the southwestern USA and Mexico. It can run at a speed of 25 kph/15 mph.

roadrunner



(Image © Research Machines plc)

The greater roadrunner is often seen on roads, as its name implies, and runs rapidly away if disturbed. It inhabits the semi-arid open country of the southwestern USA, and feeds on ground-dwelling insects, which it kills by a sudden pounce on the prey.

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robin

one of two songbirds of the thrush family. (1) North American thrush, the robin *Turdus migratorius*, 10 in/25 cm long, gray brown with brick-red underparts. (2) Eurasian and African thrush *Erithacus rubecula*, 5 in/13 cm long, olive brown above with a red breast.

Robinson, Robert (1886-1975)

English chemist who was awarded the Nobel Prize for Chemistry in 1947 for his research in organic chemistry on the structure of many natural products, including flower pigments and alkaloids. He formulated the electronic theory now used in organic chemistry. He was knighted in 1939.

Robinson's studies of the sex hormones, bile acids, and sterols were fundamental to the methods now used to investigate steroid compounds. His discovery that certain synthetic steroids could produce the same biological effects as the natural oestrogenic sex hormones paved the way for the contraceptive pill.

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robot

any computer-controlled machine that can be programmed to move or carry out work. Robots are often used in industry to transport materials or to perform repetitive tasks. For instance, robotic arms, fixed to a floor or workbench, may be used to paint machine parts or assemble electronic circuits. Other robots are designed to work in situations that would be dangerous to humans – for example, in defusing bombs or in space and deep-sea exploration.

Some robots are equipped with sensors, such as touch sensors and video cameras, and can be programmed to make simple decisions based on the sensory data received. As robots do not suffer from fatigue or become distracted, researchers in robotics aim to produce robots that can carry out sophisticated tasks more efficiently than humans, for example a voice-operated robot able to carry out some heart operations was tested successfully on a cow in the USA in 1998.

robot

The word 'robot' originated in the theatre. It was invented by the Czech playwright Karel Capek in his 1921 play *R.U.R.* (Rossum's Universal Robots).

Roche limit

in astronomy, distance from a planet within which a large moon would be torn apart by the planet's gravitational force, creating a set of rings. The Roche limit lies at approximately 2.5 times the planet's radius (the distance from its centre to its surface).

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rock

constituent of the Earth's crust composed of minerals or materials of organic origin that have consolidated into hard masses. There are three basic types of rock: igneous, sedimentary, and metamorphic. Rocks are composed of a combination (or aggregate) of minerals, and the property of a rock will depend on its components. Where deposits of economically valuable minerals occur they are termed **ores**. As a result of weathering, rock breaks down into very small particles that combine with organic materials from plants and animals to form soil. In geology the term 'rock' can also include unconsolidated materials such as sand, mud, clay, and peat.

The change of one type of rock to another is called the rock cycle.

rock

The oldest known rocks are found near the Great Slave and Great Bear lakes in Canada. The rocks, which include granite, are 4.03 billion years old.

Composition of Rocks

Go to site

From a much larger site 'Fundamentals of Physical Geography' set up by a Canadian university and covering many aspects of the area of study. The site is clear and well organized and contains maps and diagrams.

Geologylink

Go to site

Comprehensive information on geology featuring a daily update on current geologic events, virtual classroom tours, and virtual field trips to locations around the world. The site also provides an image gallery, maps, and a glossary giving clear and concise descriptions.

Rock Cycle

Go to site

Graphical depiction of the rock cycle, including the three types of rock: metamorphic, sedimentary, and igneous. Click on the links to find more information on the three types and sub-types that are present. A colourful style highlights key concepts and words in connection with the rock cycle.

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rocket

projectile driven by the reaction of gases produced by a fast-burning fuel. Unlike jet engines, which are also reaction engines, rockets carry their own oxygen supply to burn their fuel and do not require any surrounding atmosphere. For warfare, rocket heads carry an explosive device.

Rockets have been valued as fireworks since the middle ages, but their intensive development as a means of propulsion to high altitudes, carrying payloads, started only after World War I with state-supported work in Germany (primarily by German-born US rocket engineer Wernher von Braun) and the work of US rocket pioneer Robert Hutchings Goddard. Being the only form of propulsion available that can function in a vacuum, rockets are essential to exploration in outer space. Multistage rockets have to be used, consisting of a number of rockets joined together, which are successively discarded during the journey.

Rocketry Online

Go to site

Searchable site with reference materials, organizations, clubs, upcoming launches, products, and books devoted to rocketry.

Rocky Mountain goat

species of ruminant that occurs in North America. It is intermediate in position between a goat and an antelope. It resembles a goat in size and has long white hair with woolly undercoat, black, hollow horns, compressed at the base, and short ears.

classification

The Rocky Mountain goat *Oreamnos americanus* is a member of the family Bovidae, order Artiodactyla.

Rodchenko, Alexander Mikhailovich (1891-1956)

Russian avant-garde painter, designer, and photographer. The aim of his work, in all media, was to create a visual language that would reflect the new revolutionary times. His paintings were abstract works based on severe geometrical shapes; under the influence of Tatlin he made three-dimensional constructions of wood, cardboard, and metal. His photographs of everyday objects were presented in close-up, from strange angles or from high viewpoints, an approach similar to that of the Hungarian Laszlo Moholy-Nagy; they document the early years of the Soviet era.

---

rodent

any mammal of the worldwide order Rodentia, making up nearly half of all mammal species. Besides ordinary 'cheek teeth', they have a single front pair of incisor teeth in both upper and lower jaw, which continue to grow as they are worn down.

rodent

Once attached to their mother's nipple, the young of some rodent species simply do not let go. This prevents any rival sibling from muscling in on the young rodent's food supply, and also enables it to hang on if the mother is forced to run away from a predator. Tenacious clinging is characteristic of 44 rodent species, all in the mouse family.

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roebuck

male of the Eurasian roe deer.

---

roe deer

or roebuck

small deer (the buck stands about 66 cm/26 in at the shoulder, and is 1.2 m/ 4 ft in length from the nose to the tiny tail). Roe deer are reddish-brown in summer (in winter the redness disappears), and the underparts are yellowish-grey. The horns average about 20 cm/8 in in length.

The mating season is in July to August and the young are born in the following May and June. They are at first reddish-brown with white spots.

Roe deer occur over central and southern Europe, and other races range as far east as China.

classification

The roe deer *Capreolus capreolus* is in family Cervidae, order Artiodactyla.

---

roentgen

or röntgen; symbol R

unit of radiation exposure, used for X-rays and gamma rays. It is defined in terms of the number of ions produced in one cubic centimetre of air by the radiation. Exposure to 1,000 roentgens gives rise to an absorbed dose of about 870 rads (8.7 grays), which is a dose equivalent of 870 rems (8.7 sieverts).

Rogers, Carl Ransom (1902-1987)

US psychologist who developed the client-centred approach to counselling and psychotherapy. This stressed the importance of clients making their own decisions and developing their own potential (self-actualization).

He emphasized the value of genuine interest on the part of a therapist who is also accepting and empathetic. Rogers's views became widely employed.

---

roller

any brightly coloured bird of the Old World family Coraciidae, resembling crows but in the same order as kingfishers and hornbills. Rollers grow up to 32 cm/13 in long. The name is derived from the habit of some species of rolling over in flight.

---

rolling

common method of shaping metal. Rolling is carried out by giant mangles, consisting of several sets, or stands, of heavy rollers positioned one above the other. Red-hot metal slabs are rolled into sheet and also (using shaped rollers) girders and rails. Metal sheets are often cold-rolled finally to impart a harder surface.

ROM

acronym for read-only memory

in computing, a memory device in the form of a collection of integrated circuits (chips), frequently used in microcomputers. ROM chips are loaded with data and programs during manufacture and, unlike RAM (random-access memory) chips, can subsequently only be read, not written to, by a computer. However, the contents of the chips are not lost when the power is switched off, as happens in RAM.

Roman numerals

ancient European number system using symbols different from Arabic numerals (the ordinary numbers 1, 2, 3, 4, 5, and so on). The seven key symbols in Roman numerals, as represented today, are I (1), V (5), X (10), L (50), C (100), D (500), and M (1,000). There is no zero, and therefore no place-value as is fundamental to the Arabic system. The first ten Roman numerals are I, II, III, IV (or IIII), V, VI, VII, VIII, IX, and X. When a Roman symbol is preceded by a symbol of equal or greater value, the values of the symbols are added (XVI = 16).

When a symbol is preceded by a symbol of less value, the values are subtracted (XL = 40). A horizontal bar over a symbol indicates a multiple of 1,000 (= 10,000). Although addition and subtraction are fairly straightforward using Roman numerals, the absence of a zero makes other arithmetic calculations (such as multiplication) clumsy and difficult.

Roman numerals: order

To remember the Roman numerals in order for 50, 100, 500, and 1000:

Lucy **c**an't **d**rink **m**ilk or **L**ucky **c**ows **d**rink **m**ilk

L, C, D, M

Roman numerals: values

To remember the values of Roman numerals:

X shall stand for playmates Ten,
V for Five stout stalwart men,
I for One, as I'm alive,
C for Hundred and **D** for Five.
M for a Thousand soldiers true,
and **L** for Fifty, I'll tell you

Roman numerals

A horizontal line over the top of a letter indicates its value is to be multiplied by 1,000.

Roman	Arabic
I	1
II	2
III	3
IV	4
V	5
VI	6
VII	7
VIII	8
IX	9
X	10
XI	11
XIX	19
XX	20
XXX	30
XL	40
L	50
LX	60
XC	90
C	100
CC	200
CD	400
D	500
CM	900
M	1,000

---

röntgen

alternative spelling for roentgen, unit of X- and gamma-ray exposure.

Röntgen (or Roentgen), Wilhelm Konrad (1845-1923)

German physicist. He was awarded the Nobel Prize for Physics in 1901 for his discovery of X-rays in 1895. While investigating the passage of electricity through gases, he noticed the fluorescence of a barium platinocyanide screen. This radiation passed through some substances opaque to light, and affected photographic plates. Developments from this discovery revolutionized medical diagnosis.

Röntgen, Wilhelm Conrad

Go to site

Biography of Wilhelm Conrad Röntgen, the German physicist who first realized the huge potential of the electromagnetic field of X-rays. The presentation includes sections on Röntgen's early years and education, his academic career and scientific experiments, and the coincidences that led him to his great discovery of X-rays.

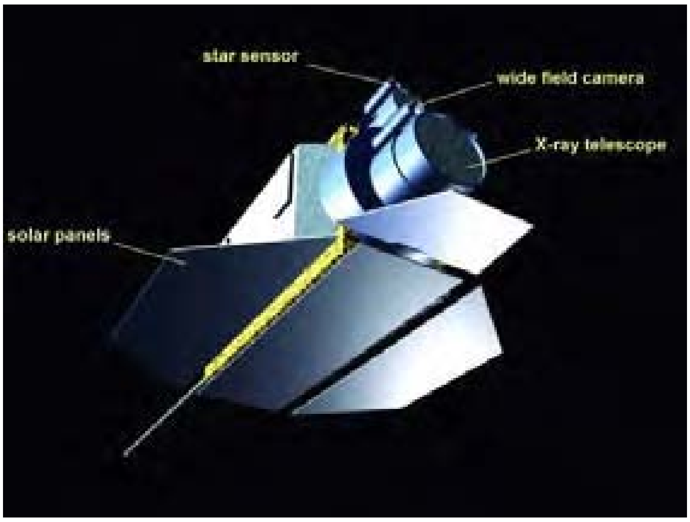
Röntgen Satellite

ROSAT

joint US-German-UK satellite launched in 1990 to study cosmic sources of X-rays and extreme-ultraviolet (EUV) wavelengths, named after German physicist Wilhelm Röntgen, the discoverer of X-rays. After more than 9,000 observations of objects including comets, quasars, black holes, clusters of galaxies, and supernovae, the satellite was finally switched off on 12 February 1999.

Rosat was designed to produce the first all-sky fully imaging surveys in the X-ray and extreme ultraviolet parts of the spectrum. The satellite used a German X-ray telescope developed under the leadership of the Max Planck Institute, and the Wide-Field Camera (extreme-ultraviolet telescope) constructed by a UK team led by the University of Leicester and funded by the UK's Particle Physics and Astronomy Research Council (PPARC). The USA provided an additional X-ray camera and the launch vehicle, and the main spacecraft and mission operations were funded by Germany.

Röntgen Satellite



(Image © Research Machines plc)

The Röntgen Satellite was powered by three solar panels, which provided one kilowatt of power during the sunlit parts of the orbit. It had a rechargeable battery for the shadow phase of its orbit.

ROSAT Guest Observer Facility

Go to site

Profiles the nine-year Röntgen Satellite (ROSAT) mission and describes the spacecraft and its science payload. There is extensive technical documentation, including the ROSAT users' handbook, access to data from the mission, and a very good image gallery.

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rook

gregarious European crow*Corvus frugilegus*. The plumage is black and lustrous and the face bare; the legs, toes, and claws are also black. A rook can grow to 45 cm/18 in long. Rooks nest in colonies (rookeries) at the tops of trees. They feed mainly on invertebrates found just below the soil surface. The last 5 mm/0.2 in of beak tip is mostly cartilage containing lots of nerve endings to enable the rook to feel for hidden food.

The nest is a large structure made of twigs and straw, and in it are laid four to six bluish-green eggs blotched with greenish-brown. Feathers round the base of the beak are present in young birds but do not grow again after the second moult.

---

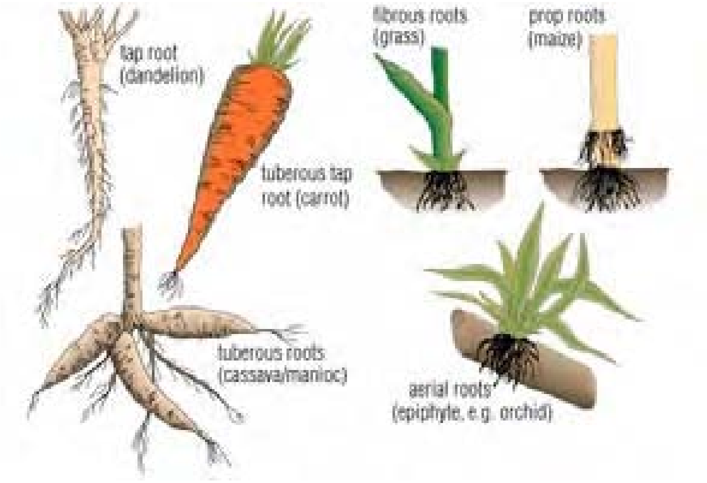
root

the part of a plant that is usually underground, and whose primary functions are anchorage and the absorption of water and dissolved mineral salts. Roots usually grow downwards and towards water (that is, they are positively geotropic and hydrotropic; see tropism). Plants such as epiphytic orchids, which grow above ground, produce aerial roots that absorb moisture from the atmosphere. Others, such as ivy, have climbing roots arising from the stems, which serve to attach the plant to trees and walls.

The absorptive area of roots is greatly increased by the numerous slender root hairs formed near the tips. A calyptra, or root cap, protects the tip of the root from abrasion as it grows through the soil.

Symbiotic associations occur between the roots of certain plants, such as clover, and various bacteria that fix nitrogen from the air (see nitrogen fixation). Other modifications of roots include contractile roots, pneumatophores, taproots, and prop roots.

root



(Image © Research Machines plc)

Types of root. Many flowers (dandelion) and vegetables (carrot) have swollen tap roots with smaller lateral roots. The tuberous roots of the cassava are swollen parts of an underground stem modified to store food. The fibrous roots of the grasses are all of equal size. Prop roots grow out from the stem and then grow down into the ground to support a heavy plant. Aerial roots grow from stems but do not grow into the ground; many absorb moisture from the air.

root

of an equation, a value that satisfies the equality. For example, $x = 0$ and $x = 5$ are roots of the equation $x^2 - 5x = 0$.

root crop

plant cultivated for its swollen edible root (which may or may not be a true root). Potatoes are the major temperate root crop; the major tropical root crops are cassava, yams, and sweet potatoes. Root crops are second in importance only to cereals as human food. Roots have a high carbohydrate content, but their protein content rarely exceeds 2%. Consequently, communities relying almost exclusively upon roots may suffer from protein deficiency. Food production for a given area from roots is greater than from cereals.

In the mid-1980s, world production of potatoes, cassava, and yams was just under 600 million tonnes. Root crops are also used as animal feed, and may be processed to produce starch, glue, and alcohol. Sugar beet has largely replaced sugar cane as a source of sugar in Europe.

root directory

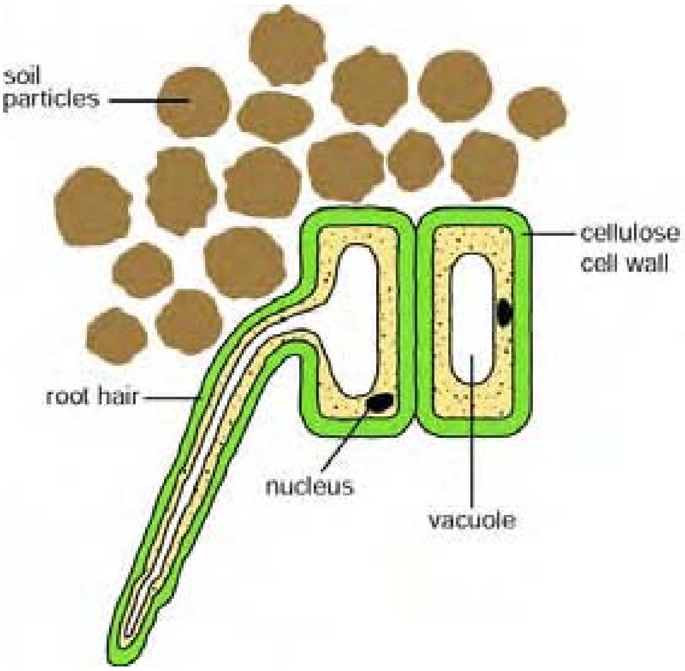
in computing, the top directory in a tree-and-branch filing system. It contains all the other directories.

root hair

tiny, hair-like outgrowth of some surface cells of plant roots that greatly increases the area available for the absorption of water and other materials such as minerals. It is a delicate structure, which survives for a few days only and does not develop into a root. Root hair cells are found just behind the root tip where they are continually being formed. They grow out into the soil for a few millimetres to produce the root hair. Each root hair is made of a single cell. At the root tip mitosis cell division is very active making new cells for growth to replace the root hair cells that die.

The majority of land plants have root hairs. The layer of the root's epidermis that produces root hairs is known as the **piliferous layer**.

root hair



(Image © Research Machines plc)

Water is absorbed from the soil by the root hair cells and then travels through the xylem to the plant's leaves. The root hair cells give the root a large surface area through which to absorb water.

root mean square

rms

in mathematics, value obtained by taking the square root of the mean of the squares of a set of values; for example the rms value of four quantities a, b, c, and d is

$\sqrt{[(a^2 + b^2 + c^2 + d^2)/4]}$.

root nodule

clearly visible swelling that develops in the roots of members of the bean family, the Leguminosae. The cells inside this tumourous growth have been invaded by the bacteria Rhizobium, a soil microbe capable of converting gaseous nitrogen into nitrate. The nodule is therefore an association between a plant and a bacterium, with both partners benefiting. The plant obtains nitrogen compounds while the bacterium obtains nutrition and shelter.

Nitrogen fixation by bacteria is one of the main ways by which the nitrogen in the atmosphere is cycled back into living things. The economic value of the process is so great that research has been carried out into the possibility of stimulating the formation of root nodules in crops such as wheat, which do not normally form an association with rhizobium.

rootstock

another name for rhizome, an underground plant organ.

rope

stout cordage with circumference over 2.5 cm/1 in. Rope is made similarly to thread or twine, by twisting yarns together to form strands, which are then in turn twisted around one another in the direction opposite to that of the yarns. Although hemp is still used to make rope, nylon is increasingly used.

rorqual

any of a family (Balaenopteridae) of baleen whales, especially the genus *Balaenoptera*, which includes the blue whale *B. musculus*, the largest of all animals, measuring 30 m/100 ft and more. The common rorqual or fin whale *B. physalus* is slate-coloured and not quite so long.

The sei whale *B. borealis*, the minke whale *B. acutorostrata*, Bryde's whale *B. edeni*, and the humpback whale *Megaptera novaeangliae* also belong to this family. All are long-bodied whales with pleated throats.

Rorschach test

in psychology, a method of diagnosis involving the use of inkblot patterns that subjects are asked to interpret, to help indicate personality type, degree of intelligence, and emotional stability. It was invented by the Swiss psychiatrist Hermann Rorschach.

ROSAT

contraction of Röntgen Satellite.

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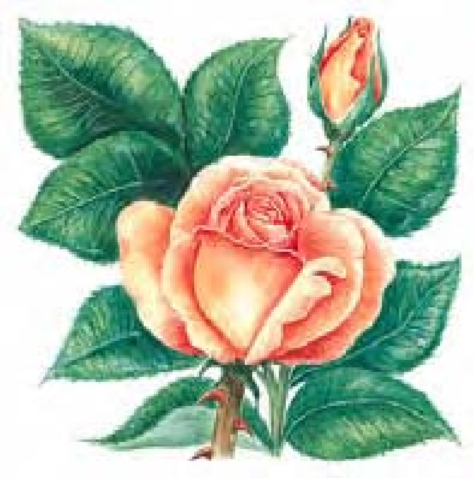
rose

any shrub or climbing plant belonging to the rose family, with prickly stems and fragrant flowers in many different colours. Numerous cultivated forms have been derived from the sweetbrier or eglantine (*R. rubiginosa*) and dogrose (*R. canina*) native to Europe and Asia. There are many climbing varieties, but the forms most commonly grown in gardens are bush roses and standards (cultivated roses grafted on to a brier stem). (Genus *Rosa*, family Rosaceae.)

rose



(Image © Research Machines plc)

There are many species of rose, and many cultivated varieties. The flowers are followed by brightly coloured false fruits called hips. These are fleshy growths formed from the stem beneath the flower. The true fruits are the 'seeds' within the hips.

Gertrude Jekyll: Roses for English Gardens

Go to site

Complete text of this work by the English landscape designer and gardener Gertrude Jekyll. The books focuses on a number of topics, such as new and old garden roses, Brier and Pompon roses, and rose arches, arbours, screens, hedges, and trellises.

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rose chafer

or rose beetle

brightly coloured insect occurring mainly in the tropics.

In the adult stage rose chafers feed on tender shoots and floral parts of plants or on the sap exuded from trees. In contrast, the larvae are generally found in soil, where they attack the roots of most plants, and hence are agricultural pests. Some also inhabit decaying wood, leaf litter, and other plant refuse. There are about 2,500 species.

classification

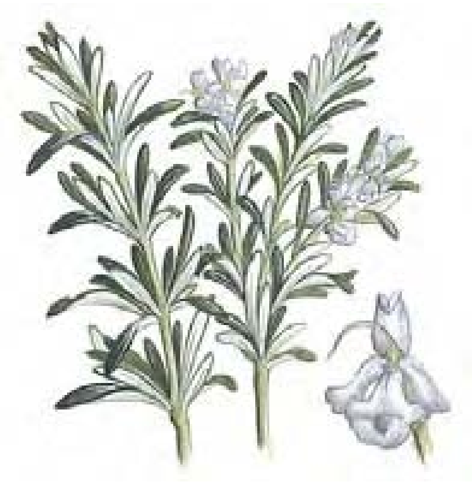
The rose chafer is in subfamily Cetoniinae, family Scarabaeidae, order Coleoptera, class Insecta, phylum Arthropoda.

---

rosemary

evergreen shrub belonging to the mint family, native to the Mediterranean and western Asia, with small, narrow, scented leaves and clusters of pale blue or purple flowers. It is widely cultivated as a herb for use in cooking and for its aromatic oil, used in perfumery and pharmaceuticals. Rosemary is a traditional symbol of remembrance. (*Rosemarinus officinalis*, family Labiatae.)

rosemary



(Image © Research Machines plc)

Rosemary is a bushy perennial shrub, often growing to a height of over 180 cm/6 ft. It has evergreen needles, dark green on top and silver underneath. It produces light-blue or purple flowers in early summer.

Rosetta

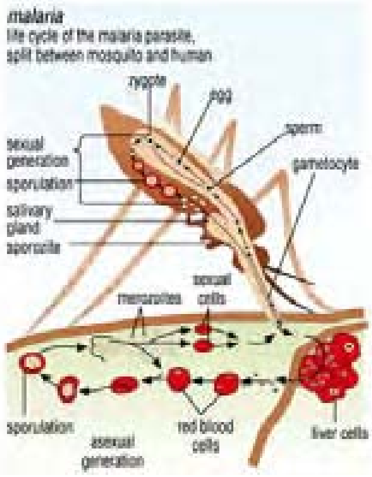
satellite of the European Space Agency, launched on 2 March 2004, to send a spacecraft to the comet Churyumov-Gerasimenko, a body 4 kilometres in diameter which at that point will be 675 million kilometres from the Sun. Rosetta is scheduled to orbit the comet for six months before selecting a landing spot for the small Philae lander. Rosetta and Philae will then travel with Churyumov-Gerasimenko as it travels toward the centre of the solar system. Rosetta is expected to reach its destination in 2014.

Rosetta is named after the Rosetta Stone that was used to decipher ancient Egyptian writing, because the probe should 'decipher' the comet.

Ross, Ronald (1857-1932)

Indian-born British physician and bacteriologist who was awarded a Nobel Prize for Physiology or Medicine in 1902 for his work on the role of the *Anopheles* mosquito in transmitting malaria. From 1881 to 1899 he served in the Indian Medical Service, and during 1895–98 identified mosquitoes of the genus *Anopheles* as being responsible for the spread of malaria. He was knighted in 1911.

malaria


malaria
life cycle of the malaria parasite,
split between mosquito and human
zygote
egg
sperm
gametocyte
sexual generation
sporulation
salivary gland
sporozoite
merozoites
sexual cells
sporulation
asexual generation
red blood cells
liver cells

(Image © Research Machines plc)

The life cycle of the malaria parasite is split between mosquito and human hosts. The parasites are injected into the human bloodstream by an infected *Anopheles* mosquito and carried to the liver. Here they attack red blood cells, and multiply asexually. The infected blood cells burst, producing spores, or merozoites, which reinfect the bloodstream. After several generations, the parasite develops into a sexual form. If the human host is bitten at this stage, the sexual form of the parasite is sucked into the mosquito's stomach. Here fertilization takes place, the zygotes formed reproduce asexually and migrate to the salivary glands ready to be injected into another human host, completing the cycle.

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rotavirus

in medicine, one of a group of viruses that infect the small intestine and are a common cause of gastroenteritis in young children.

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rotifer

any of the tiny invertebrates, also called 'wheel animalcules', of the phylum Rotifera. Mainly freshwater, some marine, rotifers have a ring of cilia that carries food to the mouth and also provides propulsion. They are the smallest of multicellular animals – few reach 0.05 cm/0.02 in.

Rottweiler

breed of dog originally developed in Rottweil, Germany, as a herding and guard dog, and subsequently used as a police dog. Powerfully built, the dog is about 63-66 cm/25-27 in high at the shoulder, black with tan markings. It has a short coat and docked tail.

American Rottweiler Club

Go to site

Information about the history of the breed, the breed standard, shows, veterinary advice, and grooming. The many tips for owners include advice on what to do if your Rottweiler bites someone. There is also a comprehensive listing of other Rottweiler sites across the world and a useful bibliography.

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roughage

alternative term for dietary fibre, material of plant origin that cannot be digested by enzymes normally present in the human gut.

---

roup

contagious respiratory disease of poultry and game birds. It is characterized by swelling of the head and purulent catarrh.

---

router

in computing, a device that pushes traffic through a packet-switched network. On the Internet, traffic travels through a series of routers that relay each **packet** of data to its destination by the best possible route.

A router is a device that may be used to connect two or more networks together, or to connect a network to the Internet. The router receives packets of data on the network and uses headers and forwarding tables to direct these packets to the appropriate network interface.

---

rove beetle

any of a number of beetles with characteristic very short elytra (wing cases) that conceal large, well developed wings that are intricately folded away. When required the wings can unfold very rapidly, for almost instantaneous flight. The family includes some 20,000 species.

classification

The rove beetle is in family Staphylinidae, in order Coleoptera, class Insecta, phylum Arthropoda.

Most of these beetles are small and inconspicuous, except the devil's coach horse, which is about 3 cm/1.2 in. Some species are predatory; others live in association with ant and termite colonies.

---

royal antelope

small nocturnal African antelope, inhabitants of dense jungle. They are the smallest of all antelopes, being no more than 30 cm/12 in high, and are slenderly built with very thin legs, no thicker than a pencil; they are generally brown in colour.

classification

The royal antelope *Neotragus pygmaeus* is in family Bovidae, in order Artiodactyla.

Royal Botanic Gardens, Kew

botanic gardens in Richmond, Surrey, England, popularly known as Kew Gardens.

Royal Botanic Gardens, Kew

Go to site

Kew Gardens' home page, with general visitor information, a history of the gardens, a guide to the main plant collections, and a searchable database.

Royal Greenwich Observatory

the Royal Greenwich Observatory (RGO) was founded in 1675 at Greenwich, East London, to provide navigational information to sailors. After World War II it moved to Herstmonceux Castle in Sussex, where the 2.5-m/8.2-ft Isaac Newton Telescope (INT) was constructed in 1967. Following the relocation of the INT to the island of La Palma, in the Canary Islands, RGO was relocated to Cambridge in 1988-90. In 1998 the Cambridge site was closed and the RGO merged with the Royal Observatory Edinburgh to form a new Astronomy Technology Centre on the Edinburgh site.

The observatory was founded by King Charles II. The eminence of its work resulted in Greenwich Time and the Greenwich Meridian being adopted as the international standard of reference in 1884.

Royal Observatory Greenwich

Go to site

Official and searchable site of the world's most famous observatory. In addition to a history and guide for visitors to the observatory's museum, there are comprehensive details of current research. This is an important site both for students of astronomy and for those seeking information on latest research.

Royal Institution of Great Britain

organization for the promotion, diffusion, and extension of science and knowledge, founded in London in 1799 by the Anglo-American physicist Count Rumford.

Royal Institution of Great Britain

Go to site

Profile of the history and role of the world's longest established independent research organization. There is information on the structure of the RI, ongoing scientific research, and its extensive programme of activities to educate the public about science.

Royal Society

oldest and premier scientific society in Britain, originating in 1645 and chartered in 1662; Robert Boyle, Christopher Wren, and Isaac Newton were prominent early members. Its Scottish equivalent is the **Royal Society of Edinburgh** (1783).

History of the Royal Society

Go to site

Web site run by St Andrews University detailing the history of the Royal Society. Biographical details of the founding members are provided, as is information on the main prizes the society awards for scientific achievement.

RU486

another name for mifepristone, an abortion pill.

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rubber

slang term for a condom.

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rubber

coagulated latex of a variety of plants, mainly from the New World. Most important is Para rubber, which comes from the tree *Hevea brasiliensis*, belonging to the spurge family. It was introduced from Brazil to Southeast Asia, where most of the world supply is now produced, the chief exporters being Peninsular Malaysia, Indonesia, Sri Lanka, Cambodia, Thailand, Sarawak, and Brunei. At about seven years the tree, which may grow to 20 m/60 ft, is ready for tapping. Small cuts are made in the trunk and the latex drips into collecting cups. In pure form, rubber is white and has the formula $(C_5H_8)_n$.

plant rubber

Other sources of rubber are the Russian dandelion *Taraxacum koksagyz*, which grows in temperate climates and can yield about 45 kg/100 lb of rubber per tonne of roots, and guayule *Parthenium argentatum*, a small shrub which grows in the southwestern USA and Mexico.

treatment

Early uses of rubber were limited by its tendency to soften on hot days and harden on colder ones, a tendency that was eliminated by Charles Goodyear's invention of vulcanization in 1839.

synthetic rubber

In the 20th century, world production of rubber increased a hundredfold, and World War II stimulated the production of synthetic rubber to replace the supplies from Malaysian sources overrun by the Japanese. There are a variety of synthetic rubbers adapted to special purposes, but economically foremost is SBR (styrene-butadiene rubber). Cheaper than natural rubber, it is preferable for some purposes, for example in car tyres, where its higher abrasion resistance is useful, and it is either blended with natural rubber or used alone for industrial moulding and extrusions, shoe soles, hoses, and latex foam.

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rubber plant

Asiatic tree belonging to the mulberry family, native to Asia and North Africa, which produces latex in its stem. It has shiny, leathery, oval leaves, and young specimens are grown as house plants. (*Ficus elastica*, family Moraceae.)

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rubefacient

in medicine, substance that produces irritation of the skin (counterirritation) and subsequently alleviates pain, whether deep seated or superficial. Creams and gels containing rubefacients, such as salicylates, are useful in relieving muscle, tendon, and joint pains and also some types of rheumatic pain.

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rubella

technical term for German measles.

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rubidium

chemical symbol Rb

(Latin rubidus 'red')

soft, silver-white, metallic element, atomic number 37, relative atomic mass 85.47. It is one of the alkali metals in Group 1 of the periodic table. Reactivity of the alkali metals increases down the group and so rubidium is more reactive than lithium, sodium, and potassium. Rubidium ignites spontaneously in air and reacts violently with water. It is used in photocells and vacuum-tube filaments.

Rubidium was discovered spectroscopically by German physicists Robert Bunsen and Gustav Kirchhoff in 1861 and named after the red lines in its spectrum.

Rubik, Ernö (1944-)

Hungarian architect who invented the **Rubik cube**, a multicoloured puzzle that can be manipulated and rearranged in a vast number of ways,only one of which displays a single colour on every face of the cube. Intended to help his students understand three-dimensional design, it became a fad that swept around the world.

Rubik Online

Go to site

Detailed site about the Rubik's cube. It allows you to play with the cube and learn how to solve the puzzle, and also provides background information about the cube, and other puzzles invented by Erno Rubik. The site also contains competitions, a forum, and a downloadable screen saver.

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ruby

red transparent gem variety of the mineral corundum Al_2O_3, aluminium oxide. Small amounts of chromium oxide, Cr_2O_3, substituting for aluminium oxide, give ruby its colour. Natural rubies are found mainly in Myanmar (Burma), but rubies can also be produced artificially and such synthetic stones are used in lasers.

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rue

shrubby perennial herb native to southern Europe and temperate Asia. It bears clusters of yellow flowers. An oil extracted from the strongly scented blue-green leaves is used in perfumery. (*Ruta graveolens*, family Rutaceae.)

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ruff

bird *Philomachus pugnax* of the sandpiper family Scolopacidae. The name is taken from the frill of erectile purple-black feathers developed in the breeding season around the neck of the male. The females (reeves) have no ruff; they lay four spotted green eggs in a nest of coarse grass made amongst reeds or rushes. The ruff is found across northern Europe and Asia, and migrates south in winter. It is a casual migrant throughout North America.

---

ruminant

any even-toed hoofed mammal with a rumen, the 'first stomach' of its complex digestive system. Plant food is stored and fermented before being brought back to the mouth for chewing (chewing the cud) and then is swallowed to the next stomach. Ruminants include cattle, antelopes, goats, deer, and giraffes, all with a four-chambered stomach. Camels are also ruminants, but they have a three-chambered stomach.

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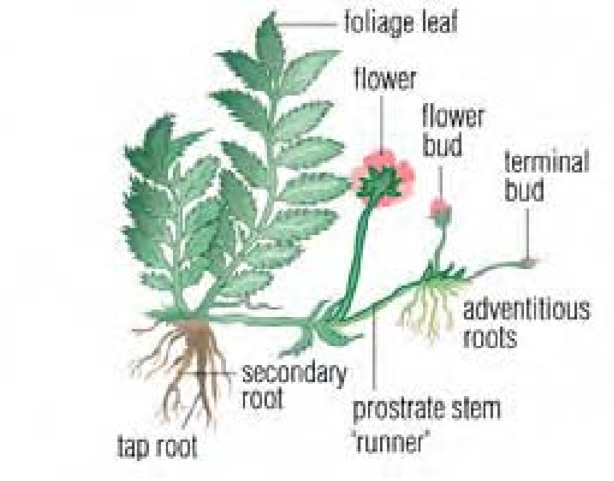
runner

or stolon

in botany, aerial stem that produces new plants.

runner



(Image © Research Machines plc)

A runner, or stolon, grows horizontally near the base of some plants, such as the strawberry. It produces roots along its length and new plants grow at these points.

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rupture

in medicine, another name for hernia.

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rush

any of a group of grasslike plants found in wet places in cold and temperate regions. The round stems and flexible leaves of some species have been used for making mats and baskets since ancient times. (Genus *Juncus*, family Juncaceae.)

Russell, Bertrand Arthur William (1872-1970)

3rd Earl Russell

English philosopher, mathematician, and peace campaigner. He contributed to the development of modern mathematical logic and wrote about social issues. His works include *Principia Mathematica* (1910-13; with A N Whitehead), in which he attempted to show that mathematics could be reduced to a branch of logic; *The Problems of Philosophy* (1912); and *A History of Western Philosophy* (1946). He was an outspoken liberal pacifist. He was awarded the Nobel Prize for Literature in 1950. He was made an Earl in 1931.

Russian Academy of Sciences

society founded in 1725 by Catherine the Great in St Petersburg. The academy has been responsible for such achievements as the Sputnik satellite, and has daughter academies in the Ukraine (welding, cybernetics), Armenia (astrophysics), and Georgia (mechanical engineering).

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russula

any of a large group of fungi (see fungus), containing many species. They are medium-to-large mushrooms with flattened caps and many are brightly coloured. (Genus *Russula*.)

R. emetica is a common species found in damp places under conifer trees. Up to 9 cm/3.5 in across, the cap is scarlet, fading to cherry, and the gills are white. This mushroom tastes acrid and causes vomiting eaten raw, but some russulas are edible.

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rust

in botany, common name for a group of minute parasitic fungi (see fungus) that appear on the leaves of their hosts as orange-red spots, later becoming darker. The commonest is the wheat rust *Puccinia graminis*, order Uredinales.

---

rust

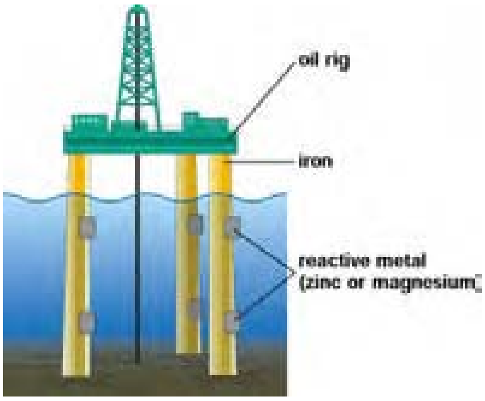
reddish-brown oxide of iron formed by the action of moisture and oxygen on the metal. It consists mainly of hydrated iron(III) oxide ($Fe_2O_3.H_2O$) and iron(III) hydroxide ($Fe(OH)_3$). Rusting is the commonest form of corrosion.

rust prevention

There are two main approaches to protect against rusting.
Barrier methods introduce a barrier between the metal and the air and moisture to minimize the reaction. This is the commonest method of rust prevention and the barrier may consist of a layer of grease, paint, plastic, or an unreactive metal, such as tin, copper, or chromium.

In **sacrificial protection**, the iron is actually covered by a more reactive metal, such a zinc (galvanization), or connected to a more reactive metal, such as magnesium, so that as long as the 'sacrificial' metal is present it will corrode first.

rust



(Image © Research Machines plc)

Sacrificial metal is used to protect pipes and other exposed metal on oil rigs from corrosion by rust. A more reactive metal than iron, such as zinc or magnesium, is attached in large lumps by conducting wires, at intervals along the pipes. Electrons released during the reaction travel along the conducting wires to the pipes, preventing rust from occurring. It is cheaper to replace the sacrificial metal than it is to replace the pipes.

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rutabaga

or swede

annual or biennial plant *Brassica napus*, widely cultivated for its edible root, which is yellow, purple, or white. It is similar in taste to the turnip *Brassica rapa* but has more carbohydrates and sugars, is firmer fleshed, and longer keeping.

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ruthenium

chemical symbol Ru

hard, brittle, silver-white, metallic element, atomic number 44, relative atomic mass 101.07. It is one of the so-called platinum group of metals; it occurs in platinum ores as a free metal and in the natural alloy osmiridium. It is used as a hardener in alloys and as a catalyst; its compounds are used as colouring agents in glass and ceramics.

Rutherford, Ernest (1871-1937)

1st Baron Rutherford of Nelson

New Zealand-born British physicist. He was a pioneer of modern atomic science. His main research was in the field of radioactivity, and he discovered alpha, beta, and gamma rays. He was the first to recognize the nuclear nature of the atom in 1911. He was awarded the Nobel Prize for Chemistry in 1908 for his work in atomic disintegration and the chemistry of radioactive substances.

Rutherford produced the first artificial transformation, changing one element to another (1919) by bombarding nitrogen with alpha particles and getting hydrogen and oxygen. After further research he announced that the nucleus of any atom must contain hydrogen nuclei; at Rutherford's suggestion, the name 'proton' was given to the hydrogen nucleus in 1920. He speculated that uncharged particles (neutrons) must also exist in the nucleus. In 1934, using heavy water, Rutherford and his co-workers bombarded deuterium with deuterons and produced tritium. This may be considered the first nuclear fusion reaction. He was knighted in 1914, and created Baron in 1931.

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rutherfordium

chemical symbol Rf

synthesized, radioactive, metallic element. It is the first of the transactinide series, atomic number 104, relative atomic mass 262. It is produced by bombarding californium with carbon nuclei and has ten isotopes, the longest-lived of which, Rf-262, has a half-life of 70 seconds.

Two institutions claim to be the first to have synthesized it: the Joint Institute for Nuclear Research in Dubna, Russia, in 1964; and the University of California at Berkeley, USA, in 1969. It was known by the temporary name unnilquadium until 1997.

---

rutile

titanium oxide mineral, TiO_2, a naturally occurring ore of titanium. It is usually reddish brown to black, with a very bright (adamantine) surface lustre. It crystallizes in the tetragonal system. Rutile is common in a wide range of igneous and metamorphic rocks and also occurs concentrated in sands; the coastal sands of eastern and western Australia are a major source. It is also used as a pigment that gives a brilliant white to paint, paper, and plastics.

Ruzicka, Leopold Stephen (1887-1976)

Swiss chemist who began research on natural compounds such as musk and civet secretions. In the 1930s he investigated sex hormones, and in 1934 succeeded in extracting the male hormone androsterone from 31,815 litres/7,000 gallons of urine and synthesizing it. Born in Croatia, Ruzicka settled in Switzerland in 1929. Ruzicka shared the Nobel Prize for Chemistry in 1939 with Adolf Butenandt for his study of polymethylenes and higher terpenes.

Rydberg constant

in physics, a constant that relates atomic spectra to the spectrum of hydrogen. Its value is 1.0977×10^7 per metre.

---

rye

tall annual cereal grass grown extensively in northern Europe and other temperate regions. The flour is used to make dark-coloured ('black') breads. Rye is grown mainly as a food crop for animals, but the grain is also used to make whisky and breakfast cereals. (*Secale cereale*.)

Ryle, Martin (1918-1984)

English radio astronomer. At the Mullard Radio Astronomy Observatory, Cambridge, he developed the technique of sky-mapping using 'aperture synthesis', combining smaller dish aerials to give the characteristics of one large one. His work on the distribution of radio sources in the universe brought confirmation of the Big Bang theory. He was awarded with his co-worker, the English radio astronomer Antony Hewish, the Nobel Prize for Physics in 1974 for his work on the development of radio astronomy, particularly the aperture-synthesis technique, and the discovery of pulsars, rapidly rotating neutron stars that emit pulses of energy. He was knighted in 1966.

S

in physics, symbol for siemens, the SI unit of electrical conductance, equal to a conductance of 1 ohm^{-1}.

S

abbreviation for **south**.

Sabatier, Paul (1854-1941)

French chemist. He found in 1897 that if a mixture of ethylene and hydrogen was passed over a column of heated nickel, the ethylene changed into ethane. Further work revealed that nickel could be used to catalyse numerous chemical reactions. He was awarded the Nobel Prize for Chemistry in 1912 for finding the method of catalytic hydrogenation of organic compounds.

Sabin, Albert Bruce (1906-1993)

Russian-born US microbiologist who developed a highly effective, live vaccine against polio. The earlier vaccine, developed by physicist Jonas Salk, was based on heat-killed viruses. Sabin was convinced that a live form would be longer-lasting and more effective, and in 1957 he succeeded in weakening the virus so that it lost its virulence. The vaccine can be given by mouth.

---

sable

marten *Martes zibellina*, about 50 cm/20 in long and usually brown. It is native to northern Eurasian forests, but now found mainly in eastern Siberia. The sable has diminished in numbers because of its valuable fur, which has long attracted hunters. Conservation measures and sable farming have been introduced to save it from extinction.

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saccharide

another name for a sugar.

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saccharin

or ortho-sulpho benzimide; $C_7H_5NO_3S$

sweet, white, crystalline solid derived from coal tar and substituted for sugar. Since 1977 it has been regarded as potentially carcinogenic. Its use is not universally permitted and it has been largely replaced by other sweetening agents.

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sadism

tendency to derive pleasure (usually sexual) from inflicting physical or mental pain on others. The term is derived from the Marquis de Sade.

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sadomasochism

sexual behaviour that combines sadism and masochism. The term was coined in 1907 by sexologist Richard von Krafft-Ebing.

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safe period

in medicine, that part of the menstrual cycle during which fertilization of the ovum is unlikely to occur.

Ovulation occurs about 15 days before the onset of the menstrual period and a woman is usually fertile for five days before ovulation, on the day of ovulation and for five days afterwards. Therefore, the safe period is the first week and the last ten days of the menstrual cycle. The safe period can be used as a form of contraception, the rhythm method.

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safety glass

glass that does not splinter into sharp pieces when smashed.
Toughened glass is made by heating a glass sheet and then rapidly cooling it with a blast of cold air; it shatters into rounded pieces when smashed.
Laminated glass is pressed and heated; when struck, it simply cracks.

---

safety lamp

portable lamp designed for use in places where flammable gases such as methane may be encountered; for example, in coal mines. The electric head lamp used as a miner's working light has the bulb and contacts in protected enclosures. The flame safety lamp, now used primarily for gas detection, has the wick enclosed within a strong glass cylinder surmounted by wire gauzes. English chemist Humphrey Davy (1815) and English engineer George Stephenson each invented flame safety lamps.

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safflower

thistlelike Asian plant with large orange-yellow flowers. It is widely grown for the oil from its seeds, which is used in cooking, margarine, and paints and varnishes; the leftovers are used as cattle feed. (*Carthamus tinctorius*, family Compositae.)

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saffron

crocus plant belonging to the iris family, probably native to southwestern Asia, and formerly widely cultivated in Europe; also the dried orange-yellow stigmas of its purple flowers, used for colouring and flavouring in cookery. (*Crocus sativus*, family Iridaceae.)

Sagan, Carl Edward (1934-1996)

US physicist and astronomer who popularized astronomy through writings and broadcasts. His main research was on planetary atmospheres. He wrote or co-wrote 27 books, which include *Broca's Brain: Reflections on the Romance of Science* (1979) and *Cosmos* (1980), based on his television series of that name.

Sagan researched the origin of life on Earth, the probable climatic effects of nuclear war, and the possibility of life on other planets.

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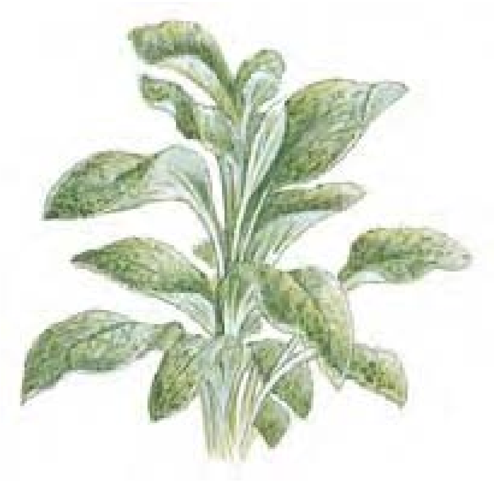
sage

perennial herb belonging to the mint family, with grey-green aromatic leaves used for flavouring in cookery. It grows up to 50 cm/20 in high and has bluish-lilac or pink flowers. (*Salvia officinalis*, family Labiatae.)

sage



(Image © Research Machines plc)

Sage is a native of the arid areas of southern Europe. The variety used in cooking is the nonflowering, broad-leafed sage. It has a very powerful flavour and can be used fresh or dried.

Sagittarius

bright zodiacal constellation in the southern hemisphere, represented as an archer aiming a bow and arrow at neighbouring Scorpius. The Sun passes through Sagittarius from mid-December to mid-January, a period that includes the solstice, when it is farthest south of the Equator. The constellation contains many nebulae and globular clusters, and open star clusters. Kaus Australis and Nunki are its brightest stars. The centre of our Galaxy, the Milky Way, is marked by the radio source Sagittarius A. In astrology, the dates for Sagittarius are about 22 November-21 December (see precession).

sago

starchy material obtained from the pith of the sago palm *Metroxylon sagu*. It forms a nutritious food and is used for manufacturing glucose and sizing textiles.

Sahel

(Arabic sahil 'coast')

marginal area to the south of the Sahara, from Senegal to Somalia, which mostly has a thin natural vegetation of savannah grasses and shrubs and whose people live by herding, often nomadic, and by the cultivation of millet and ground nuts. The Sahel experiences desert-like conditions during periods of low rainfall and there are signs of progressive desertification, partly due to climatic fluctuations but also caused by the pressures of a rapidly expanding population, which has led to overgrazing and the destruction of trees and scrub for fuelwood. In recent years many famines have taken place in the area.

The average rainfall in the Sahel ranges from 100 mm/4 in to 500 mm/20 in per year, but the rainfall over the past 30 years has been significantly below average. The resulting famine and disease are further aggravated by civil wars. The areas most affected are Ethiopia and the Sudan.

saiga

antelope *Saiga tartarica* of eastern European and western Asian steppes and deserts. Buff-coloured, whitish in winter, it stands 75 cm/30 in at the shoulder, with a body about 1.5 m/5 ft long. Its nose is unusually large and swollen, an adaptation which may help warm and moisten the air inhaled, and keep out the desert dust. The saiga can run at 80 kph/50 mph.

Only the male has horns, which are straight and up to 30 cm/1 ft long. The saiga is threatened by the demand for its horn for use in traditional Chinese medicine. Once a vanishing species, it is now protected; in 1994 it was listed in Appendix II of CITES, requiring a special permit for trade. The total 1995 population was about 1 million.

St Bernard

breed of large, heavily built dog, named after the monks of Grand St Bernard Hospice, Switzerland, who kept them for finding lost travellers in the Alps and to act as guides. They are 70 cm/30 in high at the shoulder, and weigh about 70 kg/154 lb. They have pendulous ears and lips, large feet, and drooping lower eyelids. They are usually orange and white.

St Bernard Club of America Home Page

Go to site

Information about the history of the breed, the breed standard, shows, veterinary advice, and many tips for owners. There are many tales of the dog's heroic deeds and a comprehensive listing of other Saint Bernard sites across the world.

St Elmo's fire

bluish, flamelike electrical discharge that sometimes occurs above ships' masts and other pointed objects or about aircraft in stormy weather. Although of high voltage, it is of low current and therefore harmless. St Elmo (or St Erasmus) is the patron saint of sailors.

St Vitus' dance

archaic name for Sydenham's chorea, a transient disorder of childhood and adolescence, often associated with rheumatic fever. St Vitus, martyred under the Roman emperor Diocletian, was the patron saint of dancers.

Sakharov, Andrei Dmitrievich (1921-1989)

Soviet physicist. He was an outspoken human-rights campaigner, who with Igor Tamm developed the hydrogen bomb. He later protested against Soviet nuclear tests and was a founder of the Soviet Human Rights Committee in 1970. In 1975 he was awarded the Nobel Prize for Peace for his advocacy of human rights and disarmament. For criticizing Soviet action in Afghanistan, he was sent into internal exile 1980-86.

Sakharov was elected to the Congress of the USSR People's Deputies in 1989, where he emerged as leader of its radical reform grouping before his death later the same year.

Sakharov, Andrei

Go to site

Brief autobiography written by the physicist and human rights campaigner for the Nobel Committee after he won the 1975 Peace Prize. Sakharov describes how his upbringing inculcated a love of literature, science, and music. He relates his pioneering work in Soviet nuclear physics and the deepening moral doubts this aroused. He movingly describes how it was his conscience that propelled him into an unwilling engagement with politics.

Salam, Abdus (1926-1996)

Pakistani physicist who was awarded the Nobel Prize for Physics in 1979 for his theory linking the electromagnetic and weak nuclear forces. He was the first person from his country to receive a Nobel prize.

Salam shared the Nobel Prize with US physicists Sheldon Glashow and Steven Weinberg for unifying the theories of electromagnetism and the weak force, the force responsible for a neutron transforming into a proton, an electron, and a neutrino during radioactive decay. Building on Glashow's work, Salam and Weinberg separately arrived at the same theory in 1967.

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salamander

tailed amphibian of the order Urodela. They are sometimes confused with lizards, but unlike lizards they have no scales or claws. Salamanders have smooth or warty moist skin. The order includes some 300 species, arranged in nine families, found mainly in the northern hemisphere. Salamanders include hellbenders, mudpuppies, olms, waterdogs, sirens, mole salamanders, newts, and lungless salamanders (dusky, woodland, and spring salamanders).

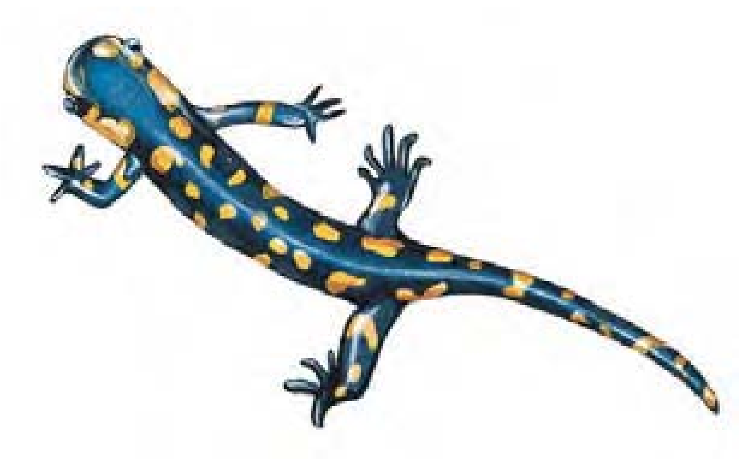
They eat insects and worms, and live in water or in damp areas in the northern temperate regions, mostly feeding at night and hiding during the day, and often hibernating during the winter. Fertilization is either external or internal, often taking place in water. The larvae have external gills. Some remain in the larval form, although they become sexually mature and breed; this is called neoteny. The Mexican axolotl and the mud puppy *Necturus maculosus* of North America are neotenic.

In 1998, five new salamander species were discovered in tropical east-central Mexico. The species all belong to the genus *Thorius*, whose members are characterized by their smallness - some species are less than 2 cm/0.8 in length.

salamander

The tongue of the Sardinian salamander is 80% of its body length and shoots out to catch an insect in a hundredth of a second.

salamander



(Image © Research Machines plc)

The fire salamander is seldom far from water, preferring moist areas. The bright markings warn predators of the salamander's poisonous body secretions, which burn the mouth and eyes of an attacker.

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salicylic acid

HOC_6H_4COOH

active chemical constituent of aspirin, an analgesic drug. The acid and its salts (salicylates) occur naturally in many plants; concentrated sources include willow bark and oil of wintergreen.

When purified, salicylic acid is a white solid that crystallizes into prismatic needles at 159°C/318°F. It is used as an antiseptic, in food preparation and dyestuffs, and in the preparation of aspirin.

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saliva

in vertebrates, an alkaline secretion from the salivary glands that aids the swallowing and digestion of food in the mouth. In mammals, it contains the enzyme amylase, which converts starch to sugar. The salivary glands of mosquitoes and other blood-sucking insects produce anticoagulants.

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salivary gland

or parotid gland

in mammals, one of two glands situated near the mouth responsible for the manufacture of saliva and its secretion into the mouth. The salivary glands are stimulated to produce saliva during a meal. Saliva contains an enzyme, ptyalin, and mucous which are essential for the mastication and initial digestion of food.

salivary gland

The human salivary glands churn out 50 g/1.8 oz of digestive enzymes every day.

Salk, Jonas Edward (1914-1995)

US physician and microbiologist. In 1954 he developed the original vaccine that led to virtual eradication of paralytic polio in industrialized countries. He was director of the Salk Institute for Biological Studies, University of California, San Diego, 1963-75.

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salmon

any of the various bony fishes of the family Salmonidae. More specifically the name is applied to several species of game fishes of the genera Salmo and Oncorhynchus of North America and Eurasia that mature in the ocean but, to spawn, return to the freshwater streams where they were born. Their normal colour is silvery with a few dark spots, but the colour changes at the spawning season.

life cycle

The spawning season is between September and January, although they occasionally spawn at other times. Once the salmon pair, the female hollows out her **redd** in the riverbed and in it deposits her orange eggs, about 6 mm/0.25 in in diameter, to be fertilized by the male. Once fertilized, the eggs are then covered with gravel by the female. The incubation period is from five weeks to five months. The young hatched fish are known as **alevins**, and when they begin feeding they are called **parr**. At about two years old, their coat becomes silvery, and they are called **smolts**. Depending on the species, they may spend up to four years at sea before returning to their home streams to spawn (at this stage called **grilse**), often overcoming great obstacles to get there and die.

As the salmon migrate up stream, their colouring changes to include greens, pinks, and blues and they increase in size, some growing to as much 1 m/ 3 ft. The jaws of the males undergo restructuring to become hook shaped to enable them to drive rival males from spawning areas. Internally, the reproductive organs increase in size in both males and females and the gut decreases to such an extent that salmon fast for their migration.

salmon farming

Salmon are increasingly farmed in cages, and 'ranched' (selectively bred, hatched, and fed before release to the sea). Stocking rivers indiscriminately with hatchery fish may destroy the precision of their homing instinct owing to interbreeding between fish originating in different rivers.

Salmon Page

Go to site

Comprehensive source of information on salmon that introduces itself: 'How to catch them, cook them, buy them, and save them...'. In addition to these four areas there are videos to download, links to school Projects on salmon which are available on the Web, and links to newsgroups to put you in contact with other salmon enthusiasts.

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salmonella

any of a very varied group of bacteria, genus *Salmonella*, that colonize the intestines of humans and some animals. Some strains cause typhoid and paratyphoid fevers, while others cause salmonella food poisoning, which is characterized by stomach pains, vomiting, diarrhoea, and headache. It can be fatal in elderly people, but others usually recover in a few days without antibiotics. Most cases are caused by contaminated animal products, especially poultry meat.

Human carriers of the disease may be well themselves but pass the bacteria on to others through unhygienic preparation of food. Domestic pets can also carry the bacteria while appearing healthy.

Bad Bug Book - Salmonella

Go to site

Fact sheet with basic information about salmonella. It offers details on the nature and the diagnostic procedures of the disease, susceptible groups, and the potential complications following the disease, as well as guidelines for cooking eggs, the food mainly associated with salmonella.

Salmonella

Go to site

Information page of a larger salmonella-based Web site. It contains basic information about salmonella, offering details on the nature and the diagnostic procedures of the disease, susceptible groups, and the potential complications following the disease, as well as guidelines on how to prevent salmonella in everyday life.

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salsify

or vegetable oyster

hardy biennial plant native to the Mediterranean region. Its white fleshy roots and spring shoots are cooked and eaten; the roots are said to taste like oysters. (*Tragopogon porrifolius*, family Compositae.)

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salt

in chemistry, any compound formed from an acid and a base through the replacement of all or part of the hydrogen in the acid by a metal or electropositive radical.
Common salt is sodium chloride.

A salt may be produced by a chemical reaction between an acid and a base, or by the displacement of hydrogen from an acid by a metal. As a solid, the ions normally adopt a regular arrangement to form crystals. Some salts form only stable crystals as hydrates (when combined with water). Most inorganic salts readily dissolve in water to give an electrolyte (a solution that conducts electricity).

salts

To create a salt:

If a soluble salt you wish to provide,
You first on the acid settle;
Then neutralize with the proper oxide,

Hydroxide, carbonate, or metal
But if the salt will not dissolve,
A simpler means you'll try:
Precipitate it, you resolve,
Then filter, wash, and dry

---

salt, common

or sodium chloride; NaCl

white crystalline solid, found dissolved in seawater and as rock salt (the mineral halite) in large deposits and salt domes. Common salt is used extensively in the food industry as a preservative and for flavouring, and in the chemical industry in the making of chlorine and sodium.

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salt marsh

wetland with halophytic vegetation (tolerant to seawater). Salt marshes develop around estuaries and on the sheltered side of sand and shingle spits. They are formed by the deposition of mud around salt-tolerant vegetation. This vegetation must tolerate being covered by seawater as well as being exposed to the air. It also traps mud as the tide comes in and out. This helps build up the salt marsh. Salt marshes usually have a network of creeks and drainage channels by which tidal waters enter and leave the marsh.

salt marsh

(Image © Garret Nagle)

Vegetation growing in a salt marsh. Salt marshes are among the world's most productive ecosystems. The daily ebb and flow of the tide carries nutrients into the salt marsh and removes waste material. For plants to survive in the salt marsh they must be able to survive being covered by seawater at high tide, being exposed at low tide, and the rapidly shifting mud flats. These specialized plants (helophytes) have deep roots to anchor the plants in mud, and can survive in seawater.

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saltpetre

or potassium nitrate; KNO_3

compound used in making gunpowder (from about 1500). It occurs naturally, being deposited during dry periods in places with warm climates, such as India.

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saluki

ancient breed of hunting dog resembling the greyhound. It is about 65 cm/26 in high and has a silky coat, which is usually fawn, cream, or white.

The saluki is a gazehound (hunts by sight) and is descended from the hound of the African desert Bedouins.

Saluki Club of America - Official Web Site

Go to site

A must for saluki fans. The site is filled with information about the history of the breed, the breed standard, shows and many tips for owners. There is a comprehensive listing of other saluki sites across the world.

Salyut

(Russian 'salute')

series of seven space stations launched by the USSR 1971-86. *Salyut* was cylindrical in shape, 15 m/50 ft long, and weighed 19 tonnes. It housed two or three cosmonauts at a time, for missions lasting up to eight months.

Salyut 1 was launched on 19 April 1971. It was occupied for 23 days in June 1971 by a crew of three, who died during their return to Earth when their *Soyuz* ferry craft depressurized. In 1973 *Salyut 2* broke up in orbit before occupation. The first fully successful *Salyut* mission was a 14-day visit to *Salyut 3* in July 1974. In 1984-85 a team of three cosmonauts endured a record 237-day flight in *Salyut 7*. In 1986 the *Salyut* series was superseded by *Mir*, an improved design capable of being enlarged by additional modules sent up from Earth.

Salyut

Go to site

History, description, and specifications of the *Salyut* space station modules. There are lots of excellent photographs of *Salyut 6* and its interior, as well as pictures and technical drawings.

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samara

in botany, a winged fruit, a type of achene.

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samarium

chemical symbol Sm

hard, brittle, grey-white, metallic element of the lanthanide series, atomic number 62, relative atomic mass 150.4. It is widely distributed in nature and is obtained commercially from the minerals monzanite and bastnaesite. It is used only occasionally in industry, mainly as a catalyst in organic reactions. Samarium was discovered by spectroscopic analysis of the mineral samarskite and named in 1879 by French chemist Paul Lecoq de Boisbaudran (1838-1912) after its source.

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samoyed

breed of dog originating in Siberia. It weighs about 25 kg/60 lb and is 58 cm/23 in tall. It resembles a chow chow, but has a more pointed face and a white or cream coat.

Samoyed Club of America

Go to site

Information about the history of the breed, the breed standard, shows, veterinary advice, and many tips for owners. There is a comprehensive listing of other samoyed sites across the world.

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samphire

or glasswort or sea asparagus

perennial plant found on sea cliffs and coastlines in Europe. The aromatic, salty leaves are fleshy and sharply pointed; the flowers grow in yellow-green open clusters. Samphire is used in salads, or pickled. (*Crithmum maritimum*, family Umbelliferae.)

San Andreas Fault

geological fault stretching for 1,125 km/700 mi northwest-southeast through the state of California, USA. It marks a conservative plate margin, where two plates slide past each other (see plate tectonics).

Friction is created as the coastal Pacific plate moves northwest, rubbing against the American continental plate, which is moving slowly southeast. The relative movement is only about 5 cm/2 in a year, which means that Los Angeles will reach San Francisco's latitude in 10 million years. The friction caused by the tectonic movement gives rise to frequent, destructive earthquakes. For example, in 1906 an earthquake originating from the fault almost destroyed San Francisco. Contemporary official figures put the death toll at 700-800, although later estimates put the figure closer to 3,000 deaths caused by the quake and its aftermath.

San Andreas Fault and Bay Area

Go to site

Detailed tour of the San Andreas Fault and the San Francisco Bay area, with information on the origination of the fault. The site is supported by a full range of area maps.

Sanctorius, Sanctorius (1561-1636)

Italian physiologist who pioneered the study of metabolism and invented the clinical thermometer and a device for measuring pulse rate.

Sanctorius introduced quantitative methods into medicine. For 30 years he weighed both himself and his food, drink, and waste products. He determined that over half of normal weight loss is due to 'insensible perspiration'.

sand

loose grains of rock, 0.0625-2.00 mm/0.0025-0.08 in in diameter, consisting most commonly of quartz, but owing their varying colour to mixtures of other minerals. Sand is used in cement-making, as an abrasive, in glass-making, and for other purposes.

Sands are classified into marine, freshwater, glacial, and terrestrial. Some 'light' soils contain up to 50% sand. Sands may eventually consolidate into sandstone.

sandalwood

fragrant heartwood of any of several Asiatic and Australian trees, used for ornamental carving, in perfume, and burned as incense. (Genus *Santalum*, family Santalaceae.)

sandbar

ridge of sand built up by the currents across the mouth of a river or bay. A sandbar may be entirely underwater or it may form an elongated island that breaks the surface. A sandbar stretching out from a headland is a **sand spit**.

Coastal bars can extend across estuaries to form **bay bars**.

sand eel

small, carnivorous fish found near the coasts of temperate seas of the northern hemisphere. Their bodies are covered with small scales, the swimbladder is absent, and they have long, sharply pointed snouts with which they bury themselves in the sand.

classification

Sand eels are in genus *Ammodytes* in the family Ammodytidae, belonging to the order Perciformes, class Osteichthyes.

sandflea

another name for jigger.

sandgrouse

any bird of the family Pteroclidae, order Columbiformes. They look like long-tailed grouse, but are actually closely related to pigeons. They live in warm, dry areas of Europe, Asia, and Africa and have long wings, short legs and bills, a wedge-shaped tail, and thick skin. They are sandy coloured and feed on vegetable matter and insects.

Sandgrouse may travel long distances to water to drink, and some carry water back to their young by soaking the breast feathers. The **pin-tailed sandgrouse** *Pterocles alchata* is a desert bird living in southern Europe, Africa, and Asia.

sandgrouse

A sandgrouse can hold about 9,000 seeds in its crop (that part of its anatomy used to store food). This is useful, as ground-feeding is a risky business and the birds need to feed rapidly as they move about.

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sand hopper

or beachflea

any of various small crustaceans belonging to the order Amphipeda, with laterally compressed bodies, that live in beach sand and jump like fleas. The eastern sand hopper *Orchestia agilis* of North America is about 1.3 cm/0.5 in long.

Sandoz

pharmaceutical company whose plant in Basel, Switzerland, suffered an environmentally disastrous chemical fire in November 1986. Hundreds of tonnes of pesticides, including mercury-based fungicides, spilled into the River Rhine, rendering it lifeless for 100-200 km/60-120 mi and killing about half a million fish.

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sandpiper

shorebird with a long, slender bill, which is compressed and grooved at the tip. They belong to the family Scolopacidae, which includes godwits, curlews, and snipes, order Charadriiformes.

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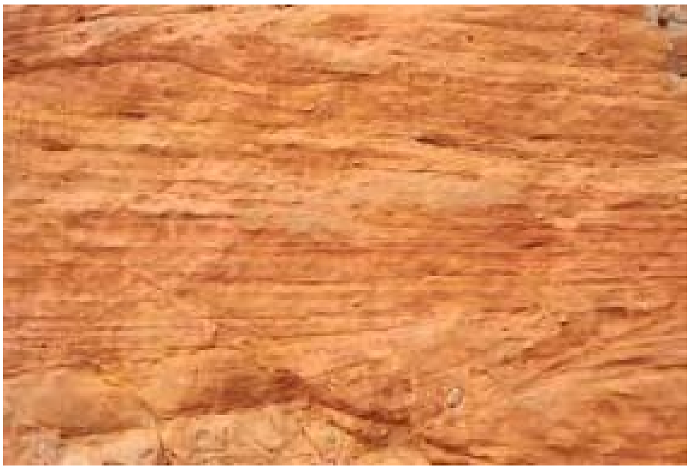
sandstone

sedimentary rocks formed from the consolidation of sand, with sand-sized grains (0.0625-2 mm/0.0025-0.08 in) in a matrix or cement. Their principal component is quartz. Sandstones are commonly permeable and porous, and may form freshwater aquifers. They are mainly used as building materials.

Sandstones are classified according to the matrix or cement material (whether derived from clay or silt).

sandstone



(Image © Garret Nagle)

Sandstone deposits on the bank of the Manchester Ship Canal. The picture clearly shows layers of sand. These are deposited under desertlike conditions, and later compressed to form solid rock. Some of the layers are not horizontal, and form lines at an angle. These show former sand dunes, created by strong winds. This cutting was exposed by the building of the Manchester Ship Canal to Liverpool.

Sanger, Frederick (1918-)

English biochemist. He was awarded the Nobel Prize for Chemistry in 1958 for determining the structure of insulin, and again in 1980 for work on the chemical structure of genes. He was the first person to be awarded the chemistry prize twice.

Sanger's second Nobel Prize was shared with two US scientists, Paul Berg and Walter Gilbert, for establishing methods of determining the sequence of nucleotides strung together along strands of RNA and DNA. He also worked out the structures of various enzymes and other proteins.

Santa Ana

periodic warm Californian wind.

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sap

fluids that circulate through vascular plants, especially woody ones. Sap carries water and food to plant tissues. Sap contains alkaloids, protein, and starch; it can be milky (as in rubber trees), resinous (as in pines), or syrupy (as in maples).

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saponification

in chemistry, the hydrolysis (splitting) of an ester by treatment with a strong alkali, resulting in the liberation of the alcohol from which the ester had been derived and a salt of the constituent fatty acid. The process is used in the manufacture of soap.

---

sapphire

deep-blue, transparent gem variety of the mineral corundum Al_2O_3, aluminium oxide. Small amounts of iron and titanium give it its colour. A corundum gem of any colour except red (which is a ruby) can be called a sapphire; for example, yellow sapphire.

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saprotroph

formerly saprophyte

organism that feeds on the excrement or the dead bodies or tissues of others. They include most fungi (the rest being parasites); many bacteria and protozoa; animals such as dung beetles and vultures; and a few unusual plants, including several orchids. Saprotrophs cannot make food for themselves, so they are a type of heterotroph. They are useful scavengers, and in sewage farms and refuse dumps break down organic matter into nutrients easily assimilable by green plants.

---

sarcoidosis

chronic disease of unknown cause involving enlargement of the lymph nodes and the formation of small fleshy nodules in the lungs. It may also affect the eyes, and skin, and (rarely) other tissue. Many cases resolve spontaneously or may be successfully treated using corticosteroids.

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sarcoma

malignant tumour arising from the fat, muscles, bones, cartilage, or blood and lymph vessels and connective tissues. Sarcomas are much less common than carcinomas.

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sard

yellow or red-brown variety of chalcedony.

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sardine

common name for various small fishes (pilchards) in the herring family.

Six species of sardine are generally recognized: five in the Pacific and Indian Oceans (*Sardinops* species) and *Sardinia pilchardus* in the Atlantic and Mediterranean. In 1998 US researchers announced, following analysis of mitochondrial DNA from the *Sardinops* species, that they were in fact probably widely dispersed regional populations of the same species, rather than different species.

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sarin

poison gas 20 times more lethal to humans than potassium cyanide. It impairs the central nervous system, blocking the action of an enzyme that removes acetylcholine, the chemical that transmits signals. Sarin was developed in Germany during World War II.

Sarin was used in 1995 in a terrorist attack on the Tokyo underground by a Japanese sect. It is estimated that the USA had a stockpile of 15,000 tonnes of sarin, and more than 1,000 US rockets with sarin warheads were found to be leaking in 1995. There are no known safe disposal methods.

SARS

acronym for severe acute respiratory syndrome

highly infectious disease with symptoms similar to influenza, notably chills, headaches, muscle pains, a sore throat, and a high fever. Pneumonia develops as the disease progresses, and can result in death - the mortality rate is estimated by the World Health Organization (WHO) at around 15%. First identified in 2003, there is no known cure or vaccine for the disease.

SARS is caused by a type of coronavirus, which usually produces colds in humans but severe conditions such as pneumonia and diarrhoea in animals. The SARS virus was thought to have mutated to allow it to jump the species barrier from animals to humans. Analysis of the virus genome suggests that it is a recombinant of a mouse hepatitis virus and a bird bronchitis virus. The incubation period of SARS varies but is on average between two and ten days. The risk of death increases with age and the mortality rate is as high as 50% in those over 60 years of age.

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satellite

any small body that orbits a larger one.
Natural satellites that orbit planets are called **moons**. The first **artificial satellite**, Sputnik 1, was launched into orbit around the Earth by the USSR in 1957. Artificial satellites can transmit data from one place on Earth to another, or from space to Earth. Satellite applications include science, communications, weather forecasting, and military use.

Space probes have been sent to natural satellites including the Earth's Moon, Mars's Deimos, and the moons of the giant planets Jupiter, Saturn, Uranus and Neptune.

At any time, there are several thousand artificial satellites orbiting the Earth, including active satellites, satellites that have ended their working lives, and discarded sections of rockets. The brightest artificial satellites can be seen by the naked eye. Artificial satellites eventually re-enter the Earth's atmosphere. Usually they burn up by friction, but sometimes debris falls to the Earth's surface, as with *Skylab* and *Salyut 7*.

Hundreds of millions of pieces of space junk, ranging from particles a millimetre across up to disabled satellites, are careering around the Earth. The US Space Command catalogues the larger items to make sure they are not mistaken for enemy missiles; currently about 10,000 items are listed.

Largest natural planetary satellites

Planet	Satellite	Diameter		Mean distance from centre of primary planet		Orbital period (Earth days)
		km	mi	km	mi	
Jupiter	Ganymede	5,262	3,300	1,070,000	664,898	7.16
Saturn	Titan	5,150	3,200	1,221,800	759,226	15.95
Jupiter	Callisto	4,800	3,000	1,883,000	1,170,096	16.69
Jupiter	Io	3,630	2,240	421,600	261,982	1.77
Earth	Moon	3,476	2,160	384,400	238,866	27.32
Jupiter	Europa	3,138	1,900	670,900	416,897	3.55
Neptune	Triton	2,700	1,690	354,300	220,162	5.88

Moon

Property	Amount
Diameter	3,476 km/2,160 mi
Maximum distance from Earth (apogee)	406,740 km/252,736 mi
Minimum distance from Earth (perigee)	356,410 km/221,463 mi
Maximum surface temperature	110°C/230°F
Minimum surface temperature	-170°C/-274°F
Surface gravity (Earth = 1)	0.16

How Satellites Work

Go to site

Entertaining introduction to satellites, with lots of interesting questions answered. There is also information on how to observe satellites.

J-Track Satellite Tracker

Go to site

Real-time tracking system that displays on a world map the current position and orbit information for the space shuttle, *Mir* space station, Hubble Space Telescope, the Upper Atmosphere Research satellite, and the Cosmic Background Explorer satellite. Pressing the shift button on your keyboard while clicking on a craft will take you to a page with information about that craft.

---

satellite applications

uses to which artificial satellites are put. These include:

scientific experiments and observation

Many astronomical observations are best taken above the disturbing effect of the atmosphere. Satellite observations have been carried out by the Infrared Astronomy Satellite (1983) which made a complete infrared survey of the skies, and Solar Max (1980), which observed solar flares. The Hipparcos satellite, launched in 1989, measured the positions of many stars. The Röntgen Satellite, launched in 1990, examined ultraviolet and X-ray radiation. In 1992, the Cosmic Background Explorer satellite detected details of the Big Bang that mark the first stage in the formation of galaxies. Medical experiments have been carried out aboard crewed satellites, such as the Russian space station *Mir*, the US *Skylab*, and the largest of all satellites, the *International Space Station*.

reconnaissance, land resource, and mapping applications

Apart from military use and routine mapmaking, the US Landsat, the French Satellite Pour l'Observation de la Terre, and equivalent Russian satellites have provided much useful information about water sources and drainage, vegetation, land use, geological structures, oil and mineral locations, and snow and ice.

weather monitoring

The US National Oceanic and Atmospheric Administration series of satellites, and others launched by the European Space Agency, Japan, and India, provide continuous worldwide observation of the atmosphere.

navigation

The US Global Positioning System uses dozens of Navstar satellites that enable users (including walkers and motorists) to find their position, typically to about 15 m/50 ft. 'Selective availability', which denied the highest precision to civilians and the armed forces of countries other than the US and its allies, was ended in 2000. However, the military can still achieve greater accuracy than civilian users.

communications

A complete worldwide communications network is now provided by satellites such as those of the US-run Intelsat system and the *Molniya* satellites of the Russian Orbita system.

---

satellite television

transmission of broadcast signals through artificial communications satellites. Mainly positioned in geostationary orbit, satellites have been used since the 1960s to relay television pictures around the world.

Higher-power satellites have more recently been developed to broadcast signals to cable systems or directly to people's homes.

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saturated compound

organic compound, such as propane, that contains only single covalent bonds. Alkanes are saturated hydrocarbons that contain only carbon to carbon single bonds. Saturated organic compounds can only undergo further reaction by substitution reactions, as in the production of chloropropane from propane.

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saturated fatty acid

fatty acid in which there are no double bonds in the hydrocarbon chain.

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saturated solution

in physics and chemistry, a solution obtained when a solvent (liquid) can dissolve no more of a solute (usually a solid) at a particular temperature. Normally, a slight fall in temperature causes some of the solute to crystallize out of solution. If this does not happen the phenomenon is called supercooling, and the solution is said to be **supersaturated**.

Saturn

sixth planet from the Sun, and the second-largest in the Solar System, encircled by bright and easily visible equatorial rings. Viewed through a telescope it is ochre. Its polar diameter is 12,000 km/7,450 mi smaller than its equatorial diameter, a result of its fast rotation and low density, the lowest of any planet. Its mass is 95 times that of the Earth and its magnetic field 1,000 times stronger.

mean distance from the Sun

1.427 billion km/0.886 billion mi

equatorial diameter

120,000 km/75,000 mi

rotational period

10 hours 14 minutes at equator, 10 hours 40 minutes at higher latitudes

year

29.46 Earth years

atmosphere

visible surface consists of swirling clouds, probably made of frozen ammonia at a temperature of -170°C/-274°F, although the markings in the clouds are not as prominent as Jupiter's. The Voyager probes, visiting in 1980 and 1981, found winds reaching 1,800 kph/1,100 mph

surface

Saturn is believed to have a small core of rock and iron, encased in ice and topped by a deep layer of liquid hydrogen

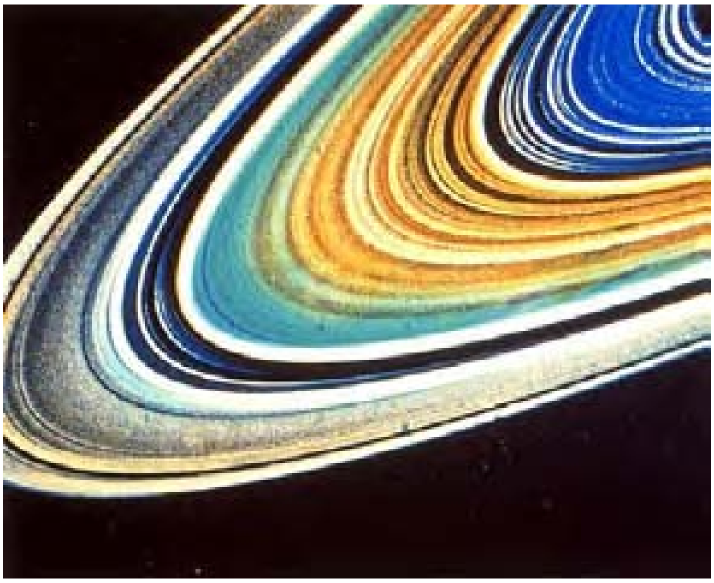
satellites

as of 2005, 49 moons were known, more than for any other planet. The largest moon, Titan, has a dense atmosphere

rings

the rings visible from Earth begin about 14,000 km/9,000 mi from the planet's cloudtops and extend out to about 76,000 km/47,000 mi. Made of small chunks of ice and rock (averaging 1 m/3.3 ft across), they are 275,000 km/170,000 mi rim to rim, but only 100 m/300 ft thick. The Voyager probes showed that the rings actually consist of thousands of closely spaced ringlets, looking like the grooves in a gramophone record. In 2004 a new ring around Saturn was reported by astronomers. They detected a 300-km/186-mi-wide dust ring located 1,200 km/746 mi beyond the main ring system of Saturn, between the A and the F rings.

Saturn



(Image © NASA)

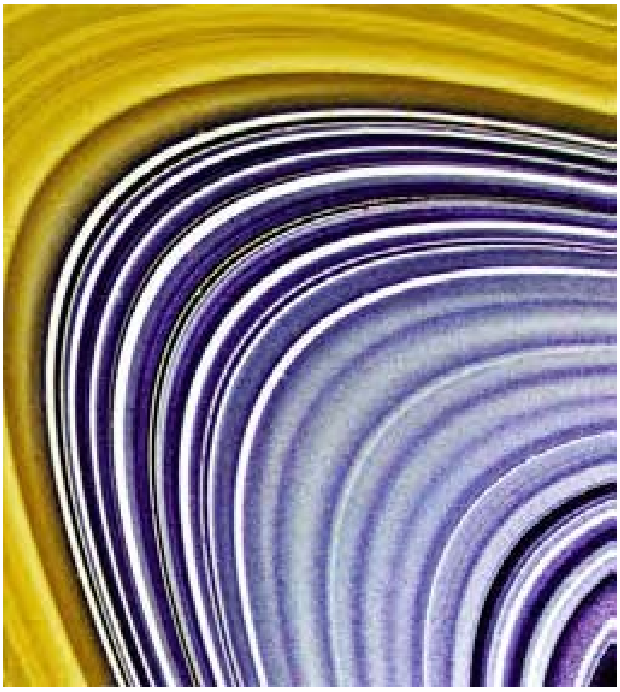
The rings of Saturn, consisting of small pieces of ice and rock, are 62,000 km/38,000 mi wide and just 100 m/300 ft thick.

Saturn

(Image © NASA)

Voyager 2 captured the images used to build this evocative picture of Saturn and three of its moons, from a distance of 21 million km/13 million mi. Furthest from the planet is Rhea, followed by Dione, and Tethys, which casts a shadow on Saturn's southern hemisphere.

Saturn



(Image © NASA)

The rings of Saturn taken by the Voyager 2 probe on 23 August 1981. Voyager 2 was 2.7 million km/1.7 million mi from the planet at the time. More than 60 bright and dark ringlets are shown here.

Saturn: moons

To remember the moons of Saturn:

MET DR THIP

Mimas, **E**nceladus, **T**ethys, **D**ione, **R**hea, **T**itan, **H**yperion, **I**apetus, **P**hoebe

Saturn's satellites

Satellite	Year of discovery	Diameter		Mean distance from Saturn	
		km	mi	km	mi

Titan	1655	5,150	3,200	1,222,000	759,000
Iapetus	1671	1,460	910	3,561,000	2,213,000
Rhea	1672	1,530	950	527,000	327,000
Dione	1684	1,120	700	377,000	234,000
Tethys	1684	1,050	650	295,000	183,000
Enceladus	1789	500	310	238,000	148,000
Mimas	1789	390	245	186,000	116,000
Hyperion	1848	shape irregular 410 × 260 × 220	shape irregular 255 × 160 × 135	1,481,000	920,000
Phoebe	1898	220	135	12,950,000	8,047,000
Janus	1966	178	111	151,000	94,000
Atlas	1980	28	17	138,000	86,000
Calypso	1980	26	16	295,000	183,000
Epimetheus	1980	114	71	151,000	94,000
Helene	1980	32	20	377,000	234,000
Pandora	1980	92	57	142,000	88,000
Prometheus	1980	92	57	139,000	86,000
Telesto	1980	30	18	295,000	183,000
Pan	1990	20	12	134,000	82,000

Saturn

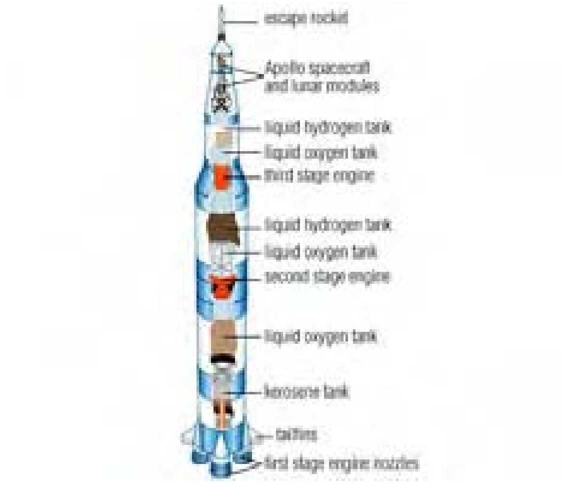
Go to site

How many rings does Saturn have? How many satellites? Find out the answers to these questions and more at this site, which also features a video of a storm in the planet's atmosphere and information on the international Cassini mission to Saturn and Titan.

Saturn rocket

family of large US rockets, developed by German-born US rocket engineer Wernher von Braun for the *Apollo* project. The two-stage Saturn IB was used for launching *Apollo* spacecraft into orbit around the Earth. The three-stage Saturn V sent *Apollo* spacecraft to the Moon, and launched the *Skylab* space station. The take-off thrust of a Saturn V was 3.4 million kg/7.5 million lb. After *Apollo* and *Skylab*, the Saturn rockets were retired in favour of the space shuttle.

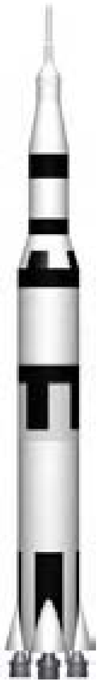
rocket


escape rocket
Apollo spacecraft and lunar modules
liquid hydrogen tank
liquid oxygen tank
third stage engine
liquid hydrogen tank
liquid oxygen tank
second stage engine
liquid oxygen tank
kerosene tank
tail fins
first stage engine nozzles

(Image © Research Machines plc)

The three-stage Saturn V rocket used in the *Apollo* launches of the 1960s and 1970s. It stood 111 m/365 ft high, as tall as a 30-storey skyscraper, weighed 2,700 tonnes when loaded with fuel, and developed a power equivalent to 50 Boeing 747 jumbo jets.

Saturn rocket



(Image © Research Machines plc)

When it was built the Saturn V was the largest operational launch vehicle ever produced. With its *Apollo* spacecraft payload it was over 111 m/363 ft high.

Saturn rocket

(Image © NASA)

Lift-off of the Saturn V rocket carrying US astronauts Neil Armstrong, Buzz Aldrin, and Michael Collins aboard the *Apollo 11* on their way to the Moon, on 16 July 1969.

Apollo Saturn Reference Page

Go to site

Apollo-Gemini project resource. There are contemporary press releases, technical reports and diagrams, and photographs. The site features a page with some truly amazing *Apollo* facts and figures.

sausage tree

tropical African tree, which grows up to 12 m/40 ft tall and has purplish flowers. Its gourdlike fruits hang from stalks and look like thick sausages; they can be up to 60 cm/2 ft long and weigh 2-5 kg/5-12 lb. (Genus *Kigelia pinnata*, family Bignoniaceae.)

---

savannah

or savanna

extensive open tropical grasslands, with scattered trees and shrubs. Savannahs cover large areas of Africa, North and South America, and northern Australia. The soil is acidic and sandy and generally considered suitable only as pasture for low-density grazing.

A new strain of rice suitable for savannah conditions was developed in 1992. It not only grew successfully under test conditions in Colombia but also improved pasture quality so that grazing numbers could be increased twentyfold.

Tropical Savannas CRC: Landscape Processes

Go to site

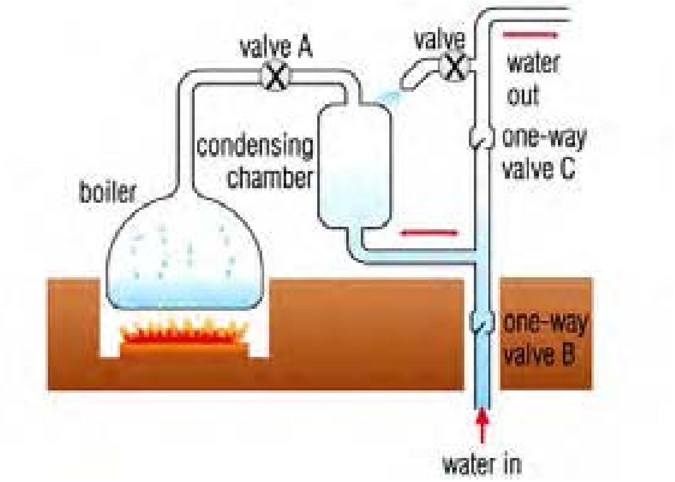
Australian-based site providing information on tropical savannahs including 'Savannah explorer', 'Savannah map maker', where you can explore relationships between landscape features such as vegetation and soils by overlaying maps, and 'Savannah search'.

Savery, Thomas (c. 1650-1715)

British engineer who invented the steam-driven water pump in 1696. It was the world's first working steam engine.

The pump used a boiler to raise steam, which was condensed (in a vessel) by an external spray of cold water. The partial vacuum created sucked water up a pipe; steam pressure was then used to force the water away, after which the cycle was repeated. Savery patented his invention in 1698, but it appears that poor-quality work and materials made his engines impractical.

Savery



(Image © Research Machines plc)

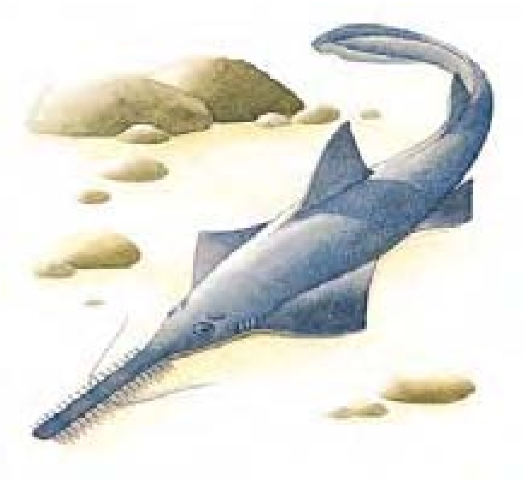
Thomas Savery's steam pump, the 'Miners' Friend', has been described as the precursor of the steam engine. However, it achieved only limited success and was not adopted widely, probably because of faulty materials and poor workmanship.

---

sawfish

any fish of the order Pristiformes of large, sharklike rays, characterized by a flat, sawlike snout edged with teeth. The common sawfish *Pristis pectinatus*, also called the smalltooth, is more than 6 m/19 ft long. It has some 24 teeth along an elongated snout (2 m/6 ft) that can be used as a weapon.

sawfish



(Image © Research Machines plc)

Sawfishes are related to skates and rays. They are large, flattened fishes averaging 5 m/16 ft in length but maximum weights of more than 2,200 kg/5,000 lb have been recorded. Sawfishes use their elongated, toothed snouts to grub for molluscs and crustaceans on muddy seabeds.

---

sawfly

any of several families of insects of the order Hymenoptera, related to bees, wasps, and ants, but lacking a 'waist' on the body. The egg-laying tube (ovipositor) of the female is surrounded by a pair of sawlike organs, which it uses to make a slit in a plant stem to lay its eggs. Horntails are closely related.

---

saxifrage

any of a group of plants belonging to the saxifrage family, found growing in rocky, mountainous, and alpine areas in the northern hemisphere. They are low plants with groups of small white, pink, or yellow flowers. (Genus *Saxifraga*, family Saxifragaceae.)

---

scabies

contagious infection of the skin caused by the parasitic itch mite *Sarcoptes scabiei*, which burrows under the skin to deposit eggs. Treatment is by antiparasitic creams and lotions.

Childhood Infections - Scabies

Go to site

Useful information about scabies. There is a detailed, illustrated description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection and details of what to do should the symptoms occur.

---

scabious

any of a group of plants belonging to the teasel family, native to Europe and Asia, with many small, usually purplish-blue flowers borne in a single head on a tall stalk. The small scabious (*S. columbaria*) and the Mediterranean sweet scabious (*S. atropurpurea*) are often cultivated. (Genus *Scabiosa*, family Dipsacaceae.)

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scalar quantity

in mathematics and science, a quantity that has magnitude but no direction, as distinct from a vector quantity, which has a direction as well as a magnitude. Temperature, mass, volume, and speed are scalar quantities.

---

scale

or limescale

in chemistry, calcium carbonate precipitates that form on the inside of a kettle or boiler as a result of boiling hard water (water containing concentrations of soluble calcium and magnesium salts). The salts present in hard water also precipitate out by reacting with soap molecules.

Scale may cause damage to water pipes and appliances such as washing machines and water boilers. The build-up of scale causes blockage of pipes, and electrical appliances have to use more electrical energy to operate efficiently.

---

scale insect

any small plant-sucking insect, order Homoptera, of the superfamily Coccoidea. Some species are major pests - for example, the citrus mealy bug (genus *Pseudococcus*), which attacks citrus fruits in North America. The female is often wingless and legless, attached to a plant by the head and with the body covered with a waxy scale. The rare males are winged.

---

scallop

any marine bivalve mollusc of the family Pectinidae, with a fan-shaped shell. There are two 'ears' extending from the socketlike hinge. Scallops use water-jet propulsion to move through the water to escape predators such as starfish. The giant Pacific scallop found from Alaska to California can reach 20 cm/8 in width.

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scaly anteater

another name for the pangolin.

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scandium

chemical symbol Sc

silver-white, metallic element, atomic number 21, relative atomic mass 44.956. Its compounds are found widely distributed in nature, but only in minute amounts. The metal has little industrial importance.

Scandium oxide (scandia) is used as a catalyst, in making crucibles and other ceramic parts, and scandium sulphate (in very dilute aqueous solution) is used in agriculture to improve seed germination. Scandium is relatively more abundant in the Sun and other stars than on Earth.

---

scanner

in computing, a device that can produce a digital image file of a document for input and storage in a computer. It uses technology similar to that of a photocopier. Small scanners can be passed over the document surface by hand; larger versions have a flat bed, like that of a photocopier, on which the input document is placed and scanned.

Scanners are widely used to input graphics for use in desktop publishing. If text is input with a scanner, the image captured is seen by the computer as a single digital picture rather than as separate characters. Consequently, the text cannot be processed by, for example, a word processor unless suitable optical character-recognition software is available to convert the image to its constituent characters. Scanners vary in their resolution, typical hand-held scanners ranging from 75 to 300 dpi (dots per inch).

Scanners also exist to scan photographic film and transparencies. These devices are used by people who take pictures with conventional cameras but then want to make a high-quality digital copy of the picture in order to manipulate the image in some way or print the image on a computer printer. Film scanners are now capable of scanning at resolutions of 4,000 dpi, and with 42-bit colour depth.

---

scanning

in medicine, the noninvasive examination of body organs to detect abnormalities of structure or function. Detectable waves - for example, ultrasound, gamma, or X-rays - are passed through the part to be scanned. Their absorption pattern is recorded, analysed by computer, and displayed pictorially on a screen.

---

scanning electron microscope

SEM

electron microscope that produces three-dimensional images, magnified 10-200,000 times. A fine beam of electrons, focused by electromagnets, is moved, or scanned, across the specimen. Secondary radiation reflected from the specimen is collected by a detector, giving rise to an electrical signal, which is then used to generate a point of brightness on a television-like screen. As the point moves rapidly over the screen, in phase with the scanning electron beam, an image of the specimen is built up.

The resolving power of an SEM depends on the size of the electron beam - the finer the beam, the greater the resolution. Present-day instruments typically have a resolution of 7-10 nm.

The first scanning electron picture was produced in 1935 by Max Knoll of the German company Telefunken, although the first commercial SEM (produced by the Cambridge Instrument Company in the UK) did not go on sale until 1965.

---

scanning transmission electron microscope

STEM

electron microscope that combines features of the scanning electron microscope (SEM) and the transmission electron microscope (TEM). First built in the USA in 1966, the microscope has both the SEM's contrast characteristics and lack of aberrations and the high resolution of the TEM. Magnifications of over 90 million times can be achieved, enough to image single atoms.

A fine beam of electrons, 0.3 nm in diameter, moves across the specimen, as in an SEM. However, because the specimen used is a thin slice, the beam also passes through the specimen (as in a TEM). The reflected electrons and those that penetrated the specimen are collected to form an electric signal, which is interpreted by computer to form an image on a screen.

---

scanning tunnelling microscope

STM

microscope that produces a magnified image by moving a tiny tungsten probe across the surface of the specimen. The tip of the probe is so fine that it may consist of a single atom, and it moves so close to the specimen surface that electrons 'tunnel' (that is, jump) across the gap between the tip and the surface.

The magnitude of the electron flow (current) depends on the distance from the tip to the surface, and so by measuring the current, the contours of the surface can be determined. These can be used to form an image on a computer screen of the surface, with individual atoms resolved. Magnifications up to 100 million times are possible. The STM can also be used to manipulate, rather than image, individual atoms on the surface of a material.

The STM was invented in 1981 by Gerd Binning from Germany and Heinrich Rohrer from Switzerland at the IBM Zürich Research Laboratory. With Ernst Ruska, who invented the transmission electron microscope in 1933, they were awarded the Nobel Prize for Physics in 1986.

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scapolite

group of white or greyish minerals, silicates of sodium, aluminium, and calcium, common in metamorphosed limestones and forming at high temperatures and pressures.

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scapula

or shoulder blade

large, flat, triangular bone which lies over the second to seventh ribs on the back, forming part of the pectoral girdle, and assisting in the articulation of the arm with the chest region. Its flattened shape allows a large region for the attachment of muscles.

---

scarab

any of a family Scarabaeidae of beetles, often brilliantly coloured, and including cockchafers, June beetles, and dung beetles. The *Scarabeus sacer* was revered by the ancient Egyptians as the symbol of resurrection.

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scarlet fever

or scarlatina

acute infectious disease, especially of children, caused by the bacteria in the *Streptococcus pyogenes* group. It is marked by fever, vomiting, sore throat, and a bright red rash spreading from the upper to the lower part of the body. The rash is followed by the skin peeling in flakes. It is treated with antibiotics.

Childhood Infections - Scarlet Fever

Go to site

Useful information about scarlet fever. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the fever, how the infection can be treated both at home and professionally, and what to do should the symptoms occur.

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scarp and dip

in geology, the two slopes that comprise an escarpment. The scarp is the steep slope and the dip is the gentle slope. Such a feature is common when sedimentary rocks are uplifted, folded, or eroded, the scarp slope cuts across the bedding planes of the sedimentary rock while the dip slope follows the direction of the strata. An example is Salisbury Crags in Edinburgh, Scotland.

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scatter diagram

or scattergram

diagram whose purpose is to establish whether or not a relationship or correlation exists between two variables; for example, between life expectancy and gross national product. Each observation is marked with a dot in a position that shows the value of both variables. The pattern of dots is then examined to see whether they show any underlying trend by means of a line of best fit (a straight line drawn so that its distance from the various points is as short as possible).

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scattering

in physics, the random deviation or reflection of a stream of particles or of a beam of radiation such as light, by the particles in the matter through which it passes.

alpha particles

Alpha particles scattered by a thin gold foil provided the first convincing evidence that atoms had very small, very dense, positive nuclei. From 1906 to 1908 Ernest Rutherford carried out a series of experiments from which he estimated that the closest approach of an alpha particle to a gold nucleus in a head-on collision was about 10^{-14} m. He concluded that the gold nucleus must be no larger than this. Most of the alpha particles fired at the gold foil passed straight through undeviated; however, a few were scattered in all directions and a very small fraction bounced back towards the source. This result so surprised Rutherford that he is reported to have commented: 'It was almost as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you'.

light

Light is scattered from a rough surface, such as that of a sheet of paper, by random reflection from the varying angles of each small part of the surface. This is responsible for the matt (non-shiny) appearance of such surfaces and their inability to form images (unlike mirrors). Light is also scattered by particles suspended in a gas or liquid. The red and yellow colours associated with sunrises and sunsets are due to the fact that red light is scattered to a lesser extent than is blue light by dust particles in the atmosphere. When the Sun is low in the sky, its light passes through a thicker, more dusty layer of the atmosphere, and the blue light radiated by it is scattered away, leaving the red sunlight to pass through to the eye of the observer.

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scent gland

gland that opens onto the outer surface of animals, producing odorous compounds that are used for communicating between members of the same species (pheromones), or for discouraging predators or competitors.

Scheele, Karl Wilhelm (1742-1786)

Swedish chemist and pharmacist who isolated many elements and compounds for the first time, including oxygen, about 1772, and chlorine in 1774, although he did not recognize it as an element. He showed that oxygen is involved in the respiration of plants and fish.

In the book *Abhandlung von der Luft und dem Feuer/Experiments on Air and Fire* 1777, Scheele argued that the atmosphere was composed of two gases. One, which supported combustion (oxygen), he called 'fire air', and the other, which inhibited combustion (nitrogen), he called 'vitiated air'. He thus anticipated Joseph Priestley's discovery of oxygen by two years.

Schiaparelli, Giovanni Virginio (1835-1910)

Italian astronomer. He drew attention to linear markings on Mars, which gave rise to the popular belief that they were canals. The markings were soon shown by French astronomer Eugène Antoniadi to be optical effects and not real lines. Schiaparelli also gave observational evidence for the theory that all meteor showers are fragments of disintegrating comets, and for this work he was awarded the Gold Medal of the Royal Astronomical Society in 1873.

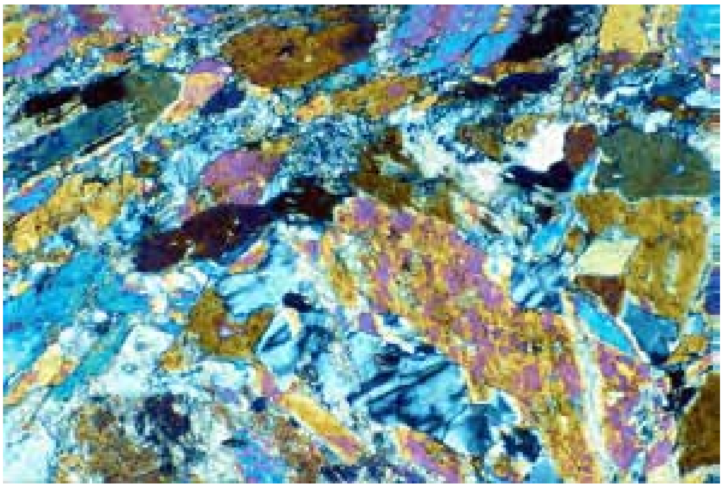
During his mapping of Mars, beginning 1877, Schiaparelli noted what his colleague in Rome, Pietro Secchi, had called 'channels' (*canali*). Schiaparelli adopted this term and also wrote of 'seas' and 'continents', but he made it quite clear that he did not mean the words to be taken literally. Nevertheless, fanciful stories of advanced life on Mars proliferated on the basis of the 'canals'.

schist

metamorphic rock containing mica; its crystals are arranged in parallel layers or bands. Schist may contain additional minerals such as garnet.

The sedimentary rocks mudstone and shale become slate under stress. When slate is subjected to higher temperatures and pressure schist is formed. The temperature causes recrystallization of new minerals, such as mica, and the pressure causes the new minerals to be aligned in bands.

schist and aconite



(Image © Corel)

Schist and actinote through a polarized microscope. Schist is produced by metamorphism of fine-grained rocks.

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schistosomiasis

another name for bilharzia.

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schizocarp

dry fruit that develops from two or more carpels and splits, when mature, to form separate one-seeded units known as mericarps.

The mericarps may be dehiscent, splitting open to release the seed when ripe, as in *Geranium*, or indehiscent, remaining closed once mature, as in mallow *Malva* and plants of the Umbelliferae family, such as the carrot *Daucus carota* and parsnip *Pastinaca sativa*.

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schizophrenia

mental disorder, a psychosis of unknown origin, which can lead to profound changes in personality, behaviour, and perception, including delusions and hallucinations. It is more common in males and the early-onset form is more severe than when the illness develops in later life. Modern treatment approaches include drugs, family therapy, stress reduction, and rehabilitation.

Schizophrenia implies a severe divorce from reality in the patient's thinking. Although the causes are poorly understood, it is now recognized as an organic disease, associated with structural anomalies in the brain. There is some evidence that early trauma, either in the womb or during delivery, may play a part in causation. There is also a genetic contribution: a gene linked to schizophrenia was identified in 2000.

According to a survey published in August 2001, there were an estimated 60 million schizophrenics worldwide. The prevalence of schizophrenia in Europe was about two to five cases per 1,000 of the population. There is an enormous variation between countries in the symptoms of schizophrenia and in the incidence of the main forms of the disease, according to a 1997 report by US investigators.
Paranoid schizophrenia, characterized by a feeling of persecution, is 50% more common in developed countries, whereas **catatonic schizophrenia**, characterized by total immobility, is six times more frequent in developing countries.
Hebephrenic schizophrenia, characterized by disorganized behaviour and speech and emotional bluntness, is four times more prevalent in developed countries overall but is rare in the USA.

research findings

Canadian researchers in 1995 identified a protein in the brain, PSA-NCAM, that plays a part in filtering sensory information. The protein is significantly reduced in the brains of schizophrenics, supporting the idea that schizophrenia occurs when the brain is overwhelmed by sensory information. In 1997, US researchers linked schizophrenia to a mutation in the gene that codes for an acetylcholine receptor. The receptor, α7-nictotinic receptor, is also stimulated by nicotine.

Schizophrenia

Go to site

Facts about schizophrenia - causes and symptoms, the different types of the disease, how it affects sufferers' family members, available treatments, and new developments. The site includes a list of available support resources.

Schliemann, Heinrich (1822-1890)

German archaeologist. In 1870 he began excavating at Hissarlik, Turkey, the traditional site of Troy, and uncovered its ruins and those of other cities on the site. His later excavations were at Mycenae, Greece, 1874-76, where he discovered the ruins of the Mycenaean civilization.

In four periods of excavation at Hissarlik, Schliemann distinguished the ruins of nine consecutive cities, believing the Troy described by the poet Homer to be the second city from the bottom. Since then research suggests that Troy III, the third city from the bottom, is probably Homeric Troy.

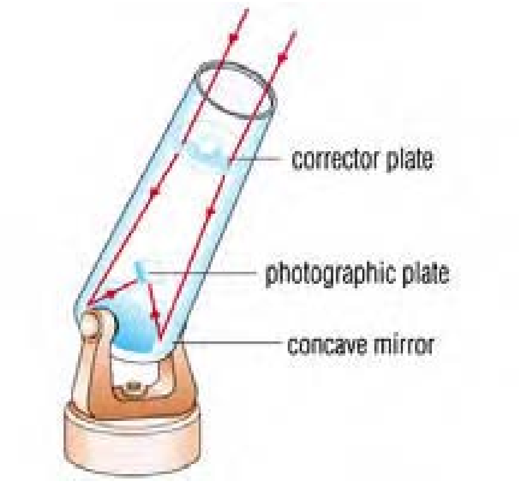
On Mycenae he excavated five shaft graves. The artefacts uncovered there were regarded as startling finds because they were stylistically unknown, and at first thought to be foreign rather than native. Dating from around 1500 BC, they included rapiers and short swords, jewellery, and spiral decoration resembling that found in central Europe.

Schliemann also worked at Orchomenus 1880 and Tiryns 1884, where he uncovered the ground plan of a Mycenaean palace.

Schmidt telescope

reflecting telescope used for taking wide-angle photographs of the sky. Invented in 1930 by Estonian lens-maker Bernhard Schmidt, it has an added corrector lens to help focus the incoming light. Examples are the 1.2-m/48-in Schmidt telescope on Mount Palomar and the UK Schmidt telescope, of the same size, at the Anglo-Australian Observatory, Siding Spring Mountain, New South Wales, Australia.

Schmidt telescope



(Image © Research Machines plc)

The Schmidt telescope uses a corrective lens (corrector plate) to achieve a wide field of view. It is one of the most widely used tools of astronomy.

Schrödinger, Erwin (1887-1961)

Austrian physicist. He advanced the study of wave mechanics to describe the behaviour of electrons in atoms. In 1926 he produced a solid mathematical explanation of the quantum theory and the structure of the atom. He shared the Nobel Prize for Physics in 1933 for his work in the development of quantum mechanics.

Schrödinger's mathematical description of electron waves superseded matrix mechanics, developed in 1925 by Max Born and Werner Heisenberg, which also described the structure of the atom mathematically but, unlike wave mechanics, gave no picture of the atom. It was later shown that wave mechanics is equivalent to matrix mechanics.

Schrödinger, Erwin

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of physicist Erwin Schrödinger. In addition to biographical information, you will find a list of references about Schrödinger and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Schrödinger. There is also an image of him, which can be enlarged, and a map of his birthplace.

Schumacher, Fritz (1911-1977)

born Ernst Friedrich Schumacher

German-born economist and conservationist. He studied in England and the USA before becoming an economic adviser first to the British Control Commission (1946-50) and then to the National Coal Board (1950-70). He founded the Intermediate Technology Group in 1966 as a non-governmental organization to work in developing countries.

Schumacher's ideas, published in his book *Small is Beautiful: Economics as if People Mattered* (1973), were based on the belief that Western methods of mass production and specialization were not an appropriate vehicle for economic development in backward countries, which lacked capital and skilled personnel but had a surplus of labour.

Schwarzschild radius

in astrophysics, the radius of the event horizon surrounding a black hole. Light originating within the event horizon cannot escape the black hole's gravitational pull.

For a black hole of mass m, the Schwarzschild radius R_S is given by $R_S = 2Gm/c^2$, where G is the universal gravitational constant and c is the speed of light. The Schwarzschild radius for a black hole of solar mass is about 3 km/1.9 mi. It is named after Karl Schwarzschild, the German astronomer who deduced the possibility of black holes from Einstein's general theory of relativity in 1916.

Schweitzer, Albert (1875-1965)

Protestant theologian, organist, and missionary surgeon. He founded the hospital at Lambaréné in Gabon in 1913, giving organ recitals to support his work there. He wrote a life of German composer J S Bach and *Von reimarus zu Wrede/The Quest for the Historical Jesus* (1906). He was awarded the Nobel Prize for Peace in 1952 for his teaching of 'reverence for life' and for his medical and other work in Africa.

International Albert Schweitzer Foundation

Go to site

Detailed biography and chronology of the theologian, organist, and missionary surgeon Albert Schweitzer. There is information and reviews about a number of his writings, of which many are quoted, and details of his commitment to the disarmament movement.

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sciatica

persistent pain in the back and down the outside of one leg, along the sciatic nerve and its branches. Causes of sciatica include inflammation of the nerve or pressure of a displaced disc on a nerve root leading out of the lower spine.

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science

(Latin scientia 'knowledge')

any systematic field of study or body of knowledge that aims, through experiment, observation, and deduction, to produce reliable explanations of phenomena, with reference to the material and physical world.

history

Activities such as healing, star-watching, and engineering have been practised in many societies since ancient times. Pure science, especially physics (formerly called natural philosophy), had traditionally been the main area of study for philosophers. The European scientific revolution between about 1650 and 1800 replaced speculative philosophy with a new combination of observation, experimentation, and rationality.

philosophy of science

Today, scientific research involves an interaction between tradition, experiment and observation, and deduction. The subject area called philosophy of science investigates the nature of this complex interaction, and the extent of its ability to gain access to the truth about the material world. It has long been recognized that induction from observation cannot give explanations based on logic. In the 20th century Karl Popper described scientific method as a rigorous experimental testing of a scientist's ideas or hypotheses (see hypothesis). The origin and role of these ideas, and their interdependence with observation, have been examined, for example, by the US thinker Thomas S Kuhn, who places them in a historical and sociological setting.

sociology of science

The sociology of science investigates how scientific theories and laws are produced, and questions the possibility of objectivity in any scientific endeavour. One controversial point of view is the replacement of scientific realism with scientific relativism, as proposed by Paul K Feyerabend. Questions concerning the proper use of science and the role of science education are also restructuring this field of study.

Science and Religion

enemies or partners?

In recent years the truce between science and religion has shown itself to be uneasy. Public perception of the status and role of science in society has shifted from approval, and a conviction that science has all the answers, to ambivalence. This leaves many scientists defensive about their particular contribution in society.

Any suggestion that scientists might have something to learn from theology was roundly dismissed on 1 April 1993 by the editor of *Nature*, a leading scientific weekly magazine. He asserted that the creation of a lectureship in theology and the natural sciences, funded by a £1 million endowment from the English author Susan Howatch and named the Starbridge Lectureship after her best-selling series, was non-academic and amounted to a university's giving in to pressure to accept finances from what he believed to be 'dubious' sources. His lead article attracted a flurry of correspondence from both scientists and theologians.

natural partners

One position is that science and religion are partners rather than enemies. According to this view, it was the belief in a divine creator that allowed the first scientific investigations to take place. Both Christians and Muslims perceived the world as a product of divine creation. Scientists eagerly studied creation as a way of finding out the wisdom of God as revealed in it.

The early scientists, including Johannes Kepler, Galileo Galilei, Robert Boyle, René Descartes, Francis Bacon, Blaise Pascal, John Ray, Isaac Newton, and Michael Faraday, were all concerned to relate their scientific studies to their faith. The areas of theology and natural science can coexist if theology is seen as bringing in layers of meaning that are missing from purely scientific accounts.

Some Christians argue that science itself requires a leap of faith that is at least as strong as religious commitment, and some scientists would urge us to see our religious predisposition as having survival value, if religious belief leads to an overall increase in 'goodness'. In this view, our genetic make-up is not conditioned by selfish competition but by altruism.

secular v. sacred

An alternative view is that science and religion are incompatible. Science is a form of knowledge that can be proved, while religion cannot be proved and so is, by implication, not knowledge.

The church resisted the teaching of the early scientists, such as Galileo, because he seemed to be able to do away with the necessary existence of God for the creation of the universe. Science responded to such attacks by becoming increasingly secular and working in detachment from the teaching of the Christian Church or other religions.

Established science tended to equate religious teachings with superstitious ornamentations of life of no intellectual value. Science began to explain religion as a way of responding psychologically to pressures in society. Belief in miracles and other supernatural events was seen as a function of a fantasy world created by the religious participants.

The origin of humanity, crucially attributed to a creator god in religion, is explained by scientific principles according to the theory of evolution, where only those populations that best fit the environment survive. The weak and defenceless are weeded out in the process.

the power of the scientist

Scientists are popularly perceived as either innocent bystanders with regard to the way the technology for which they have provided the basis has been used, or scapegoats who can be blamed for contemporary problems such as the ecological crisis. The application of scientific ideas by other parties such as politicians, industrial entrepreneurs, and the military, has changed the face of our planet and broken up ancient, more stable social structures and religious patterns of living. Scientists injected the original ideas into our cultures, even if they were not involved in their implementation.

a living planet?

In the last 30 years there has been an increased interest in cross-disciplinary studies. One of the pioneers of work of this type is James Lovelock, who argues that the world as a whole behaves rather like a giant organism.The composition of the atmosphere is controlled by the sum total of life on the planet.

He is most controversial when he mixes his scientific hypothesis with an ancient belief in the Earth goddess, Gaia. Such controversy stems from the unease of the scientific establishment about the academic worth of religious ideas, since such ideas are a matter of opinion and cannot be proved in any objective sense.

ethics: the common ground

In establishing the policy for future scientific practice, questions of faith are also raised. What kind of guidelines can we draw up in deciding what the limits of medical research should be? Do we need to take a wider ethical approach when using advances in biological technology that were unimaginable in earlier centuries?

Advances in genetics, and genetic engineering in particular, posit a future in which scientists may be able to produce certain characteristics or eliminate 'undesirable' ones in humans, as well as other animals - a future where even the role of creator is usurped by science. An appreciation by scientists of religious concerns is more likely to lead to a lasting contribution by science to society; and an understanding of science by the religious is more likely to prevent a retreat into fanaticism.

Scientific discoveries

Discovery	Date	Discoverer	Nationality
Absolute zero, concept	1851	William Thomson, 1st Baron Kelvin	Irish
Adrenalin, isolation	1901	Jokichi Takamine	Japanese
Alizarin, synthesized	1869	William Perkin	English
Allotropy (in carbon)	1841	Jöns Jakob Berzelius	Swedish
Alpha particles	1899	Ernest Rutherford	New Zealand-born British
Alternation of generations (ferns and mosses)	1851	Wilhelm Hofmeister	German
Aluminium, extraction by electrolysis of aluminium oxide	1886	Charles Hall, Paul Héroult	US, French
Aluminium, improved isolation	1827	Friedrich Wöhler	German
Anaesthetic, first use (ether)	1842	Crawford Long	US
Anthrax vaccine	1881	Louis Pasteur	French
Antibacterial agent, first specific (Salvarsan for treatment of syphilis)	1910	Paul Ehrlich	German
Antiseptic surgery (using phenol)	1865	Joseph Lister	English
Argon	1892	William Ramsay	Scottish
Asteroid, first (Ceres)	1801	Giuseppe Piazzi	Italian
Atomic theory	1803	John Dalton	English
Australopithecus	1925	Raymond Dart	Australian-born South African
Avogadro's hypothesis	1811	Amedeo Avogadro	Italian
Bacteria, first observation	1683	Anton van Leeuwenhoek	Dutch
Bacteriophages	1916	Felix D'Herelle	Canadian
Bee dance	1919	Karl von Frisch	Austrian
Benzene, isolation	1825	Michael Faraday	English
Benzene, ring structure	1865	Friedrich Kekulé	German
Beta rays	1899	Ernest Rutherford	New Zealand-born British
Big Bang theory	1948	Ralph Alpher, George Gamow	US
Binary arithmetic	1679	Gottfried Leibniz	German
Binary stars	1802	William Herschel	German-born English
Binomial theorem	1665	Isaac Newton	English
Blood, circulation	1619	William Harvey	English
Blood groups, ABO system	1900	Karl Landsteiner	Austrian-born US
Bode's law	1772	Johann Bode, Johann Titius	German
Bohr atomic model	1913	Niels Bohr	Danish
Boolean algebra	1854	George Boole	English
Boyle's law	1662	Robert Boyle	Irish
Brewster's law	1812	David Brewster	Scottish
Brownian motion	1827	Robert Brown	Scottish
Cadmium	1817	Friedrich Strohmeyer	German
Caesium	1861	Robert Bunsen	German
Carbon dioxide	1755	Joseph Black	Scottish
Charles's law	1787	Jacques Charles	French
Chlorine	1774	Karl Scheele	Swedish
Complex numbers, theory	1746	Jean d'Alembert	French
Conditioning	1902	Ivan Pavlov	Russian
Continental drift	1912	Alfred Wegener	German
Coriolis effect	1834	Gustave-Gaspard Coriolis	French
Cosmic radiation	1911	Victor Hess	Austrian
Decimal fractions	1576	François Viète	French
Dinosaur fossil, first recognized	1822	Mary Ann Mantell	English
Diphtheria bacillus, isolation	1883	Edwin Krebs	US
DNA	1869	Johann Frederick Miescher	Swiss
DNA and RNA	1909	Phoebus Levene	Russian-born US
DNA, double-helix structure	1953	Francis Crick, James Watson	English, US
Doppler effect	1842	Christian Doppler	Austrian
Earth's magnetic pole	1546	Gerardus Mercator	Flemish
Earth's molten core	1916	Albert Michelson	German-born US
Earth's molten core, proof	1906	Richard Oldham	Welsh
Earth's rotation, demonstration	1851	Léon Foucault	French
Eclipse, prediction	585 BC	Thales of Miletus	Greek
Electrolysis, laws	1833	Michael Faraday	English
Electromagnetic induction	1831	Michael Faraday	English

Electromagnetism	1819	Hans Christian Oersted	Danish
Electron	1897	J J Thomson	English
Electroweak unification theory	1967	Sheldon Lee Glashow, Abdus Salam, Steven Weinberg	US, Pakistani, US
Endorphins	1975	John Hughes	US
Enzyme, first animal (pepsin)	1836	Theodor Schwann	German
Enzyme, first (diastase from barley)	1833	Anselme Payen	French
Enzymes, 'lock and key' hypothesis	1899	Emil Fischer	German
Ether, first anaesthetic use	1842	Crawford Long	US
Eustachian tube	1552	Bartolomeo Eustachio	Italian
Evolution by natural selection	1858	Charles Darwin	English
Exclusion principle	1925	Wolfgang Pauli	Austrian-born Swiss
Fallopian tubes	1561	Gabriello Fallopius	Italian
Fluorine, preparation	1886	Henri Moissan	French
Fullerenes	1985	Harold Kroto, David Walton	English
Gay-Lussac's law	1808	Joseph-Louis Gay-Lussac	French
Geometry, Euclidean	300 BC	Euclid	Greek
Germanium	1886	Clemens Winkler	German
Germ theory	1861	Louis Pasteur	French
Global temperature and link with atmospheric carbon dioxide	1896	Svante Arrhenius	Swedish
Gravity, laws	1687	Isaac Newton	English
Groups, theory	1829	Evariste Galois	French
Gutenberg discontinuity	1914	Beno Gutenberg	German-born US
Helium, production	1896	William Ramsay	Scottish
Homo erectus	1894	Marie Dubois	Dutch
Homo habilis	1961	Louis Leakey, Mary Leakey	Kenyan, English
Hormones	1902	William Bayliss, Ernest Starling	English
Hubble's law	1929	Edwin Hubble	US
Hydraulics, principles	1642	Blaise Pascal	French
Hydrogen	1766	Henry Cavendish	English
Iapetus	1671	Giovanni Cassini	Italian-born French
Infrared solar rays	1801	William Herschel	German-born English
Insulin, isolation	1921	Frederick Banting, Charles Best	Canadian
Insulin, structure	1969	Dorothy Hodgkin	English
Interference of light	1801	Thomas Young	English
Irrational numbers	450 BC	Hipparcos	Greek
Jupiter's largest satellites	1610	Galileo	Italian
Kinetic theory of gases	1850	Rudolf Clausius	German
Krypton	1898	William Ramsay, Morris Travers	Scottish, English
Lanthanum	1839	Carl Mosander	Swedish
Lenses, how they work	1039	Ibn al-Haytham Alhazen	Arabic
Light, finite velocity	1675	Ole Römer	Danish
Light, polarization	1678	Christiaan Huygens	Dutch
Linnaean classification system	1735	Carolus Linnaeus	Swedish
'Lucy', hominid	1974	Donald Johanson	US
Magnetic dip	1576	Robert Norman	English
Malarial parasite in *Anopheles* mosquito	1897	Ronald Ross	British
Malarial parasite observed	1880	Alphonse Laveran	French
Mars, moons	1877	Asaph Hall	US
Mendelian laws of inheritance	1866	Gregor Mendel	Austrian
Messenger RNA	1960	Sydney Brenner, François Jacob	South African, French
Micro-organisms as cause of fermentation	1856	Louis Pasteur	French
Monoclonal antibodies	1975	César Milstein, Georges Köhler	Argentine-born British, German
Motion, laws	1687	Isaac Newton	English
Natural selection	1859	Charles Darwin	English
Neon	1898	William Ramsay, Morris Travers	Scottish, English
Neptune	1846	Johann Galle	German
Neptunium	1940	Edwin McMillan, Philip Abelson	US
Nerve impulses, electric nature	1771	Luigi Galvani	Italian
Neutron	1932	James Chadwick	English
Nitrogen	1772	Daniel Rutherford	Scottish
Normal distribution curve	1733	Abraham De Moivre	French
Nuclear atom, concept	1911	Ernest Rutherford	New Zealand-born British
Nuclear fission	1938	Otto Hahn, Fritz Strassman	German
Nucleus, plant cell	1831	Robert Brown	Scottish
Ohm's law	1827	Georg Ohm	German

Organic substance, first synthesis (urea)	1828	Friedrich Wöhler	German
Oxygen	1774	Joseph Priestley	English
Oxygen, liquefaction	1894	James Dewar	Scottish
Ozone layer	1913	Charles Fabry	French
Palladium	1803	William Hyde Wollaston	English
Pallas (asteroid)	1802	Heinrich Olbers	German
Pendulum, principle	1581	Galileo	Italian
Penicillin	1928	Alexander Fleming	Scottish
Penicillin, widespread preparation	1940	Ernst Chain, Howard Florey	German, Australian
Pepsin	1836	Theodor Schwann	German
Periodic law for elements	1869	Dmitri Mendeleyev	Russian
Period-luminosity law	1912	Henrietta Swan	US
Phosphorus	1669	Hennig Brand	German
Piezoelectric effect	1880	Pierre Curie	French
Pi meson (particle)	1947	Cecil Powell, Giuseppe Occhialini	English, Italian
Pistils, function	1676	Nehemiah Grew	English
Planetary nebulae	1790	William Herschel	German-born English
Planets, orbiting Sun	1543	Nicolas Copernicus	Polish
Pluto	1930	Clyde Tombaugh	US
Polarization of light by reflection	1808	Etienne Malus	French
Polio vaccine	1952	Jonas Salk	US
Polonium	1898	Marie and Pierre Curie	French
Positron	1932	Carl Anderson	US
Potassium	1806	Humphry Davy	English
Probability theory	1654	Blaise Pascal, Pierre de Fermat	French
Probability theory, expansion	1812	Pierre Laplace	French
Proton	1914	Ernest Rutherford	New Zealand-born British
Protoplasm	1846	Hugo von Mohl	German
Pulsar	1967	Jocelyn Bell Burnell	Irish
Pythagoras' theorem	550 BC	Pythagoras	Greek
Quantum chromodynamics	1972	Murray Gell-Mann	US
Quantum electrodynamics	1948	Richard Feynman, Seymour Schwinger, Shin'chiro Tomonaga	US, US, Japanese
Quark, first suggested existence	1963	Murray Gell-Mann, George Zweig	US
Quasar	1963	Maarten Schmidt	Dutch-born US
Rabies vaccine	1885	Louis Pasteur	French
Radioactivity	1896	Henri Becquerel	French
Radio emissions, from Milky Way	1931	Karl Jansky	US
Radio waves, production	1887	Heinrich Hertz	German
Radium	1898	Marie and Pierre Curie	French
Radon	1900	Friedrich Dorn	German
Refraction, laws	1621	Willibrord Snell	Dutch
Relativity, general theory	1915	Albert Einstein	German-born US
Relativity, special theory	1905	Albert Einstein	German-born US
Rhesus factor	1940	Karl Landsteiner, Alexander Wiener	Austrian, US
Rubidium	1861	Robert Bunsen	German
Sap circulation	1846	Giovanni Battista Amici	Italian
Sap flow in plants	1733	Stephen Hales	English
Saturn, 18th moon	1990	Mark Showalter	US
Saturn's largest satellites	1656	Christiaan Huygens	Dutch
Smallpox inoculation	1796	Edward Jenner	English
Sodium	1806	Humphry Davy	English
Stamens, function	1676	Nehemiah Grew	English
Stars, luminosity sequence	1905	Ejnar Hertzsprung	Danish
Stereochemistry, foundation	1848	Louis Pasteur	French
Stratosphere	1902	Léon Teisserenc	French
Sunspots	1611	Galileo, Christoph Scheiner	Italian, German
Superconductivity	1911	Heike Kamerlingh-Onnes	Dutch
Superconductivity, theory	1957	John Bardeen, Leon Cooper, John Schrieffer	US
Thermodynamics, second law	1834	Benoit-Pierre Clapeyron	French
Thermodynamics, third law	1906	Hermann Nernst	German
Thermoelectricity	1821	Thomas Seebeck	German
Thorium-X	1902	Ernest Rutherford, Frederick Soddy	New Zealand-born British, English
Titius-Bode law	1772	Johan Bode, Johann Titius	German
Tranquillizer, first (reserpine)	1956	Robert Woodward	US
Transformer	1831	Michael Faraday	English

Troposphere	1902	Léon Teisserenc	French
Tuberculosis bacillus, isolation	1883	Robert Koch	German
Tuberculosis vaccine	1923	Albert Calmette, Camille Guérin	French
Uranus	1781	William Herschel	German-born English
Urea cycle	1932	Hans Krebs	German
Urease, isolation	1926	James Sumner	US
Urea, synthesis	1828	Friedrich Wöhler	German
Valves, in veins	1603	Geronimo Fabricius	Italian
Van Allen radiation belts	1958	James Van Allen	US
Virus, first identified (tobacco mosaic disease, in tobacco plants)	1898	Martinus Beijerinck	Dutch
Vitamin A, isolation	1913	Elmer McCollum	US
Vitamin A, structure	1931	Paul Karrer	Russian-born Swiss
Vitamin B, composition	1955	Dorothy Hodgkin	English
Vitamin B, isolation	1925	Joseph Goldberger	Austrian-born US
Vitamin C	1928	Charles Glen King, Albert Szent-Györgi	US, Hungarian-born US
Vitamin C, isolation	1932	Charles Glen King	US
Vitamin C, synthesis	1933	Tadeus Reichstein	Polish-born Swiss
Wave mechanics	1926	Erwin Schrödinger	Austrian
Xenon	1898	William Ramsay, Morris Travers	Scottish, English
X-ray crystallography	1912	Max von Laue	German
X-rays	1895	Wilhelm Röntgen	German

Andy Darvill's Science Site

Go to site

Constructed by an ex-teacher, this site contains a variety of resources. In the 'Online materials' section there are some excellent physics Web pages created by the teacher. There are online quizzes with hints available, links to relevant downloadable science resources, recommendations of other science software, plus a useful section on revision tips.

Bad Science

Go to site

Unusual and thought-provoking site set up to make teachers and pupils aware of examples of bad science teaching. It opens with a display of some major preconceptions behind incorrect presentation of science in the classroom, and also provides links to a number of bad science sites with a specific focus.

BBC Online Science

Go to site

Comprehensive science site from the British Broadcasting Corporation (BBC). It covers topics such as 'The basics', 'Human body', 'Science at nine', and 'Space technology'. In addition, there are many articles covering the latest science news stories, plus information relating to the BBC science programmes, such as *Tomorrow's World* and *Walking with Dinosaurs*. A great site for researching science homework.

BBC Science

Go to site

Well-presented site from the British Broadcasting Corporation. The site is divided up into numerous sections, each containing several topics. The scientific principles behind each topic are explained, followed by a series of activities and investigations. The activities require either Shockwave or Flash plug-ins to work, but they can be downloaded from the site.

Bizarre Stuff you Can Make in your Kitchen

Go to site

Instructions on how to make or build many scientific projects from things found in the home. It includes how to make an electric lemon, a home-made hurricane, and even dancing mothballs. The experiments are graded for difficulty and organized by category so there is something for every age group here. Take note of the safety warning on the front page, though, as some of these experiments do use dangerous chemicals, electricity, and so on, and younger children will need supervision.

Discovery Channel

Go to site

Content-rich site containing information on a number of subjects, such as 'Reality', 'Science', and 'History'. There are additional features such as Webcams, and a 'Fun and games' section where you can play the 'EcoHome game' or 'Senet', an ancient Egyptian strategy game.

Explore Science

Go to site

Interactive explanations of some basic scientific concepts that are supported by an effective use of Shockwave animations. The sections covered on this site include mechanics, life sciences, optics, and astrophysics.

Gondar Design Science: GCSE Subjects

Go to site

Extremely comprehensive general site, written by a science teacher for students taking double science GCSE. However, single subject science students will find that about 80% of their course is also covered here. Each subject (chemistry, physics, biology) is split into sections, reflecting the topics students cover. Every section of notes features clear diagrams to explain the key concepts, as well as links at the bottom of the page to the next relevant topic.

Invention Dimension!

Go to site

All about inventors and inventions. This US-based site includes an 'Inventor of the week' plus links to many other invention-related Web sites. As well as giving details of the major players in the annual Lemelson-MIT invention awards, the site also includes a list of independent inventors.

Mad Scientist Network

Go to site

Indispensable resource for those in need of answers to scientific questions. The Mad Scientist Network is a group of scientists prepared to field queries on a vast range of subjects. There is an online archive of previous questions and answers, and helpful guides to accessing other general interest science Web sites.

Museum of Science

Go to site

In Boston, Massachusetts, USA. This is a well-designed site with a range of programmes available to the public, including online tours and exhibitions.

Museum of the History of Science

Go to site

Based in Oxford, UK. This site offers exhibitions - both from the galleries and especially for the Web - together with news of museum activities, publications, events, and courses.

New Scientist

Go to site

Online, searchable version of the prestigious science journal. Read about the 'Top stories' and 'Latest news' in science, or look for an article on a particular topic. Past editions of the magazine are also available to read online.

Reeko's Mad Scientist Lab

Go to site

Free, fun, and educational science experiments for kids and adults. Designed so you can to learn about basic science principles painlessly. The experiments can be sorted by category or skill level. Most of them can be done in the home and each of them contains detailed instructions and an explanation of the scientific principle demonstrated.

Satrosphere

Go to site

Satrosphere is an interactive exhibition of Science and Technology based in Aberdeen, Scotland. This Web site contains a selection of exhibits, including the geology of northwest Scotland, a 'Bernoulli blower' and a reaction timer. There are also practical details about the museum's opening hours and its links with schools.

Science Club

Go to site

General science site, with loads of science projects to build, from a 'Quick and simple telescope' to an electrostatic loudspeaker. This site also includes a 'Science fair ideas exchange' section and pages of links in an attempt to answer any science questions you might have.

Science Jokes Archive

Go to site

Masses of jokes based around the scientific community. Quite a few gems are included in this vast repository which offers separate sections of jokes on maths, physics, biology, chemistry, scientists in general, mathematicians, physicists, engineers, and academic life.

Science Museum

Go to site

Web site of the Science Museum in London, England. It contains a variety of information about the museum itself, such as a virtual tour around the newest galleries in the Wellcome Wing. In addition, there are online exhibitions, or 'exhiblets', on a selection of topics, plus interactive games and further science information.

Sciences Explorer

Go to site

Educational learning experience in the fields of maths, biology, chemistry, and physics. This site includes a unit converter, crossword puzzles, and details on how to make a chemical garden, as well as a good 'Interact!' section that allows you to ask questions and take part in a chat forum with other scientists, both amateur and professional.

Why Files

Go to site

Well-designed and topical science site tackling a couple of recent issues in each bimonthly update. As well as having a lively presentation, it also includes a lot of useful background information on a wide range of topics. This site also retains many of its previous entries, which are fully searchable.

You can with Beakman and Jax

Go to site

Answers to many important questions, such as: 'Why do your ears pop'? 'What is colour made out of'? 'How can you be sure stuff you can't see is really there?' It also includes interactive demonstrations to find out how gravity works, how the Internet works, and why leaves change colour in the autumn.

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scientific law

principles that are taken to be universally applicable.

Laws (for instance, Boyle's law and Newton's laws of motion) form the basic theoretical structure of the physical sciences, so that the rejection of a law by the scientific community is an almost inconceivable event. On occasion a law may be modified, as was the case when Einstein showed that Newton's laws of motion do not apply to objects travelling at speeds close to that of light.

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scilla

any of a group of bulbous plants belonging to the lily family, with blue, pink, or white flowers; they include the spring squill (*S. verna*). (Genus *Scilla*, family Liliaceae.)

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scintillation counter

instrument for measuring very low levels of radiation. The radiation strikes a scintillator (a device that emits a photon – a single unit of light – when a charged elementary particle collides with it), whose light output is 'amplified' by a photomultiplier; the current pulses of its output are in turn counted or added by a scaler to give a numerical reading.

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sclerenchyma

plant tissue whose function is to strengthen and support, composed of thick-walled cells that are heavily lignified (toughened). On maturity the cell inside dies, and only the cell walls remain.

Sclerenchyma may be made up of one or two types of cells: **sclereids**, occurring singly or in small clusters, are often found in the hard shells of fruits and in seed coats, bark, and the stem cortex; **fibres**, frequently grouped in bundles, are elongated cells, often with pointed ends, associated with the vascular tissue (xylem and phloem) of the plant.

Some fibres provide useful materials, such as flax from *Linum usitatissimum* and hemp from *Cannabis sativa*.

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scleroderma

in medicine, condition characterized by thickening of the skin. This results in the skin becoming hard, the joints stiffening, and a gradual wasting of the muscles. It is thought to be caused by malfunctioning of the immune system.

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sclerosis

any abnormal hardening of body tissues, especially the nervous system or walls of the arteries. See multiple sclerosis and atherosclerosis.

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scoliosis

lateral (sideways) deviation of the spine. It may be congenital or acquired (through bad posture, illness, or other deformity); or it may be idopathic (of unknown cause). Treatments include mechanical or surgical correction, depending on the cause.

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scopolamine

alternative name for hyoscine, a sedative drug.

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scorpion

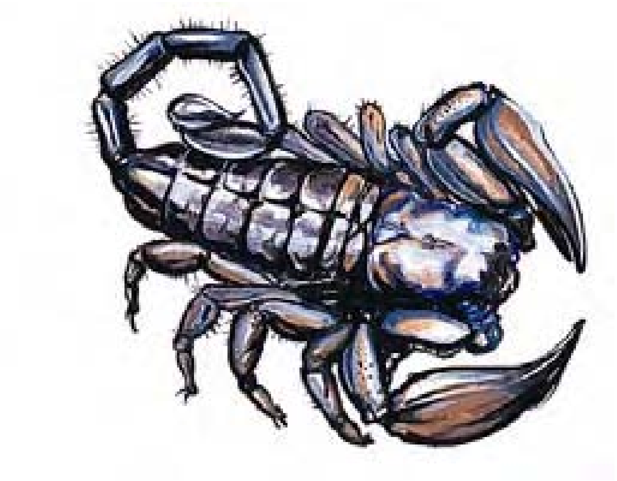
any arachnid of the order Scorpiones, common in the tropics and subtropics. Scorpions have four pairs of walking legs, large pincers, and long tails ending in upcurved poisonous stings, though the venom is not usually fatal to a healthy adult human. Some species reach 25 cm/10 in. There are about 600 different species.

They are nocturnal in habit, hiding during the day beneath stones and under the loose bark of trees. The females are viviparous (producing live young), the eggs being hatched in the enlarged oviducts. Scorpions sometimes prey on each other, but their main food is the woodlouse. They seize their prey with their powerful claws or palpi. They are also able to survive for a long time without eating; one scorpion managed to survive for 17 months on a single housefly.

scorpion

If disturbed, whip scorpions emit a spray that is 84% acetic acid (the acid in vinegar). The spray also contains a powerful solvent to ensure that the irritant acid penetrates its target fully.

scorpion



(Image © Research Machines plc)

The scorpion belongs to an ancient group of animals. Scorpions were perhaps the first arachnids to adapt to life on land, some 400 million years ago. There are about 800 species known today.

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scorpion fly

any insect of the order Mecoptera. They have a characteristic downturned beak with jaws at the tip, and many males have a scorpion-like upturned tail, giving them their common name. Most feed on insects or carrion. They are an ancient group with relatively few living representatives.

Scorpius

bright zodiacal constellation in the southern hemisphere between Libra and Sagittarius, represented as a scorpion. The Sun passes briefly through Scorpius in the last week of November. The heart of the scorpion is marked by the bright red supergiant star Antares. Scorpius contains rich Milky Way star fields, plus the strongest X-ray source in the sky, Scorpius X-1. The whole area is rich in clusters and nebulae. In astrology, the dates for Scorpius are about 24 October–21 November (see precession). Some see in it the scorpion that killed Orion who, still in fear, sets as Scorpius rises.

scrapie

fatal disease of sheep and goats that attacks the central nervous system, causing deterioration of the brain cells, and leading to the characteristic staggering gait and other behavioural abnormalities, before death. It is caused by the presence of an abnormal version of the brain protein PrP and is related to bovine spongiform encephalopathy, the disease of cattle known as 'mad cow disease', and Creutzfeldt–Jakob disease in humans. It is a transmissible spongiform encephalopathy.

screamer

any South American marsh-dwelling bird of the family Anhimidae, order Anseriformes; there are only three species, all in the genus *Anhima*. They are about 80 cm/30 in long, with short curved beaks, long toes, dark plumage, spurs on the fronts of the wings, and a crest or horn on the head.

Screamers wade in wet forests and marshes, although their feet are scarcely webbed. They are related to ducks and are placed in the same order. The **horned screamer** *A. cornuta* is found in certain parts of Central and South America, and has glossy black plumage with a white abdomen; it has a long, slender, yellowish horn on its head.

screen dump

in computing, the process of making a printed copy of the current VDU screen display. The screen dump is sometimes stored as a data file instead of being printed immediately.

screening

or health screening

systematic search for evidence of a disease, or of conditions that may precede it, in people who are at risk but not suffering from any symptoms. The aim of screening is to try to limit ill health from preventable diseases that might otherwise go undetected in the early stages. Examples are hypothyroidism and phenylketonuria, for which all newborn babies in Western countries are screened; breast cancer (mammography) and cervical cancer; and stroke, for which high blood pressure is a known risk factor.

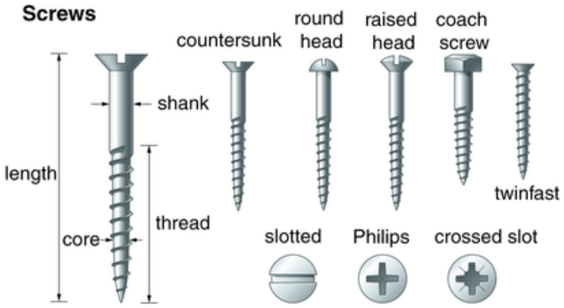
The criteria for a successful screening programme are that the disease should be important and treatable, the population at risk identifiable, the screening test acceptable, accurate, and cheap, and that the results of screening should justify the costs involved.

screw

in construction, cylindrical or tapering piece of metal or plastic (or formerly wood) with a helical groove cut into it. Each turn of a screw moves it forward or backwards by a distance equal to the pitch (the spacing between neighbouring threads).

Its mechanical advantage equals $2r/P$, where P is the pitch and r is the radius of the thread. Thus the mechanical advantage of a tapering wood screw, for example, increases as it is rotated into the wood.

screw



(Image © Research Machines plc)

Some different types of wood screw. The screw heads vary depending on the nature of the job; for example, countersunk screws are used for work where it is important that the screw head is flush to the surface.

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scrofula

tuberculosis of the lymph glands, especially of the neck, marked by enlargement, abscess formation, and scarring. Treatment is with drugs. Scrofula, which mostly affects children and young adults, is uncommon outside the developing world.

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scuba

acronym for Self-Contained Underwater Breathing Apparatus

another name for aqualung.

Welcome to Aquanaut

Go to site

Online scuba diving magazine with comprehensive details on all aspects of the sport. The regularly updated contents include information about equipment, places to learn to dive, reports from dive sites, weather reports, information about fish, a photo gallery, safety advice, and what to do in an emergency. There is a guide to the technical terms used in the sport and links to a number of other dive sites and to newsgroups.

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scurvy

disease caused by deficiency of vitamin C (ascorbic acid), which is contained in fresh vegetables and fruit. The signs are weakness and aching joints and muscles, progressing to bleeding of the gums and other spontaneous haemorrhage, and drying-up of the skin and hair. It is reversed by giving the vitamin.

---

scurvy grass

plant found growing in salt marshes and on banks by the sea in the northern hemisphere. Shoots may grow low, or more upright, up to 50 cm/20 in, with fleshy heart-shaped lower leaves; the flowers are white and have four petals. The edible, sharp-tasting leaves are a good source of vitamin C and were formerly eaten by sailors as a cure for the disease scurvy. (*Cochlearia officinalis*, family Cruciferae.)

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scythe

harvesting tool with long wooden handle and sharp, curving blade.

It is similar to a sickle. The scythe was in common use in the Middle East and Europe from the dawn of agriculture until the early 20th century, by which time it had generally been replaced by machinery.

Until the beginning of the 19th century, the scythe was used in the hayfield for cutting grass, but thereafter was applied to cereal crops as well, because it was capable of a faster work rate than the sickle. One person could mow 0.4 hectares/1 acre of wheat in a day with a scythe. Next came a team of workers to gather and bind the crop into sheaves and stand them in groups, or stooks, across the field.

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sea anemone

invertebrate marine animal of the phylum Cnidaria with a tubelike body attached by the base to a rock or shell. The other end has an open 'mouth' surrounded by stinging tentacles, which capture crustaceans and other small organisms. Many sea anemones are beautifully coloured, especially those in tropical waters.

Anemones

Go to site

Article on keeping anemones in an aquarium environment. The site offers information on species, feeding, and tank maintenance practices to help these creatures thrive in captivity.

Seaborg, Glenn Theodore (1912-1999)

US nuclear chemist. He shared the Nobel Prize for Chemistry in 1951 with his co-worker Edwin McMillan for the discovery of plutonium and research on the transuranic elements.

All transuranic elements are radioactive and none occurs to any appreciable extent in nature; they are synthesized by transmutation reactions. Seaborg was involved in the identification of plutonium (atomic number 94) in 1940, americium (95) in 1944-45, curium (96) in 1944, berkelium (97) in 1949, californium (98) in 1950, einsteinium (99) in 1952, fermium (100) in 1952, mendelevium (101) in 1955, and nobelium (102) in 1958.

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seaborgium

chemical symbol Sg

synthesized radioactive element of the transactinide series, atomic number 106, relative atomic mass 263. It was first synthesized in 1974 in the USA and given the temporary name unnilhexium. The discovery was not confirmed until 1993. It was officially named in 1997 after US nuclear chemist Glenn Seaborg.

The University of California, Berkeley, bombarded californium with oxygen nuclei to get isotope 263; the Joint Institute for Nuclear Research, Dubna, Russia, bombarded lead with chromium nuclei to obtain isotopes 259 and 260.

Seacole, Mary (1805-1881)

Jamaican nurse. Her popularity during the Crimean War rivalled that of Florence Nightingale. She was rejected as a nurse by the British War Office, and by one of Florence Nightingale's assistants, which she suspected was due to race prejudice, but in 1855 opened a hotel and store serving British troops near Kadikoy (modern Kadikeui, Turkey). She was present at the Battle of Tchernaya and was the first woman to enter the town of Sevastopol when it fell.

She was born in Kingston, where her mother ran a boarding house for invalid officers. In 1853 the medical authorities in Jamaica asked her to provide nurses for British soldiers. At the end of the Crimean War in 1856 she returned to London bankrupt; her cause was taken up in *The Times* and *Punch*, and a four-day music festival raised money for her. In 1857 she published her autobiography *Wonderful adventures of Mrs Seacole in many lands*. She was awarded a Crimean medal.

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sea cucumber

any echinoderm of the class Holothuroidea with a cylindrical body that is tough-skinned, knobbed, or spiny. The size ranges from 3 cm/1.2 in to 2 m/6.6 ft. There are around 900 species, which are mostly black, brown, or olive green in colour. Sea cucumbers are sometimes called 'cotton-spinners' because of the sticky filaments they eject from the anus in self-defence.

The dried flesh of sea cucumbers is a delicacy in Japan and Taiwan, and overfishing has threatened some populations. A high density is vital to sustain a population as they reproduce by releasing sperm or ova into the water; other sea cucumbers must also be releasing sperm or ova nearby.

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seafloor spreading

growth of the ocean crust outwards (sideways) from ocean ridges. The concept of seafloor spreading has been combined with that of continental drift and incorporated into plate tectonics.

Seafloor spreading was proposed in 1960 by US geologist Harry Hess (1906-1969), based on his observations of ocean ridges and the relative youth of all ocean beds. In 1963 British geophysicists Fred Vine and Drummond Matthews observed that the floor of the Atlantic Ocean was made up of rocks that could be arranged in strips, each strip being magnetized either normally or reversely (due to changes in the Earth's polarity when the North Pole becomes the South Pole and vice versa, termed polar reversal). These strips were parallel and formed identical patterns on both sides of the ocean ridge. The implication was that each strip was formed at some stage in geological time when the magnetic field was polarized in a certain way. The seafloor magnetic-reversal patterns could be matched to dated magnetic reversals found in terrestrial rock. It could then be shown that new rock forms continuously and spreads away from the ocean ridges, with the oldest rock located farthest away from the midline. The observation was made independently in 1963 by Canadian geologist Lawrence Morley, studying an ocean ridge in the Pacific near Vancouver Island.

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seagull

see gull.

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sea horse

any marine fish of several related genera, especially *Hippocampus*, of the family Syngnathidae, which includes the pipefishes. The body is small and compressed and covered with bony plates raised into tubercles or spines. The tail is prehensile, and the tubular mouth sucks in small shellfish and larvae as food. The head and foreparts, usually carried upright, resemble those of a horse. They swim vertically and beat their fins up to 70 times a second.

Unusually for fish, sea horses are monogamous and have a relatively long courtship, from 3-7 days. The female deposits her eggs, from dozens to hundreds, in a special pouch in the male. The male fertilizes the eggs whilst they are in his pouch, and nourishes them for six weeks or so until they are finally released as young fish.

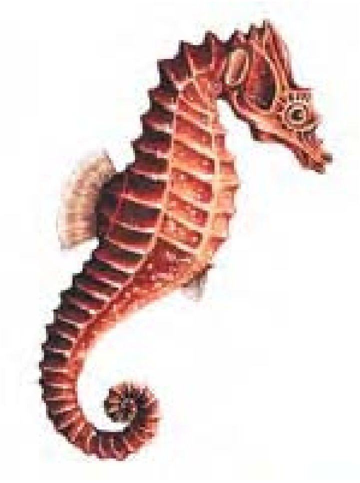
sea horse: largest

The largest sea horse is the Australian leafy sea horse, which grows to 30 cm/12 in.

sea horse: reproduction

In sea horses it is the male that carries the babies. The female deposits her eggs into his brood pouch, where he fertilizes them. They remain there for up to six weeks while he nourishes them till they reach independence.

sea horse



(Image © Research Machines plc)

The dwarf sea horse swims in an upright position, propelled by gentle movements of its dorsal fin. It is found in the western Atlantic Ocean from Florida to the Caribbean.

sea horse

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

Unlike most fish, the sea horse has a rigid body and cannot propel itself by oscillating from side to side. Instead, it uses its paired pectoral fins to travel, in jerky vertical motions. It normally has no need to go fast or far. Generally, the sea horse uses its prehensile tail to cling to weeds, choosing a place where there is a good supply of its staple food.

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seakale

perennial European coastal plant with broad, fleshy leaves and white flowers; it is cultivated in Europe and the young shoots are eaten as a vegetable. (*Crambe maritima*, family Cruciferae.)

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seal

aquatic carnivorous mammal of the families Otariidae and Phocidae (sometimes placed in a separate order, the Pinnipedia). The eared seals or sea lions (Otariidae) have small external ears, unlike the true seals (Phocidae). Seals have a streamlined body with thick blubber for insulation, and front and hind flippers. They are able to close their nostrils as they dive, and obtain oxygen from their blood supply while under water. They feed on fish, squid, or crustaceans, and are commonly found in Arctic and Antarctic seas, but also in Mediterranean, Caribbean, and Hawaiian waters.

seal

Because of the richness of seal milk, when seal pups are weaned at six weeks, their bodies are 45% fat.

Cape fur seal

(Image © Corel)

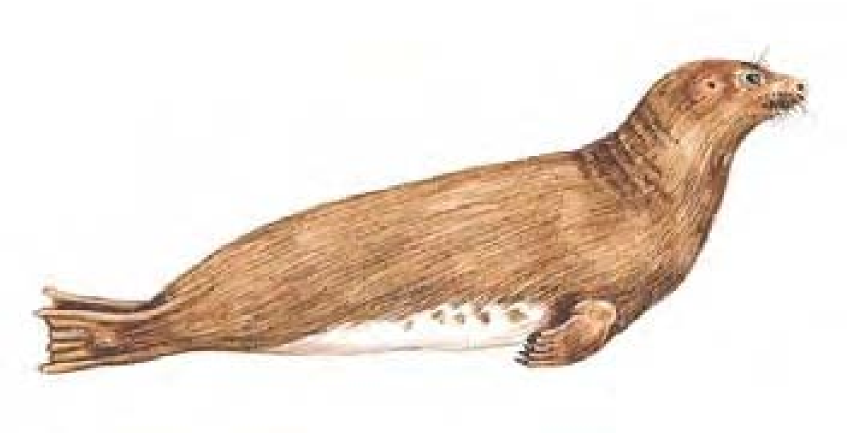
Cape fur seal. The adult male can weigh up to 200 kg/441 lb.

harp seal

(Image © Corel)

Harp seal *Phoca groenlandica* mother and pup. The Harp seal is a true seal and breeds in the north Atlantic and Arctic oceans. The adult seals grow to a length of nearly 2m/ 6.5ft and can weigh up to 180kg/ 400lb.

seal



(Image © Research Machines plc)

The Mediterranean monk seal breeds on remote rocky islets and cliffs of the eastern Atlantic. It has been found from the Canary Islands to the Mediterranean and along the Turkish coast to the Black Sea. The seals are easily upset by any disturbance, with pregnant females aborting, contributing to the decline of the species.

Elephant Seals

Go to site

Descriptions and images of northern and southern elephant seals. This site includes information about their appearance, distribution, feeding habits, and life history. There are also two useful bibliographies.

North Pacific Fur Seal

Go to site

Biology, distribution, and the effect of humans on the population of North Pacific fur seals. Once hunted to near extinction, the seals' greatest threat now is pollution.

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sea lily

any echinoderm of the class Crinoidea. In most, the rayed, cuplike body is borne on a sessile stalk (permanently attached to a rock) and has feathery arms in multiples of five encircling the mouth. However, some sea lilies are free-swimming and unattached.

---

sea lion

any of several genera of seals of the family Otariidae (eared seals), which also includes the fur seals. These streamlined animals have large fore flippers which they use to row themselves through the water. The hind flippers can be turned beneath the body to walk on land.

There are two species of sea lion in the northern hemisphere, and three in the south. They feed on fish, squid, and crustaceans.
Steller's sea lion *Eumetopias jubatus* lives in the North Pacific, large numbers breeding on the Aleutian Islands. Males may be up to 3.4 m/11 ft long, with a thick neck with a characteristic mane, and weigh up to one tonne. Females are one-third the weight. The **Californian sea lion** *Zalophus californianus* only reaches 2.3 m/7 ft, and is the species most often seen in zoos and as a 'performing seal'.

The **Australian sea lion** *Neophoca cinerea* is found only in southern Australian waters, especially on offshore islands such as Kangaroo Island. It is one of the larger sea lions; males weigh up to 300 kg/660 lb, three times as much as females, and are 2 m/6.5 ft long. The **New Zealand sea lion** *Phocarctos hookeri*, of similar size, is found mainly on Auckland Island, 322 km/200 mi south of New Zealand. It is the rarest sea lion, with only about 12,000 existing in 1998.

California Sea Lion

Go to site

Illustrated guide to the California sea lion including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

Sealyham

breed of terrier dog, named after the place in Pembrokeshire, Wales, where it originated in the 19th century as a cross between the Welsh and Jack Russell terriers. It has a coarse white coat and reaches a height of 30 cm/12 in.

sea mouse

any of a genus *Aphrodite* of large marine annelid worms (polychaetes), with oval bodies covered in bristles and usually found on muddy sea floors.

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seaplane

aeroplane capable of taking off from, and landing on, water. There are two major types, floatplanes and flying boats. The floatplane is similar to an ordinary aeroplane but has floats in place of wheels; the flying boat has a broad hull shaped like a boat and may also have floats attached to the wing tips.

Seaplanes depend on smooth water for a good landing, and since World War II few have been built, although they were widely used in both world wars and the first successful international airlines, such as Pan Am, relied on a fleet of flying boats in the 1920s and 1930s.

In 1998 a British firm produced a seaplane with a narrower, more streamlined hull, thus improving on the design that has remained relatively unchanged since World War II.

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sea potato

yellow-brown sea urchin *Echinocardium cordatum* covered in short spines, and found burrowing in sand from the lower shore downwards.

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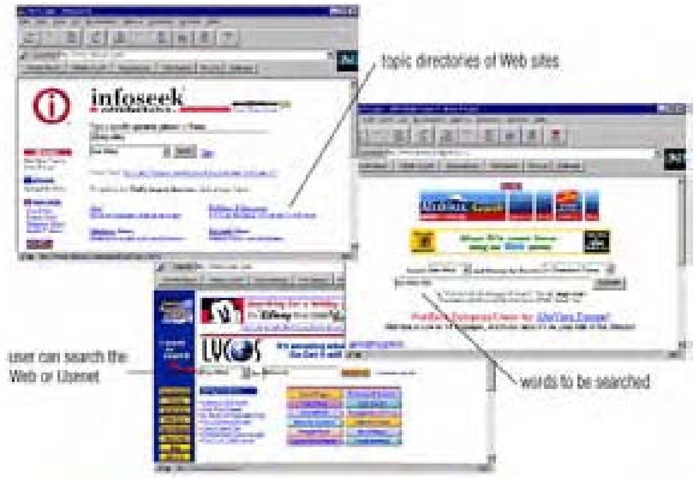
search engine

in computing, online program to help users find information on the Internet. Commercial search engines such as Google, Yahoo!, and Lycos comprise databases of documents, Usenet articles, images, and news stories, which can be searched by keying in a key word or phrase. The databases are compiled by a mixture of automated agents (spiders) and webmasters registering their sites.

US researchers estimate that about 500 times as much Web site information is hidden from search engines as is open to them. This is partly because many Web sites generate pages on request, filling in standard Web page templates with information from databases.

search engine


topic directories of Web sites
infoseek
LYCOS
user can search the Web or Usenet
words to be searched

(Image © Research Machines plc)

User interfaces of some typical Internet search engines. The user may search by a selection of keywords in particular subject areas.

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search for extraterrestrial intelligence

full name of SETI.

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searching

in computing, extracting a specific item from a large body of data, such as a file or table. The method used depends on how the data are organized. For example, a binary search, which requires the data to be in sequence, involves first deciding which half of the data contains the required item, then which quarter, then which eighth, and so on until the item is found.

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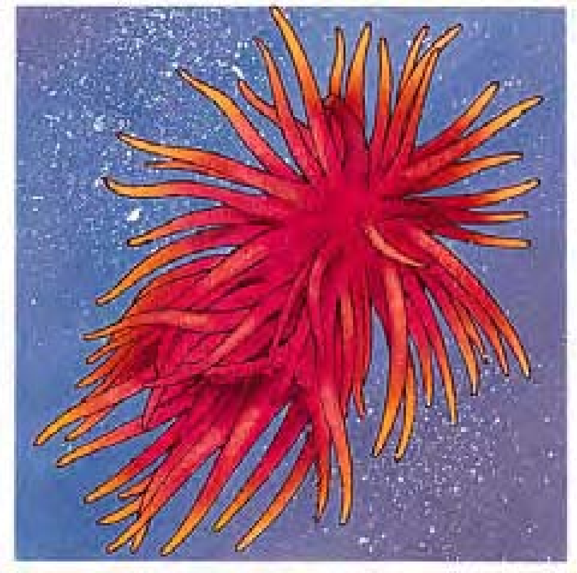
sea slug

any of an order (Nudibranchia) of marine gastropod molluscs in which the shell is reduced or absent. The order includes some very colourful forms, especially in the tropics. They are largely carnivorous, feeding on hydroids and sponges.

Most are under 2.5 cm/1 in long, and live on the sea bottom or on vegetation, although some live in open waters. Tentacles on the back help take in oxygen.

sea slug



(Image © Research Machines plc)

Sea slugs are molluscs related to snails, with a reduced or absent shell. Their bright coloration warns predators that they contain poisons and are distasteful.

---

sea snake

one of a number of aquatic venomous snakes. Their tails are compressed laterally, and form powerful swimming organs. The eyes are extremely small, have round pupils, and the snakes are practically blind when out of water. The poison secreted by the animals is very virulent, and is used by them to kill the fish on which they feed.

All the species are viviparous (the young develop inside the mother), and inhabit the Indian and Pacific Oceans. A considerable number of human deaths each year are caused by these animals, particularly in the Indian Ocean.

classification

Sea snakes are all members of family Hydrophiidae, order Squamata, class Reptilia.

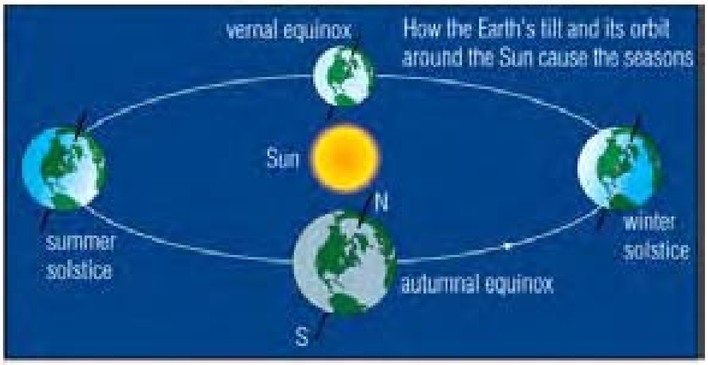
---

season

period of the year having a characteristic climate. The change in seasons is mainly due to the Earth's axis being tilted in relation to the Sun, and hence the position of the Sun in the sky at a particular place changes as the Earth orbits the Sun.

When the northern hemisphere is tilted away from the Sun (winter) the Sun's rays have further to travel through the atmosphere (they strike the Earth at a shallower angle) and so have less heating effect, resulting in colder weather. The days are shorter and the nights are longer. At the same time, the southern hemisphere is tilted towards the Sun (summer) and experiences warmer weather, with longer days and shorter nights. The opposite occurs when the northern hemisphere is tilted towards the Sun and the southern hemisphere away from the Sun.

season


vernal equinox
How the Earth's tilt and its orbit around the Sun cause the seasons
Sun
N
summer solstice
winter solstice
autumnal equinox
S

(Image © Research Machines plc)

The cause of the seasons. As the Earth orbits the Sun, its axis of rotation always points in the same direction. This means that, during the northern hemisphere summer solstice (usually 21 June), the Sun is overhead in the northern hemisphere. At the northern hemisphere winter solstice (usually 22 December), the Sun is overhead in the southern hemisphere.

Seasons

Times are for the northern hemisphere in Greenwich Mean Time (GMT).

2006	
Vernal equinox (spring begins)	20 March (18:26)
Summer solstice (summer begins)	21 June (12:26)
Autumnal equinox (autumn begins)	23 September (04:03)
Winter solstice (winter begins)	21 December (00:22)
2007	
Vernal equinox (spring begins)	21 March (00:07)
Summer solstice (summer begins)	21 June (18:06)
Autumnal equinox (autumn begins)	23 September (09:51)
Winter solstice (winter begins)	22 December (06:08)
2008	
Vernal equinox (spring begins)	20 March (05:48)
Summer solstice (summer begins)	20 June (23:59)
Autumnal equinox (autumn begins)	23 September (09:51)
Winter solstice (winter begins)	21 December (12:04)
2009	
Vernal equinox (spring begins)	20 March (11:44)
Summer solstice (summer begins)	21 June (05:45)
Autumnal equinox (autumn begins)	22 September (21:18)
Winter solstice (winter begins)	21 December (17:47)
2010	
Vernal equinox (spring begins)	20 March (17:32)
Summer solstice (summer begins)	21 June (11:28)
Autumnal equinox (autumn begins)	23 September (03:09)
Winter solstice (winter begins)	21 December (23:38)
2011	
Vernal equinox (spring begins)	20 March (23:21)
Summer solstice (summer begins)	21 June (17:16)
Autumnal equinox (autumn begins)	23 September (09:04)
Winter solstice (winter begins)	22 December (05:30)
2012	
Vernal equinox (spring begins)	20 March (05:14)
Summer solstice (summer begins)	20 June (23:09)
Autumnal equinox (autumn begins)	22 September (14:49)
Winter solstice (winter begins)	21 December (11:11)
2013	
Vernal equinox (spring begins)	20 March (11:02)
Summer solstice (summer begins)	21 June (05:46)
Autumnal equinox (autumn begins)	22 September (20:44)
Winter solstice (winter begins)	21 December (17:11)
2014	

Vernal equinox (spring begins)	20 March (16:57)
Summer solstice (summer begins)	21 June (10:51)
Autumnal equinox (autumn begins)	23 September (02:29)
Winter solstice (winter begins)	21 December (23:03)

Earth's Seasons: Equinoxes, Solstices, Perihelion, and Aphelion

Go to site

Part of a larger site on astronomical data maintained by the US Naval Observatory, this site gives the dates and hours (in Universal Time) of the changing of the seasons from 1992 through to 2005. It also includes sections of 'Frequently Asked Questions' and research information.

seasonal affective disorder

SAD

form of depression that occurs in winter and is relieved by the coming of spring. Its incidence decreases closer to the Equator. One type of SAD is associated with increased sleeping and appetite.

SAD is linked to the circadian clock (see circadian rhythm) mechanism, which not only adjusts our physiological rhythm to day length but also measures day length and thereby senses the change of season. Melatonin, a hormone produced by the pineal body in the brain during the normal sleeping hours has also been linked to SAD. Melatonin secretion is inhibited by bright daylight. Thus, bright lights can be used to treat SAD.

Seasonal Light - SAD Home Page

Go to site

Thorough source of support for SAD (seasonal affective disorder) sufferers and those treating them. The site includes information about this form of depression as well as reference to books, and articles. There is information on seasonal light device manufacturers and contacts for self help - 'walkers in darkness' - groups in the UK.

sea squirt

or tunicate

any solitary or colonial-dwelling saclike chordate of the class Ascidiacea. A pouch-shaped animal attached to a rock or other base, it draws in food-carrying water through one siphon and expels it through another after straining it through numerous gill slits. The young are free-swimming tadpole-shaped organisms, which, unlike the adults, have a notochord.

Sea squirts have transparent or translucent tunics made of cellulose. They vary in size from a few millimetres to 30 cm/12 in in length and are cylindrical, circular, or irregular in shape. Their defences against predators include sulphuric acid secretion and the accumulation of vanadium, a toxic heavy metal.

sea urchin

any of various orders of the class Echinoidea among the echinoderms. They all have a globular body enclosed with plates of lime and covered with spines. Sometimes the spines are anchoring organs, and they also assist in locomotion. Sea urchins feed on seaweed and the animals frequenting them, and some are edible, as is their roe.

seaweed

any of a vast group of simple multicellular plant forms belonging to the algae group, and found growing in the sea, brackish estuaries, and salt marshes, from near the high-tide mark to depths of 100-200 m/300-600 ft. Many seaweeds have holdfasts (attaching them to rocks or other surfaces), stalks, and fronds, sometimes with air bladders to keep them afloat, and are green, blue-green, red, or brown.

Worldwide there are approximately 2,000 species of brown macroalgae (Phaecophyceae), 5,500 reds (Rhodophyceae), and 1,200 greens (Chlorophyceae), most of which are marine. Some have traditionally been gathered for food, such as purple laver (*Porphyra umbilicalis*, which is used by the Japanese to make sushi), green laver (*Ulva lactuca*), and carragheen (*Chondrus crispus*). From the 1960s, seaweeds have been farmed, and the alginates (salts) that are extracted are used in convenience foods, ice cream, and animal feeds, as well as in toothpaste, soap, and the manufacture of iodine and glass.

seaweed

(Image © Research Machines plc)

Seaweed being harvested for commercial use. Generally growing in shallow water, where sunlight is able to reach, seaweed is relatively easy to gather. The purple laver, dulse, brown gulfweed, and the green laver (or sea lettuce) are among the seaweeds harvested for food. Other varieties such as kelp are used in fertilizers, while *Gelidium* is used to make agar (a thickening agent used in the food industry).

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sebum

oily secretion from the sebaceous glands that acts as a skin lubricant. Acne is caused by inflammation of the sebaceous glands and over-secretion of sebum.

---

sec

or s

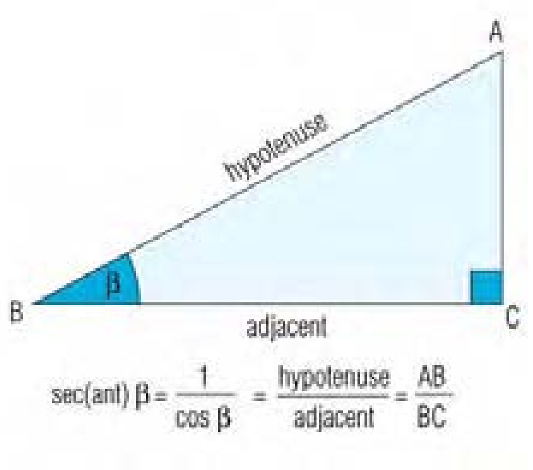
abbreviation for **second**, a unit of time.

---

secant

in trigonometry, the function of a given angle in a right-angled triangle, obtained by dividing the length of the hypotenuse (the longest side) by the length of the side adjacent to the angle. It is the reciprocal of the cosine (sec = 1/cos).

secant


A
hypotenuse
β
B
adjacent
C
$\sec(\mathrm{ant})\,\beta = \frac{1}{\cos\beta} = \frac{\text{hypotenuse}}{\text{adjacent}} = \frac{AB}{BC}$

(Image © Research Machines plc)

The secant of an angle is a trigonometrical function. If the secant of angle B is known, then the hypotenuse can be found given the length of the adjacent side, or the adjacent side can be found from the hypotenuse.

---

second

symbol sec or s

basic SI unit of time, one-sixtieth of a minute. It is defined as the duration of 9,192,631,770 cycles of regulation (periods of the radiation corresponding to the transition between two hyperfine levels of the ground state) of the caesium-133 isotope. In mathematics, the second is a unit (symbol ") of angular measurement, equalling one-sixtieth of a minute, which in turn is one-sixtieth of a degree.

secondary data

information that has been collected by another agency. Examples of secondary data include government reports and statistics, company reports and accounts, and weather reports in newspapers.

secondary emission

emission of electrons from the surface of certain substances when they are struck by high-speed electrons or other particles from an external source. It can be detected with a photomultiplier.

secondary growth

or secondary thickening

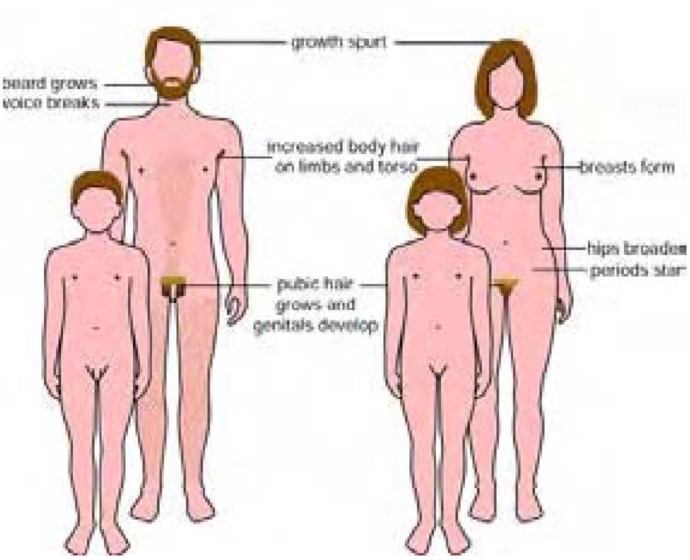
increase in diameter of the roots and stems of certain plants (notably shrubs and trees) that results from the production of new cells by the cambium. It provides the plant with additional mechanical support and new conducting cells, the secondary xylem and phloem. Secondary growth is generally confined to gymnosperms and, among the angiosperms, to the dicotyledons. With just a few exceptions, the monocotyledons (grasses, lilies) exhibit only primary growth, resulting from cell division at the apical meristems.

secondary sexual characteristic

external feature of an organism that is indicative of its gender (male or female), but not the reproductive organs themselves. They include facial hair in men and breasts in women, combs in cockerels, brightly coloured plumage in many male birds, and manes in male lions. In many cases, they are involved in displays and contests for mates and have evolved by sexual selection. Their development is stimulated by sex hormones - in humans the change in concentrations of these hormones at puberty results not only in the development of the physical secondary sexual characteristics, but also emotional changes.

In humans the development of secondary sexual characteristics is stimulated at puberty by the hormone oestrogen in women and testosterone in men. Testosterone is produced in the testes of males, while oestrogen and progesterone are produced in the ovaries of females. Women develop breasts and wider hips; men develop a deeper voice, body and facial hair, and stronger body odour; and both develop hair in underarm and genital regions. However, at puberty the reproductive organs also mature as a consequence of growth and changes in circulating hormones, ready for sexual reproduction.

secondary sexual characteristic



(Image © Research Machines plc)

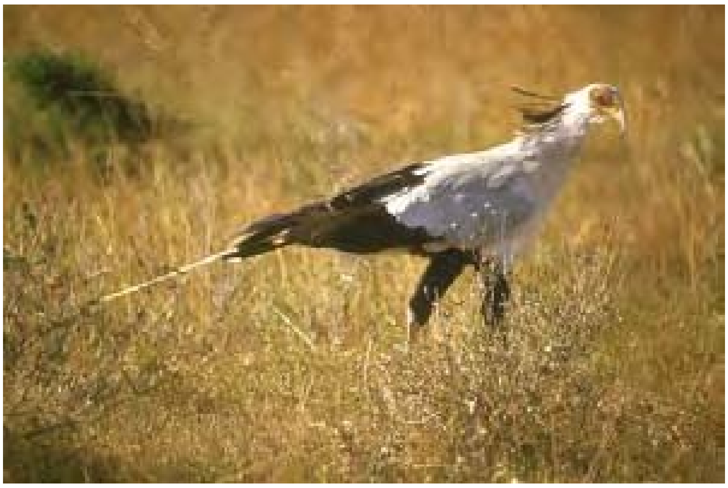
The secondary sexual characteristics. At puberty in both sexes, there is a growth spurt, an increase in body hair, the development of pubic hair, and increase in genital size. In females breasts develop, hips broaden, and periods start. In males the voice breaks and facial hair develops.

secretary bird

ground-hunting, long-legged, mainly grey-plumaged bird of prey *Sagittarius serpentarius*. It is about 1.2 m/4 ft tall, with an erectile head crest tipped with black. It is protected in southern Africa because it eats poisonous snakes.

It gets its name from the fact that its head crest supposedly looks like a pen behind a clerk's ear. It is the only member of the family Sagittariidae, in the same order (Falconiformes) as vultures, eagles, and hawks.

secretary bird



(Image © Corel)

The secretary bird *Sagittarius serpentarius* feeds mainly on snakes and lizards, and inhabits the dry uplands regions of Africa. This individual was photographed in Kenya.

Secretary Bird

Go to site

Information about the secretary bird, with concise descriptions of its African habitat, physical characteristics, reproduction, social habits, diet, and conservation status. The page is illustrated with a colour photograph of the bird.

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secretin

hormone produced by the small intestine of vertebrates that stimulates the production of digestive secretions by the pancreas and liver.

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secretion

in biology, any substance (normally a fluid) produced by a cell or specialized gland, for example, sweat, saliva, enzymes, and hormones. The process whereby the substance is discharged from the cell is also known as secretion.

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sector

in geometry, part of a circle enclosed by two radii and the arc that joins them. A **minor sector** has an angle at the centre of the circle of less than 180°. A **major sector** has an angle at the centre of the circle of more than 180°.

The area of a sector is found by dividing the angle at the centre by 360 and multiplying by πr^2, where r is the radius of the circle.

---

sedan chair

enclosed chair for one passenger carried on poles by two or more bearers. Introduced into England by Sanders Duncombe in 1634, by the 18th century it was the equivalent of a one-person taxi. The name derives from an Italian dialect word for seat, rather than from the French town of Sedan.

---

sedative

any drug that has a calming effect, reducing anxiety and tension.

Sedatives in larger doses will induce sleep. Examples are barbiturates, narcotics, and benzodiazepines. Overdoses can be fatal.

---

sedge

any of a group of perennial grasslike plants, usually with three-cornered solid stems, common in low water or on wet and marshy ground. (Genus *Carex*, family Cyperaceae.)

sedge

To tell the difference between grasses and sedges:

'Sedges have edges'. Unlike grasses, sedges have three-sided stems in cross-section; also, sedges grow in wet spots, often along marsh edges whereas grasses prefer drier upland areas

---

sediment

any loose material that has 'settled' after deposition from suspension in water, ice, or air, generally as the water current or wind speed decreases. Typical sediments are, in order of increasing coarseness: clay, mud, silt, sand, gravel, pebbles, cobbles, and boulders.

Sediments differ from sedimentary rocks, in which deposits are fused together in a solid mass of rock by a process called lithification (solidification). Pebbles are cemented into conglomerates; sands become sandstones; muds become mudstones or shales; peat is transformed into coal.

---

sedimentary rock

rock formed by the accumulation and cementation of deposits that have been laid down by water, wind, ice, or gravity. Sedimentary rocks cover more than two-thirds of the Earth's surface and comprise three major categories: clastic, chemically precipitated, and organic (or biogenic). Clastic sediments are the largest group and are composed of fragments of pre-existing rocks; they include clays, sands, and gravels.

Chemical precipitates include some limestones and evaporated deposits such as gypsum and halite (rock salt). Coal, oil shale, and limestone made of fossil material are examples of organic sedimentary rocks.

Most sedimentary rocks show distinct layering (stratification), because they are originally deposited as more or less horizontal layers.

sedimentary rock

(Image © Garret Nagle)

Behind the wire mesh is bare sedimentary rock, exposed by weathering. Many cliff faces remain steep due to rapid breakdown. Weathering of the rock followed by rock falls (a type of mass movement) help to preserve a steep incline. In this picture, layers of sediment in the rock are clearly visible.

Composition of sedimentary rocks

Rock	Type	Composition
arkose	medium mechanical	silicon dioxide with aluminosilicate
breccia	coarse mechanical	angular rock fragments
chert	siliceous	silicon dioxide
coal	carbonaceous	mostly carbon
conglomerate	coarse mechanical	angular rock fragments
dolomite	calcareous	calcium and magnesium carbonate
flint	siliceous	silicon dioxide
greywacke	medium mechanical	silicon dioxide with aluminosilicate
grit	medium mechanical	silicon dioxide
gypsum	saline	calcium sulphate
ironstone	ferruginous	iron mineral and calcium carbonate
mudstone	fine mechanical	clay minerals
oolitic limestone	calcareous	calcium carbonate
rock phosphate	phosphatic	calcium phosphate
rock salt	saline	sodium chloride
sandstone	medium mechanical	silicon dioxide
shale	fine mechanical	clay minerals
siltstone	fine mechanical	clay minerals with silicon dioxide
tillite	coarse mechanical	rock fragments in shale or slate
travertine	calcareous	calcium carbonate

Seebeck effect

generation of a voltage in a circuit containing two different metals, or semiconductors, by keeping the junctions between them at different temperatures. Discovered by the German physicist Thomas Seebeck (1770–1831), it is also called the thermoelectric effect, and is the basis of the thermocouple. It is the opposite of the Peltier effect (in which current flow causes a temperature difference between the junctions of different metals).

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seed

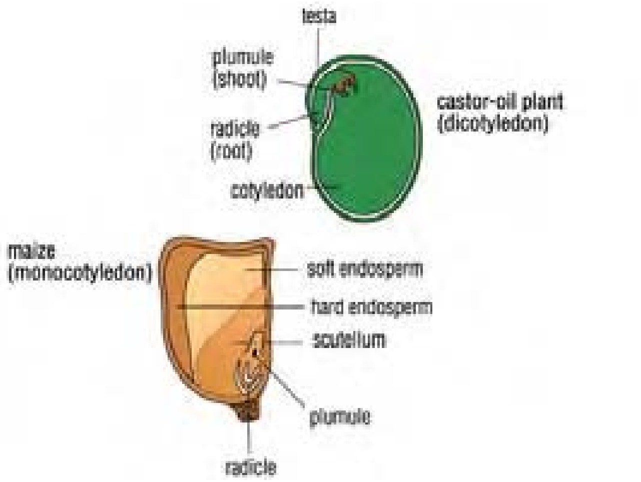
reproductive structure of higher plants (angiosperms and gymnosperms). It develops from a fertilized ovule and consists of an embryo and a food store, surrounded and protected by an outer seed coat, called the testa. The food store is contained either in a specialized nutritive tissue, the endosperm, or in the cotyledons of the embryo itself. In angiosperms the seed is enclosed within a fruit, whereas in gymnosperms it is usually naked and unprotected, once shed from the female cone.

Following germination the seed develops into a new plant.

Seeds may be dispersed from the parent plant in a number of different ways. Agents of dispersal include animals, as with burs and fleshy edible fruits, and wind, where the seed or fruit may be winged or plumed. Water can disperse seeds or fruits that float, and various mechanical devices may eject seeds from the fruit, as in the pods of some leguminous plants (see legume).

There may be a delay in the germination of some seeds to ensure that growth occurs under favourable conditions (see after-ripening, dormancy). Most seeds remain viable for at least 15 years if dried to about 5% water and kept at -20°C/-4°F, although 20% of them will not survive this process.

seed



(Image © Research Machines plc)

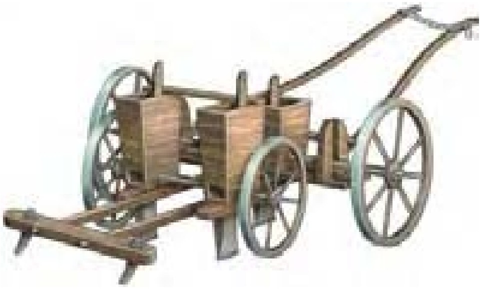
The structure of seeds. The castor is a dicotyledon, a plant in which the developing plant has two leaves, developed from the cotyledon. In maize, a monocotyledon, there is a single leaf developed from the scutellum.

seed drill

machine for sowing cereals and other seeds, developed by Jethro Tull in England in 1701, although simple seeding devices were known in Babylon in 2000 BC.

The seed is stored in a hopper and delivered by tubes into furrows in the ground. The furrows are made by a set of blades, or coulters, attached to the front of the drill. A harrow is drawn behind the drill to cover up the seeds.

seed drill



(Image © Research Machines plc)

English agriculturist Jethro Tull invented the mechanized seed drill in about 1701. The sowing of seeds in uniform rows allowed weeding between the rows of seedlings during growth, so improving the yield. Previously seeds had been broadcast by hand across the land.

seed plant

any seed-bearing plant; also known as a **spermatophyte**.

The seed plants are subdivided into two classes: the angiosperms, or flowering plants, and the gymnosperms, principally the cycads and conifers.

Together, they comprise the major types of vegetation found on land.

Angiosperms are the largest, most advanced, and most successful group of plants, occupying a highly diverse range of habitats. There are estimated to be about 250,000 different species. Gymnosperms differ from angiosperms in their ovules which are borne unprotected (not within an ovary) on the scales of their cones.

The arrangement of the reproductive organs, and their more simplified internal tissue structure, also distinguishes them from the flowering plants. In contrast to the gymnosperms, the ovules of angiosperms are enclosed within an ovary and many species have developed highly specialized reproductive structures associated with pollination by insects, birds, or bats.

segment

in geometry, part of a circle cut off by a straight line or chord, running from one point on the circumference to another. All angles in the same segment are equal.

seiche

pendulous movement seen in large areas of water resembling a tide. It was originally observed on Lake Geneva and is created either by the wind, earth tremors or other atmospheric phenomena.

seismic wave

energy wave generated by an earthquake or an artificial explosion. There are two types of seismic waves: **body waves** that travel through the Earth's interior; and **surface waves** that travel through the surface layers of the crust and can be felt as the shaking of the ground, as in an earthquake.

Seismic waves show similar properties of reflection and refraction as light and sound waves. Seismic waves change direction and speed as they travel through different densities of the Earth's rocks.

body waves

There are two types of body waves: P-waves and S-waves, so-named because they are the primary and secondary waves detected by a seismograph.
P-waves, or compressional waves, are longitudinal waves (wave motion in the direction the wave is travelling), whose compressions and rarefactions resemble those of a sound wave.
S-waves are transverse waves or shear waves, involving a back-and-forth shearing motion at right angles to the direction the wave is travelling (see wave).

Because liquids have no resistance to shear and cannot sustain a shear wave, S-waves cannot travel through liquid material. The Earth's outer core is believed to be liquid because S-waves disappear at the mantle-core boundary, while P-waves do not.

surface waves

Surface waves travel in the surface and subsurface layers of the crust.
Rayleigh waves travel along the free surface (the uppermost layer) of a solid material. The motion of particles is elliptical, like a water wave, creating the rolling motion often felt during an earthquake.
Love waves are transverse waves trapped in a subsurface layer due to different densities in the rock layers above and below. They have a horizontal side-to-side shaking motion transverse (at right angles) to the direction the wave is travelling.

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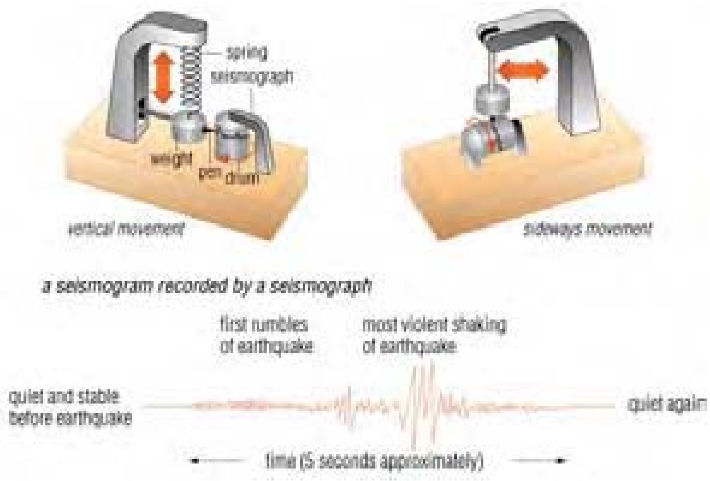
seismograph

instrument used to record ground motion. A heavy inert weight is suspended by a spring and attached to this is a pen that is in contact with paper on a rotating drum. During an earthquake the instrument frame and drum move, causing the pen to record a zigzag line on the paper; held steady by inertia, the pen does not move.

seismograph


spring
seismograph
weight
pen
drum
vertical movement
sideways movement
a seismogram recorded by a seismograph
first rumbles of earthquake
most violent shaking of earthquake
quiet and stable before earthquake
quiet again
time (5 seconds approximately)

(Image © Research Machines plc)

A seismogram, or recording made by a seismograph. Such recordings are used to study earthquakes and in prospecting.

---

seismology

study of earthquakes, the seismic waves they produce, the processes that cause them, and the effects they have. By examining the global pattern of waves produced by an earthquake, seismologists can deduce the nature of the materials through which they have passed. This leads to an understanding of the Earth's internal structure.

On a smaller scale, artificial earthquake waves, generated by explosions or mechanical vibrators, can be used to search for subsurface features in, for example, oil or mineral exploration. Earthquake waves from underground nuclear explosions can be distinguished from natural waves by their shorter wavelength and higher frequency.

Seismology: Earthquake Prediction

earthquakes: advances in prediction and protection

1990 saw a number of earthquakes around the world, including the devastating Iranian earthquakes in June which measured 7.7 on the Richter scale and cost 50,000 lives. Earthquakes are caused by movement along faults, and so they are more frequent in regions that are known to have a great deal of fault activity - particularly areas close to the boundaries of the Earth's tectonic plates. Iran lies on the boundary between the Arabian and the Asian plates and so such an earthquake was not surprising. Other earthquakes, however, occurred in regions not known for earthquake activity, such as Missouri in the USA on 26 Sept 1990 and the Welsh borders and Sheffield in the UK on 2 April and 8 Feb 1990, respectively. Research conducted at the US Geological Survey's National Earthquake Information Center in Colorado, and the US Geological Survey Seismic Observatory in Virginia suggests that a big earthquake occurring in an area not traditionally prone to earthquakes could cause much more damage than one in the more earthquake-susceptible regions such as California. Historical statistics show that a big earthquake in the central and eastern part of the continent is about two-thirds as likely as one in California over the next 30 years. East of the Rockies the continental rocks are old and strong. They transmit shock waves much more efficiently. Should an earthquake disrupt them the effect will be felt over a much larger area than in the shattered faulted rocks of the west. Besides that, buildings of the east tend not to be designed with possible earthquake damage in mind.

how buildings can be protected from earthquakes

A tall building whips back and forth with the vibration of an earthquake. If the dimensions of the building are such that the speed of the whipping action happens to be 'tuned' to the vibration of the earthquake, then the whipping builds up and the building collapses. The earthquake vibration depends largely on the nature of the surface on which the foundations are set, and so nowadays the vibration characteristics of the underlying soil are taken into account before a building is designed. A design feature that is under investigation by the University of California's Earthquake Engineering Research Center in San Francisco is that of 'base isolation'. The theory is that the building is separated from its foundations by bearings or rubber joints that absorb much of the earthquake shock before it reaches the building itself. Another idea, being pursued by the National Center for Earthquake Research at the State University of New York, involves encasing the building with wire mesh covered with cement. This would prevent the wall components, like bricks or blocks, from sliding sideways in relation to one another during the shaking. More highly technological techniques are being tried out in Japan. These involve computerized sets of sensors in the basement that analyse the earthquake's vibration and instantaneously transmit the results to pistons and counterweights throughout the building. These continually adjust the building's loading and reduce the stresses in the structure.

earthquake prediction

The science of earthquake proofing is developing swiftly, but that of earthquake prediction less so. One development is the discovery, by Stanford University, that very low frequency radio waves passing through rocks change their amplitude a few hours before an earthquake. This may be due to electrical currents generated by pressure in the rocks, or it may be related to the opening of microscopic cracks as the rocks begin to fail. Possibly related to this is the discovery by Japanese researchers that electromagnetic radiation is emitted by rocks immediately prior to an earthquake. Up to now this has not been useful, as there was no way to tell the difference between this radiation and that produced by the Earth's ionosphere or by industry. Two researchers, Takahashi and Fijinawa, have managed to distinguish the horizontal electrical fields generated by ionospheric radiation from the vertical fields produced by the rocks, and have eliminated the artificial interference by siting their instruments far from cities and industry. Since their installation in March 1989 the instruments have recorded changes in radiation several hours before earthquakes on 5, 9, and 13 July 1990. A National Center for Earthquake Engineering Research investigator at the State University of New York at Buffalo, monitors performance of a structure subjected to earthquake vibrations on the university's 'shake table'. The three-storey steel-frame structure is equipped with active tendon controls which give the model human-like ability to counter earthquake forces.

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selective serotonin-reuptake inhibitor

SSRI

in medicine, one of a group of drugs that prevent the uptake of serotonin in neurones, resulting in an increase in its concentration in the brain. They are used in the treatment of depression. Fluoxetine (Prozac) is an example of a commonly prescribed selective serotonin-reuptake inhibitor.

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selenium

chemical symbol Se

(Greek Selene 'Moon')

grey, non-metallic element, atomic number 34, relative atomic mass 78.96. It belongs to the sulphur group and occurs in several allotropic forms that differ in their physical and chemical properties. It is an essential trace element in human nutrition.

Obtained from many sulphide ores and selenides, it is used as a red colouring for glass and enamel.

Because its electrical conductivity varies with the intensity of light, selenium is used extensively in photoelectric devices. It was discovered in 1817 by Swedish chemist Jöns Berzelius and named after the Moon because its properties follow those of tellurium, whose name derives from Latin *Tellus* 'Earth'.

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self-inductance

or self-induction

in physics, the creation of an electromotive force opposing the current. See inductance.

Sellafield

site of a nuclear power station on the coast of Cumbria, northwest England. It was known as **Windscale** until 1971, when the management of the site was transferred from the UK Atomic Energy Authority to

British Nuclear Fuels Ltd. It reprocesses more than 1,000 tonnes of spent fuel from nuclear reactors annually. The plant is the world's greatest discharger of radioactive waste: between 1968 and 1979, 180 kg/400 lb of plutonium was discharged into the Irish Sea. According to a report by Britain's nuclear safety watchdog, the Nuclear Installations Inspectorate (NII), published in January 1999, the storage facilities, which store 65 tonnes (25%) of the world's civilian plutonium, are in poor structural condition presenting a significant hazard risk of leakage.

In 1996, British Nuclear Fuels was fined £25,000 after admitting 'serious and significant' failures in safety that left a Sellafield plant worker contaminated with radioactivity.

In 1998, the Norwegian environment minister called for a ban on the release of technetium-99 into the sea. It is being released from Sellafield and causing raised concentrations along the coast of Norway.

For accidents, see nuclear safety.

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selva

equatorial rainforest, such as that in the Amazon basin in South America.

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semelparity

in biology, the occurrence of a single act of reproduction during an organism's lifetime. Most semelparous species produce very large numbers of offspring when they do reproduce, and normally die soon afterwards. Examples include the Pacific salmon and the pine looper moth. Many plants are semelparous, or monocarpic. Repeated reproduction is called iteroparity.

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semen

see sperm.

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semiconductor

material with electrical conductivity intermediate between metals and insulators and used in a wide range of electronic devices. Certain crystalline materials, most notably silicon and germanium, have a small number of free electrons that have escaped from the bonds between the atoms. The atoms from which they have escaped possess vacancies, called holes, which are similarly able to move from atom to atom and can be regarded as positive charges. Current can be carried by both electrons (negative carriers) and holes (positive carriers). Such materials are known as **intrinsic semiconductors**.

Conductivity of a semiconductor can be enhanced by doping the material with small numbers of impurity atoms which either release free electrons (making an **n-type semiconductor** with more electrons than holes) or capture them (a **p-type semiconductor** with more holes than electrons). When p-type and n-type materials are brought together to form a p-n junction, an electrical barrier is formed that conducts current more readily in one direction than the other. This is the basis of the semiconductor diode, used for rectification, and numerous other devices including transistors, rectifiers, and integrated circuits (silicon chips).

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semiconductor diode

or p-n junction diode

in electronics, a two-terminal semiconductor device that allows electric current to flow in only one direction, the **forward-bias** direction. A very high resistance prevents current flow in the opposite, or **reverse-bias**, direction. It is used as a rectifier, converting alternating current (AC) to direct current (DC).

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senile dementia

dementia associated with old age, often caused by Alzheimer's disease.

The Ageing Brain and Alzheimer's Disease

introduction

'Omnia fert aetas, animum quoque; saepe ego longas cantando puerum memini me condere soles: nunc oblita mihi tot carmina)' 'Time wastes all things, the mind too: often I remember how in boyhood I outwore long sunlit days in singing: now I have forgotten so many a song)' (Virgil, 'Eclogue IX', translation by Mackail)

background

Was Virgil right? Is it really true that dementia, a decline in our mental and cognitive functions illustrated here by a declining memory, is an inevitable part of ageing? If so, then we will soon be facing a very serious problem because the world's population is ageing rapidly as advances in medicine, surgery and nutrition help to extend the human lifespan. The future demographic predictions are alarming. Between 1990 and 2030 the proportion of people over 60 will grow by about 75% in OECD countries, with a dramatic rise of almost 100% in Japan. It has been known for a long time that the incidence of dementia increases with age, so we can expect the proportion with dementia to increase by similar amount. Dementia, of which Alzheimer's disease is by far the most common cause, is a dreadful devastation of the human mind and spirit; it involves a progressive loss of those very features that make us human: the mind, normal behaviour and even our very personality disintegrates. Modern medicine has followed Virgil in the view that dementia is an inevitable consequence of the ageing of the brain. However, recent discoveries have cast serious doubt on this view and have led to a different idea, that dementia is a true disease, which, if its causes can be identified, should be possible to treat or even to prevent. In other words, to understand dementia we do not have to unravel the secrets of ageing but should consider it just like any other common disease such as cancer, heart disease or diabetes.

first recorded case

Alzheimer's disease (AD) was first described in a woman in her 50s by Alois Alzheimer in 1907. He examined the brain after she died and found in the microscope two kinds of structures that were stained by silver salts. One is called the amyloid plaque and lies outside the cells, while the other is called the neurofibrillary tangle and is found mainly within nerve cells in the cerebral cortex. Both these silver-staining structures are composed of highly insoluble proteins in a fibrillar form. The amyloid plaque is mainly composed of a protein called beta-amyloid peptide which has 40-43 amino acid residues per molecule but which is normally completely insoluble because the individual molecules aggregate together to form fibrils. The protein that makes up the neurofibrillary tangle is different and is derived from a protein called tau whose normal function is to stabilize the microtubules in the nerve's axon, so maintaining the function of this long process of the nerve cell.

early research

Most research into dementia has concentrated on these two proteins and on the question: 'What causes them to accumulate in the brain in people with AD?' However, it has been realized that the deposition of these proteins might not be the primary cause of the symptoms of dementia; perhaps they are the end products of a process that is more closely related to the loss of normal functioning of the brain. This process is in fact the loss of nerve cells and, in particular, the loss of the connections between nerve cells that occur at synapses. The long nerve fibres in the cerebral cortex that pass from one part of the cortex to another die back in AD and so the different functional parts of the cortex are no longer connected to each other. The disease first strikes in the part of the brain that is known to be crucial for memory, the medial temporal lobe which lies deep in the middle of the brain. Nerve cells in some parts of the medial temporal lobe (the hippocampus) die earliest, so that more than 70% of them have disappeared by the time the patient dies. This process of continual death of nerve cells (neurodegeneration) can be followed in life by a simple brain scan, using computed tomography or magnetic resonance imaging. The loss of tissue in the medial temporal lobe occurs at 15% per year and correlates very well with the decline in cognitive function as measured by standard neuropsychological tests. No such rapid loss of tissue occurs with normal ageing and healthy individuals followed each year also show no obvious loss in cognitive function. It is likely that the finding that old people on average have a lower performance in some cognitive tests is mainly explained by the fact that any group of elderly people will include some in whom AD has already begun even though the symptoms are not readily detected.

importance of the nerve cells

The nerve cells of the medial temporal lobe are connected to almost all other parts of the cerebral cortex and must serve some kind of integrative role, such as the consolidation of memory. The loss of these connections as the neurons die may be one of the causes of the different symptoms of AD, which arise from abnormal functioning of different parts of the cortex. The death of nerve cells in the medial temporal lobe is accompanied by the death of another small group of nerve cells that lie in the basal nucleus of the forebrain. These basal forebrain neurons make the transmitter called acetylcholine and their main function is to regulate all parts of the cerebral cortex. The only available current treatments for AD act by inhibiting the enzyme that normally destroys acetylcholine, but they are not very effective and they do not slow down the progression of the disease. What is this disease process that strikes at nerve cells in the middle of the cerebral cortex and in the base of the forebrain? Why are these nerve cells particularly vulnerable? These are crucial questions for current research. If we can find the answers to these questions we should be able to devise drugs that slow down or stop the death of cells from occurring and so slow down the decline in cognitive function. There are several current views about what causes the nerve cells to die. One is that the cells are killed by the accumulation of beta-amyloid, and it has indeed been found that beta-amyloid peptide is toxic to nerve cells under certain circumstances. However, the paradox is that amyloid plaques occur most densely in parts of the brain where relatively few cells die. Nevertheless, several of the next generation of drugs being developed for AD are based on the view that if we can stop beta-amyloid being generated from its precursor protein (amyloid precursor protein) then we may be able to slow down progression of the disease. Another view is that the nerve cells die because they are 'strangled' from within by the accumulation of abnormal tau protein. Again, if ways can be found to prevent this from occurring then the disease might be treatable. A third view is that the nerve cells die because there is an excessive production of free radicals in the brain. Free radicals are molecules that have an extra electron and so they are very reactive and combine readily with many of the cell's important proteins. The consequence is that the protein's normal functioning is disturbed. Because free radicals are so reactive, they cannot readily be detected in brain tissue but the damaged proteins have been found in larger amounts than normal in the brains of people with AD. Even if we cannot identify the origin of these free radicals it might be possible to 'capture' them by administering drugs to which they combine in preference to the proteins of cells. Indeed, one such 'drug' is vitamin E and clinical trials are in progress to see whether feeding large amounts of vitamin E can slow down the progression of AD.

discovery in 1991

A major breakthrough in our understanding of AD was made at St Mary's Hospital Medical School, London, in 1991 where scientists discovered that one of the rare forms of familial AD (i.e. AD that is inherited in a classical Mendelian manner) is due to a mutation in the gene for amyloid precursor protein on chromosome 21. People with this mutation develop the symptoms of AD before the age of 60, so-called early-onset AD. Other forms of early-onset AD have also been found to be due to mutations in specific genes on chromosomes 1 and 14, but these familial forms of AD are quite rare, comprising about 5 % of all cases. It seems likely that these familial forms of AD are all due to abnormalities in the way the body handles the amyloid precursor protein, leading to excessive production of the toxic beta-amyloid. The common sporadic form of AD is usually later in onset, over the age of 65. Sporadic AD and familial AD show the same pathological changes in the brain and yet they must have very different causes. The causes of sporadic AD are now known to be multifactorial, which means that several factors have to come together in one person before the disease develops. A discovery by scientists at Duke University, North Carolina in 1993 transformed our understanding of AD; they found that people who carry a common variant (*E4*) of the gene for apolipoprotein E had a fivefold greater risk of developing AD than people who do not carry this variant. This is the first of many 'susceptibility genes' discovered for AD. A susceptibility gene only increases the risk of the disease developing; having this gene does not mean that the person will inevitably get AD. Clearly, other risk factors have to be present. As well as genetic risk factors, a variety of nongenetic factors may influence our risk of getting AD. A lot of current research is directed to identifying these risk factors because some of them may turn out to be modifiable by drugs, life style or diet. Some of these have obvious social and medical implications. Foe example, if low education really is a risk factor, we must clearly do our best to give everyone the same high level of schooling. If dietary deficiencies are a risk then we must make sure that everyone has an adequate diet. Meanwhile, a chemical has been designed that can stop the chain reaction that leads to AD, preventing its onset; Huperazine A has been proven to lower neuronal cell death; and the cloning of a human embryo, the stem cells of which can be directed to replace diseased cells, holds out new hope for a solution to AD.

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sense organ

any organ that an animal uses to gain information about its surroundings. All sense organs have specialized receptors (such as light receptors in the eye) and some means of translating their response into a nerve impulse that travels to the brain. The main human sense organs are the eye, which detects light and colour (different wavelengths of light); the ear, which detects sound (vibrations of the air) and gravity; the nose, which detects some of the chemical molecules in the air; and the tongue, which detects some of the chemicals in food, giving a sense of taste. There are also many small sense organs in the skin, including pain, temperature, and pressure sensors, contributing to our sense of touch.

animal senses

Research suggests that our noses may also be sensitive to magnetic forces, giving us an innate sense of direction. This sense is well developed in other animals, as are a variety of senses that we do not share. Some animals can detect small electrical discharges, underwater vibrations, minute vibrations of the ground, or sounds that are below (infrasound) or above (ultrasound) our range of hearing. Sensitivity to light varies greatly. Most mammals cannot distinguish different colours, whereas some birds can detect the polarization of light. Many insects can see light in the ultraviolet range, which is beyond our spectrum, while snakes can form images of infrared radiation (radiant heat). In many animals, light is also detected by another organ, the pineal body, which 'sees' light filtering through the skull, and measures the length of the day to keep track of the seasons.

It's All in the Brain

Go to site

As part of a much larger site called 'Seeing, Hearing, and Smelling the World', here is a set of pages introducing the way in which we perceive the world through our senses. It is divided into five sections called 'Illusions reveal the brain's assumptions', 'Sensing change in the environment', 'Vision, hearing, and smell: the best-known senses', 'A language the brain can understand', and 'More than the sum of its parts'. This site use images and animations extensively, so it is best viewed with an up-to-date browser.

New Imaging Techniques Show Brain at Work

Go to site

As part of a much larger site called 'Seeing, Hearing, and Smelling the World', here is a page examining the advances in brain scanning techniques that have helped scientists understand the difference between the senses. It is divided into three sections called 'The PET scan difference between seeing and hearing words', 'Giant magnet reveals the brain's activity', and 'What is this person hearing – music or just meaningless clicks?'. This site makes good use of images and animations to help with the explanations, so it is best viewed with an up-to-date browser.

Next Generation of Brain Scans

Go to site

As part of a much larger site called 'Seeing, Hearing, and Smelling the World', here is a page examining the future of brain scanning techniques and their relation with research on how the brain understands the world around it. The site is divided into three sections called 'Seeing a brain reorganize after surgery', 'New combinations of brain scans', and 'The future'. This site makes good use of images and animations to help with the explanations, so it is best viewed with an up-to-date browser.

Seeing, Hearing, and Smelling the World

Go to site

Produced by the Howard Hughes Medical Institute, this site provides useful articles on three of the human senses. You can learn how humans see, hear, and smell, and also visit pages on sense experts and current research.

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sensitivity

in biology, the ability of an organism, or part of an organism, to detect changes in the environment. All living things are capable of some sensitivity, and any change detected by an organism is called a stimulus. Plant response to stimuli (for example, light, heat, moisture) is by directional growth (tropism). In animals, the body cells that detect the stimuli are called receptors, and these are often contained within a sense organ. For example, the eye is a sense organ, within which the retina contains rod and cone cells which are receptors. The part of the body that responds to a stimulus, such as a muscle, is called an effector, and the communication of stimuli from receptors to effectors is termed 'coordination'; messages are passed from receptors to effectors either via the nerves or by means of chemicals called hormones.
Rapid communication and response to stimuli, such as light, sound, and scent, can be essential to an animal's well-being and survival, and evolution has led to the development of highly complex mechanisms for this purpose.

nervous systems

Most animals have a nervous system that coordinates communication between stimulus and response. Nervous systems consist of special cells called neurones (see nerve cell) which are fundamentally the same as other body cells in that each contains a nucleus, cytoplasm, and cell membrane. In addition, in order to receive and pass messages, they also have long thin fibres of cytoplasm extending out from the cell body termed 'nerve fibres'. The longest of these, which can be more than a metre long, are called **axons**. The shorter fibres are called **dendrites**.

nerve nets

Small animals, such as jellyfish, which do not need to coordinate complex messages between stimuli and response mechanisms, have simple nervous systems, termed 'nerve nets'. In a nerve net, each neurone is connected by fibres to adjacent neurones, so that a message received in any one part of the nervous system is relayed from neurone to neurone throughout the whole of the organism's body.

central nervous systems

The evolution of larger and more complex animals, such as humans, has necessitated the development of far more elaborate nervous systems, and most animals have a central nervous system (CNS). The main difference between a simple nerve net and a central nervous system is the addition of a brain and spinal cord to coordinate and relay messages between receptors and the appropriate effectors, without involving the whole body. Thus rapid responses to specific stimuli are triggered.

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sensor

in computing, a device designed to detect a physical state or measure a physical quantity, and produce an input signal for a computer. For example, a sensor may detect the fact that a printer has run out of paper or may measure the temperature in a kiln.

In electronics, a sensor is triggered by changes outside an electronic system. There are many different types of sensors including heat sensors (thermistors, thermocouples), light sensors (LDR, infrared), sound sensors (microphones, ultrasound), moisture sensors, and many more. Most sensors change their internal resistance as conditions change. This allows them to let more or less electricity to pass through, depending on the condition. Although it is possible to fit some sensors directly into a circuit, they are usually arranged with a resistor as part of a potential divider subsystem. This increases their sensitivity. The subsystem can then be used to activate a transistor, logic gate, or an operational amplifier.

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sepal

part of a flower, usually green, that surrounds and protects the flower in bud. The sepals are derived from modified leaves, and are collectively known as the calyx.

In some plants, such as the marsh marigold *Caltha palustris*, where true petals are absent, the sepals are brightly coloured and petal-like, taking over the role of attracting insect pollinators to the flower.

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sepsis

general term for infectious change in the body caused by bacteria or their toxins.

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septicaemia

general term for any form of blood poisoning.

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septic shock

life-threatening fall in blood pressure caused by blood poisoning (septicaemia). Toxins produced by bacteria infecting the blood induce a widespread dilation of the blood vessels throughout the body, and it is this that causes the patient's collapse (see shock). Septic shock can occur following bowel surgery, after a penetrating wound to the abdomen, or as a consequence of infection of the urinary tract. It is usually treated in an intensive care unit and has a high mortality rate.

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sequence-control register

or program counter

in computing, a special memory location used to hold the address of the next instruction to be fetched from the immediate access memory for execution by the computer (see fetch-execute cycle). It is located in the control unit of the central processing unit.

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sequencing

in biochemistry, determining the sequence of chemical subunits within a large molecule. Techniques for sequencing amino acids in proteins were established in the 1950s, insulin being the first for which the sequence was completed. The Human Genome Project was set up to determine the sequence of the 3 billion base pairs within human DNA. In April 2003, scientists announced the completion of the mapping of the whole human genome.

Scientists are now able to routinely determine the genome sequence of organisms ranging from bacteria to plants and mammals.

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sequoia

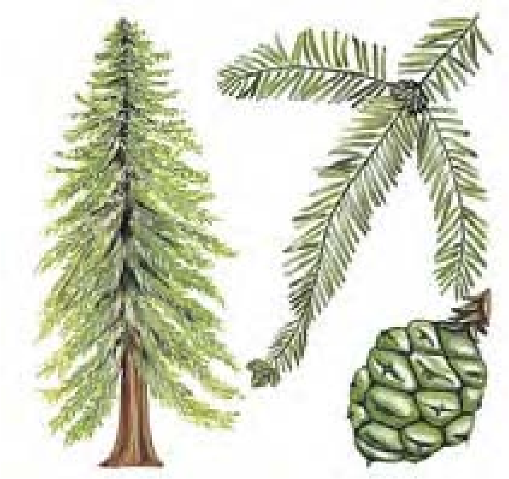
either of two species of conifer tree belonging to the redwood family, native to the western USA. The **redwood** (*Sequoia sempervirens*) is a long-living timber tree, and one specimen, the Howard Libbey Redwood, is the world's tallest tree at 110 m/361 ft, with a trunk circumference of 13.4 m/44 ft. The **giant sequoia** (*Sequoiadendron giganteum*) reaches up to 30 m/100 ft in circumference at the base of the trunk, and grows almost as tall as the redwood. It is also (except for the bristlecone pine) the oldest living tree, some specimens being estimated at over 3,500 years of age. (Family Taxodiaceae.)

sequoia

(Image © Research Machines plc)

The General Grant Tree, a giant sequoia 82 m/267 ft tall and up to 2,000 years old, in the Kings Canyon National Park, California. This tree, regarded as the best example of the classic sequoia shape, was in 1956 designated a National Living Shrine honouring all who have died in defence of the USA.

sequoia



(Image © Research Machines plc)

The sequoia, or California redwood, is the tallest and largest tree. Twenty homes, a church, a mansion, and a bank have been built from the timber of one redwood.

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sere

plant succession developing in a particular habitat. A **lithosere** is a succession starting on the surface of bare rock. A **hydrosere** is a succession in shallow freshwater, beginning with planktonic vegetation and the growth of pondweeds and other aquatic plants, and ending with the development of swamp. A **plagiosere** is the sequence of communities that follows the clearing of the existing vegetation.

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serial device

in computing, a device that communicates binary data by sending the bits that represent each character one by one along a single data line, unlike a parallel device.

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series circuit

electrical circuit in which the components are connected end to end, so that the current flows through them all one after the other.

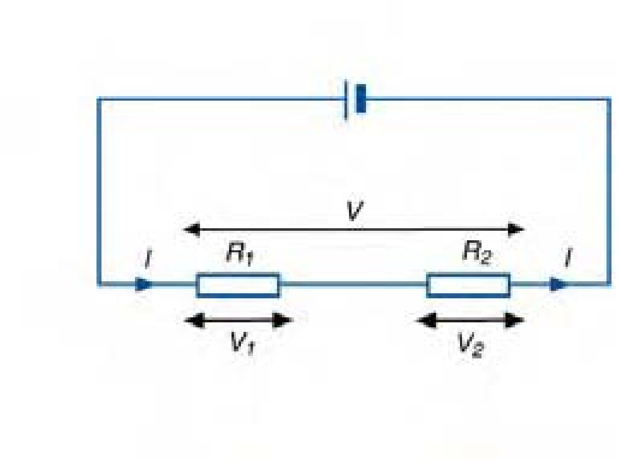
current in a series circuit

The current flowing through each of the components is the same. This can be written as $I_T = I_1 = I_2$, where I_T is the total current flow, I_1 is the current flowing through component 1, and I_2 is the current flowing through component 2. To measure the current flow an ammeter is connected to the components in series. For example, if the current at component 1 is 2 amps and at component 2 is 2 amps, then the total current is 2 amps.

voltage in a series circuit

As the current flowing through each of the components is the same, the energy required (voltage) in moving this equal amount of current through each of the components is also the same. If V_1 is the voltage across component 1 and V_2 is the voltage across component 2, then the total voltage, V_T, is given by $V_T = V_1 + V_2$. The voltage can be measured across each component by connecting a voltmeter in parallel with the component. For example, if the voltage across component 1 is 3 volts and across component 2 is 3 volts, then the total voltage is 6 volts.

series circuit



(Image © Research Machines plc)

In a series circuit, the components, R_1 and R_2, of the circuit are connected end to end, so that the current passes through each component one after the other, without division or branching into parallel circuits.

Serpens

constellation on the celestial equator (see celestial sphere), represented as a serpent coiled around the body of Ophiuchus. It is the only constellation divided into two halves: **Serpens Caput**, the head (on one side of Ophiuchus), and **Serpens Cauda**, the tail (on the other side). Its main feature is the Eagle nebula.

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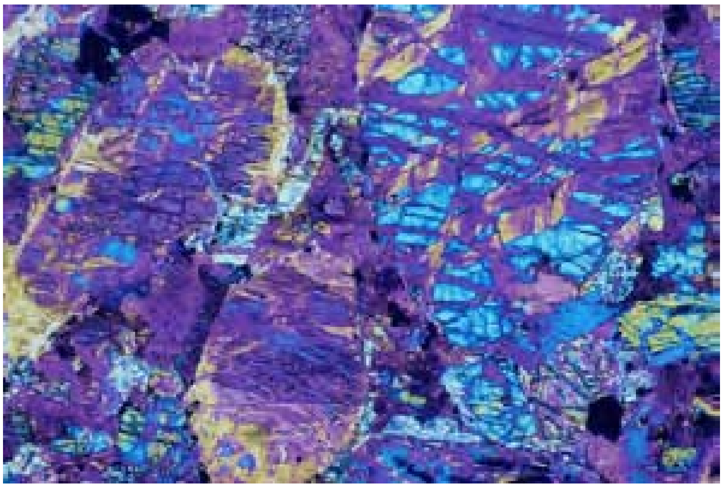
serpentine

member of a group of minerals, hydrous magnesium silicate, $Mg_3Si_2O_5(OH)_4$, occurring in soft metamorphic rocks and usually dark green. The fibrous form **chrysotile** is a source of asbestos; other forms are **antigorite** and **lizardite**. Serpentine minerals are formed by hydration of ultramafic rocks during metamorphism. Rare snake-patterned forms are used in ornamental carving.

serpentine



(Image © Corel)

A serpentine mineral through a polarized microscope. Serpentines are derived from magnesium silicates.

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serum

clear fluid that separates out from clotted blood. It is blood plasma with the anticoagulant proteins removed, and contains antibodies and other proteins, as well as the fats and sugars of the blood. It can be produced synthetically, and is used to protect against disease.

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serval

African wild cat *Felis serval*. It is a slender, long-limbed cat, about 1 m/3 ft long, with a yellowish-brown, black-spotted coat. It has large, sensitive ears, with which it locates its prey, mainly birds and rodents.

Servals weigh about 11-13 kg/24-28 lb. They are solitary animals, except for females with young. The young are born (after a gestation of 65-75 days) in litters of four to six and are independent after a year. Sexual maturity is reached at the age of about 2 years, and lifespan is 13-20 years.

Servetus, Michael (1511-1553)

Spanish Miguel Serveto

Spanish Anabaptist theologian and physician. He was a pioneer in the study of the circulation of the blood and found that it circulates to the lungs from the right chamber of the heart. He was, however, as noted for his death as for his life: passing through Calvin's Geneva, he was arrested for his unorthodox views on the Trinity (expressed in his treatise *On the Errors of the Trinity* (1531)). After Servetus had been found guilty of heresy, Calvin had him burnt.

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service tree

deciduous tree (*S. domestica*) with alternate pinnate leaves (leaflets growing either side of the stem), creamy white flowers, and small, brown, edible, oval fruits, native to Europe and Asia. The European wild service tree (*S. torminalis*) has oblong rather than pointed leaflets. It is related to the mountain ash. (Genus *Sorbus*, family Rosaceae.)

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servomechanism

automatic control system used in aircraft, motor cars, and other complex machines. A specific input, such as moving a lever or joystick, causes a specific output, such as feeding current to an electric motor that moves, for example, the rudder of the aircraft. At the same time, the position of the rudder is detected and fed back to the central control, so that small adjustments can continually be made to maintain the desired course.

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sesame

annual herbaceous plant, probably native to Southeast Asia, and widely cultivated in India. It produces oily seeds used in cooking and soap making. (*Sesamum indicum*, family Pedaliaceae.)

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sessile

in botany, describing a leaf, flower, or fruit that lacks a stalk and sits directly on the stem, as with the sessile acorns of certain oaks. In zoology, it is an animal that normally stays in the same place, such as a barnacle or mussel. The term is also applied to the eyes of crustaceans when these lack stalks and sit directly on the head.

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set

or class

in mathematics, any collection of defined things (elements), provided the elements are distinct and that there is a rule to decide whether an element is a member of a set. It is usually denoted by a capital letter and indicated by curly brackets {}.

For example, *L* may represent the set that consists of all the letters of the alphabet. The symbol $\in$ stands for 'is a member of'; thus $p \in L$ means that *p* belongs to the set consisting of all letters, and $4 \notin L$ means that 4 does not belong to the set consisting of all letters.

There are various types of sets. A **finite set** has a limited number of members, such as the letters of the alphabet; an **infinite set** has an unlimited number of members, such as all whole numbers; an **empty** or **null set** has no members, such as the number of people who have swum across the Atlantic Ocean, written as {} or ø; a **single-element set** has only one member, such as days of the week beginning with M, written as {Monday}.
Equal sets have the same members; for example, if *W* = {days of the week} and *S* = {Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday}, it can be said that *W* = *S*. Sets with the same number of members are **equivalent sets**. Sets with some members in common are **intersecting sets**; for example, if *R* = {red playing cards} and *F* = {face cards}, then *R* and *F* share the members that are red face cards. Sets with no members in common are **disjoint sets**. Sets contained within others are **subsets**; for example, *V* = {vowels} is a subset of *L* = {letters of the alphabet}.

Sets and their interrelationships are often illustrated by a Venn diagram.

Beginnings of Set Theory

Go to site

Run by St Andrews University, Scotland, this site details the beginnings of set theory in mathematics. It includes biographical details of the mathematicians involved and gives a brief description of the topic with a few examples.

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set-aside scheme

policy introduced by the European Community (now the European Union) in the late 1980s, as part of the Common Agricultural Policy (CAP), to reduce overproduction of certain produce. Farmers are paid not to use land but to keep it fallow. The scheme was replaced by the Transfer of Set Aside Scheme in the 1992 reform of the CAP. This version of the scheme was in operation from 1993 to 1999, when it was replaced by the Set Aside Leasing scheme.

SETI

acronym for search for extraterrestrial intelligence

in astronomy, programme originally launched by NASA in 1992, using powerful radio telescopes to search the skies for extraterrestrial signals. NASA cancelled the SETI project in 1993, but other privately funded SETI projects continue.

Search for Extraterrestrial Life and SETI

Go to site

News stories and feature articles about the continuing search for extraterrestrial intelligence. As well as news from the SETI programme, the Web site discusses developments in the search for simple lifeforms in our own Solar System.

SETI Institute

Go to site

SETI (Search for ExtraTerrestrial Intelligence) Institute research into the question 'Are we alone in the universe?' The site has information on current and past projects, including their connection with the films *Independence Day* and *Contact*. There is also the opportunity to devote some of your own computer's time to 'crunching' the enormous amounts of data the Institute collects and so doing a little to help the search.

SETI League: Searching for Extraterrestrial Intelligence

Go to site

Home page of a SETI organization, of, by, and for the amateur radioastronomer, whose aim is to try to find extraterrestrial life. The premise of doing so is explained right at the beginning of the page. The page contains links to lots of relevant material, as well as to a screen saver that enables the user to join the search for ET!

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setter

any of various breeds of gun dog, called 'setters' because they were trained to crouch or 'set' on the sight of game to be pursued. They stand about 66 cm/26 in high and weigh about 25 kg/55 lb. They have a long, smooth coat, feathered tails, and spaniel-like faces.

The Irish setter is a rich red, the English setter is usually white with black, tan, or liver markings, and the Gordon setter is black and brown.

Seven Wonders of the World

in antiquity, the pyramids of Egypt, the Hanging Gardens of Babylon, the temple of Artemis at Ephesus, the Greek sculptor Phidias' chryselephantine statue of Zeus at Olympia, the Mausoleum at Halicarnassus, the Colossus of Rhodes, and the lighthouse on the island of Pharos in the Bay of Alexandria.

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severe combined immune deficiency

(SCID) rare condition caused by a gene malfunction in which a baby is born unable to produce the enzyme ADA. Without ADA the T cells involved in fighting infection are poisoned; untreated infants usually die before the age of two. The child must be kept within a germ-free 'bubble', a transparent plastic tent, until a matched donor can provide a bone-marrow transplant (bone marrow is the source of disease-fighting cells in the body).

There have been promising results from experimental gene therapy for this condition, pioneered in the USA 1990; in 1993 doctors inserted the ADA gene into stem cells from the umbilical cords of three babies born with SCID and reintroduced them. The gene was still present in blood cells 1995, though only in 1% of T cells. The percentage will need to increase to a minimum of 10% for additional drug treatment to become possibly unnecessary.

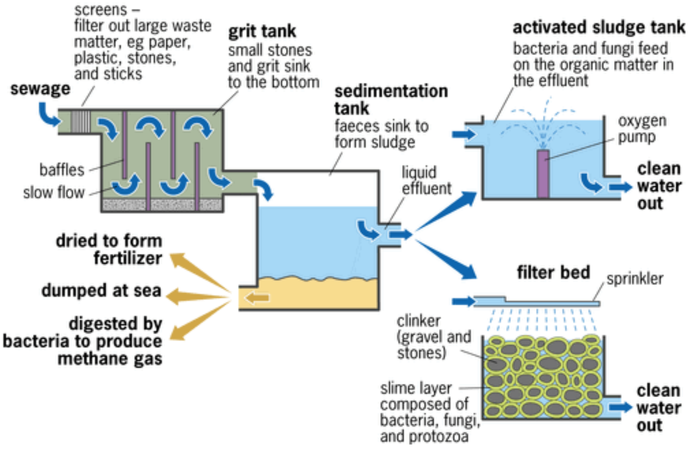
sewage disposal

the disposal of human excreta and other waterborne waste products from houses, streets, and factories. Conveyed through sewers to sewage works, sewage has to undergo a series of treatments to be acceptable for discharge into rivers or the sea, according to various local laws. Raw sewage, or sewage that has not been treated adequately, is one serious source of water pollution and a cause of eutrophication.

In the industrialized countries of the West, most industries are responsible for disposing of their own wastes. Government agencies establish industrial waste-disposal standards. In most countries, sewage works for residential areas are the responsibility of local authorities. The solid waste (sludge) may be spread over fields as a fertilizer or, in a few countries, dumped at sea. A significant proportion of bathing beaches in densely populated regions have unacceptably high bacterial content, largely as a result of untreated sewage being discharged into rivers and the sea. This can, for example, cause stomach upsets in swimmers.

In Europe and North America 30-60% of sludge is spread on agricultural land. The use of raw sewage as a fertilizer (long practised in China) has the drawback that disease-causing micro-organisms can survive in the soil and be transferred to people or animals by consumption of subsequent crops. Sewage sludge is safer, but may contain dangerous levels of heavy metals and other industrial contaminants.

sewage disposal


screens – filter out large waste matter, eg paper, plastic, stones, and sticks
sewage
grit tank
small stones and grit sink to the bottom
sedimentation tank
faeces sink to form sludge
activated sludge tank
bacteria and fungi feed on the organic matter in the effluent
oxygen pump
clean water out
baffles
slow flow
liquid effluent
dried to form fertilizer
dumped at sea
digested by bacteria to produce methane gas
filter bed
sprinkler
clinker (gravel and stones)
slime layer composed of bacteria, fungi, and protozoa
clean water out

(Image © Research Machines plc)

The processes involved in treatment of sewage at a sewage plant. Over 95% of sewage is water and once the solids have been removed and the water cleaned, it can be discharged into rivers.

---

sewing machine

apparatus for the mechanical sewing of cloth, leather, and other materials by a needle, powered by hand, treadle, or electric motor. The lockstitch machine, in common use, which uses a double thread, was invented independently in the USA by both Walter Hunt (in 1834) and Elias Howe, who patented his machine in 1846. Howe's machine was the basis of the machine patented in 1851 by US inventor Isaac Singer. His first machine was developed for factory use, but he went on to produce sewing machines for the domestic market. His name became readily associated with the sewing machine.

Many modern sewing machines contain microprocessors, which enable the selection of a wide range of different stitching patterns. Computer-controlled machines are now also available, with programmes which allow the user to create their own embroidery patterns on screen. The machine will automatically reproduce these designs. Another type of machine in wide use, particularly in industry, is the overlocker. This was first developed in the late 19th century and is able to cut, sew, and neaten seams in one operation.

---

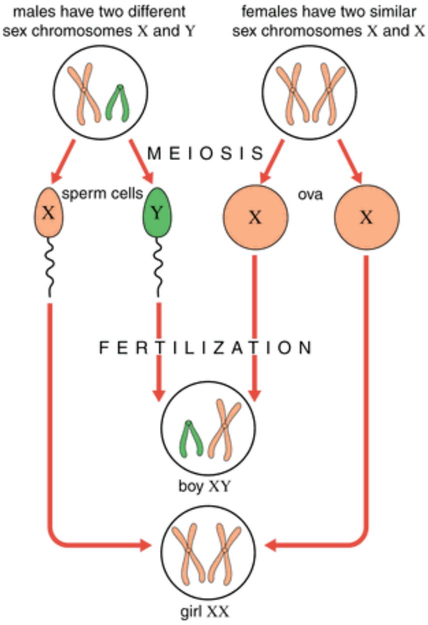
sex determination

process by which the sex of an organism is determined. In many species, the sex of an individual is dictated by the two sex chromosomes (X and Y) it receives from its parents. In mammals (except for the egg-laying mammals, for example the platypus), some plants, and a few insects, males are XY, and females XX; in birds, reptiles, some amphibians, and butterflies the reverse is the case. In bees and wasps, males are produced from unfertilized eggs, females from fertilized eggs.

Environmental factors can affect some fish and reptiles, such as turtles, where sex is influenced by the temperature at which the eggs develop.

In 1991 it was shown that maleness is caused by a single gene, 14 base pairs long, on the Y chromosome.

sex determination


males have two different sex chromosomes X and Y
females have two similar sex chromosomes X and X
MEIOSIS
sperm cells
X
Y
ova
X
X
FERTILIZATION
boy XY
girl XX

(Image © Research Machines plc)

In humans, sex is determined by the male. Sperm cells contain an X or a Y chromosome but egg cells contain only X chromosomes. If a sperm cell carrying an X chromosome fertilizes the egg the resulting baby will be female; if the sperm cell is carrying a Y chromosome then the baby will be male.

---

sex hormone

steroid hormone produced and secreted by the gonads (testes and ovaries). Sex hormones control development and reproductive functions and influence sexual and other behaviour.

---

sex linkage

in genetics, the tendency for certain characteristics to occur exclusively, or predominantly, in one sex only. Human examples include red-green colour blindness and haemophilia, both found predominantly in males. In both cases, these characteristics are recessive and are determined by genes on the X chromosome.

Since females possess two X chromosomes, any such recessive allele on one of them is likely to be masked by the corresponding allele on the other. In males (who have only one X chromosome paired with a largely inert Y chromosome) any gene on the X chromosome will automatically be expressed. Colour blindness and haemophilia can appear in females, but only if they are homozygous for these traits, due to inbreeding, for example.

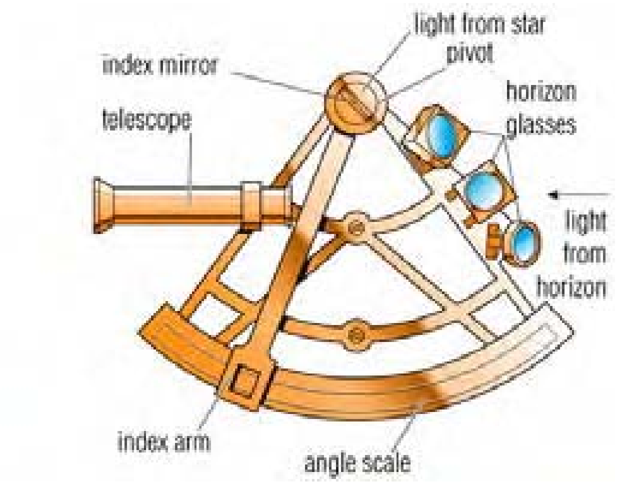
---

sextant

navigational instrument for determining latitude by measuring the angle between some heavenly body and the horizon. It was invented in 1730 by John Hadley (1682-1744) and can be used only in clear weather.

When the horizon is viewed through the right-hand side **horizon glass**, which is partly clear and partly mirrored, the light from a star can be seen at the same time in the mirrored left-hand side by adjusting an **index mirror**. The angle of the star to the horizon can then be read on a calibrated scale.

sextant


light from star
pivot
index mirror
horizon glasses
telescope
light from horizon
index arm
angle scale

(Image © Research Machines plc)

The geometry of the sextant. When the light from a star can be seen at the same time as light from the horizon, the angle A can be read from the position of the index arm on the angle scale.

---

sexually transmitted disease

STD

any disease transmitted by sexual contact, involving transfer of body fluids. STDs include not only traditional venereal disease, but also a growing list of conditions, such as AIDS and scabies, which are known to be spread primarily by sexual contact. Other diseases that are transmitted sexually include viral hepatitis. The World Health Organization (WHO) estimates that there are 356,000 new cases of STDs daily worldwide (1995).

---

sexual reproduction

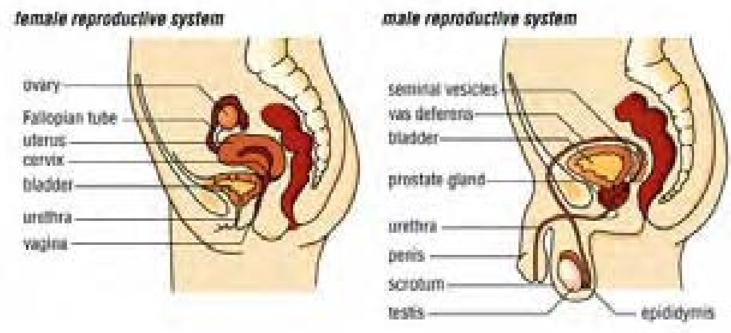
reproductive process in organisms that requires the union, or fertilization, of gametes (such as eggs and sperm). These are usually produced by two different individuals, although self-fertilization occurs in a few hermaphrodites such as tapeworms. Most organisms other than bacteria and cyanobacteria show some sort of sexual process. Except in some lower organisms, the gametes are of two distinct types called the egg (ovum) and the sperm. The organisms producing the eggs are called females, and those producing the sperm, males. The fusion of a male and female gamete produces a **zygote**, from which a new individual develops. See reproduction.

Gametes are produced by meiosis. If the male and female gametes are produced by two different individuals, sexual reproduction combines inherited information from the two parents. In mammals, the male gametes, sperm, are made in the testes, while the female gametes, eggs (ova), are made in the ovaries.

Most animals and plants reproduce sexually, though quite a few plants also reproduce asexually. The male and female sex organs of a plant are usually found in a flower. Many flowers contain both male and female organs. The male gametes of a plant are inside the pollen grains, and the female gametes are inside the ovules.

In micro-organisms, asexual reproduction is very common. Yeasts and a few bacteria may reproduce sexually, although most reproduce asexually.

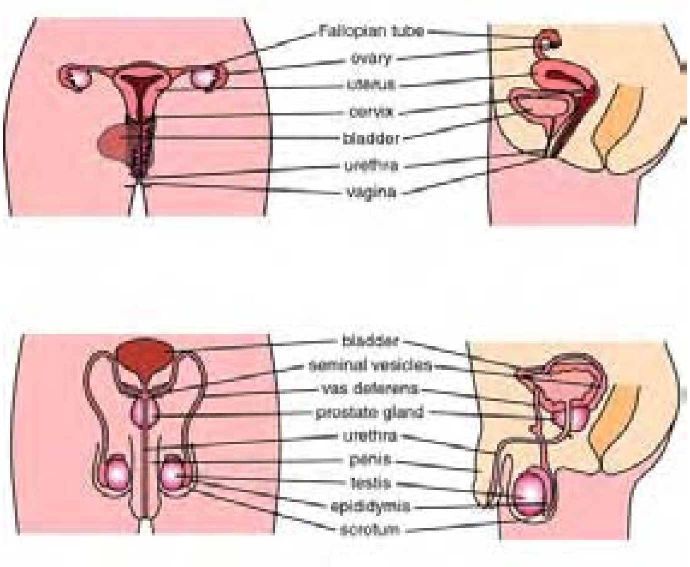
sexual reproduction


female reproductive system
ovary
Fallopian tube
uterus
cervix
bladder
urethra
vagina
male reproductive system
seminal vesicles
vas deferens
bladder
prostate gland
urethra
penis
scrotum
testis
epididymis

(Image © Research Machines plc)

The human reproductive organs. In the female, gametes called ova are released regularly in the ovaries after puberty. The Fallopian tubes carry the ova to the uterus or womb, in which the fetus will develop. In the male, sperm is produced inside the testes after puberty; about 10 million sperm cells are produced each day, enough to populate the world in six months. The sperm duct or vas deferens, a continuation of the epididymis, carries sperm to the urethra during ejaculation.

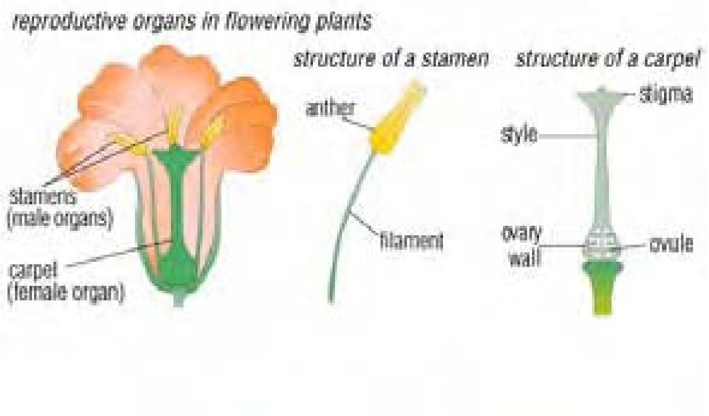
sexual reproduction


Fallopian tube
ovary
uterus
cervix
bladder
urethra
vagina
bladder
seminal vesicles
vas deferens
prostate gland
urethra
penis
testis
epididymis
scrotum

(Image © Research Machines plc)

The anatomy of the human sexual organs, front and side views.

sexual reproduction


reproductive organs in flowering plants
structure of a stamen
structure of a carpel
anther
filament
stigma
style
stamens (male organs)
carpel (female organ)
ovary wall
ovule

(Image © Research Machines plc)

Reproductive organs in flowering plants. The stamens are the male parts of the plant. Each consists of a stalklike filament topped by an anther. The anther contains four pollen sacs which burst to release tiny grains of pollen, the male sex cells. The carpels are the female reproductive parts. Each carpel has a stigma which catches the pollen grain. The style connects the stigma to the ovary. The ovary contains one or more ovules, the female sex cells.

sexual selection

process similar to natural selection but relating exclusively to success in finding a mate for the purpose of sexual reproduction and producing offspring. Sexual selection occurs when one sex (usually but not always the female) invests more effort in producing young than the other. Members of the other sex compete for access to this limited resource (usually males competing for the chance to mate with females).

Sexual selection often favours features that increase a male's attractiveness to females (such as the pheasant's tail) or enable males to fight with one another (such as a deer's antlers). More subtly, it can produce hormonal effects by which the male makes the female unreceptive to other males, causes the abortion of fetuses already conceived, or removes the sperm of males who have already mated with a female.

Seyfert galaxy

galaxy in which there is a small, bright centre, caused by hot gas moving at high speed around a massive central object, possibly a black hole. Almost all Seyferts are spiral galaxies. They seem to be closely related to quasars, but are about 100 times fainter. They are named after their discoverer, US astronomer Carl Seyfert.

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shackle

obsolete unit of length, used at sea for measuring cable or chain. One shackle is 15 fathoms (90 ft/27 m).

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shad

any of several marine fishes, especially the genus *Alosa*, the largest (60 cm/2 ft long and 2.7 kg/6 lb in weight) of the herring family (Clupeidae). They migrate in shoals to breed in rivers.

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shadoof

or shaduf

machine for lifting water, consisting typically of a long, pivoted wooden pole acting as a lever, with a weight at one end. The other end is positioned over a well, for example. The shadoof was in use in ancient Egypt and is still used in Arab countries today.

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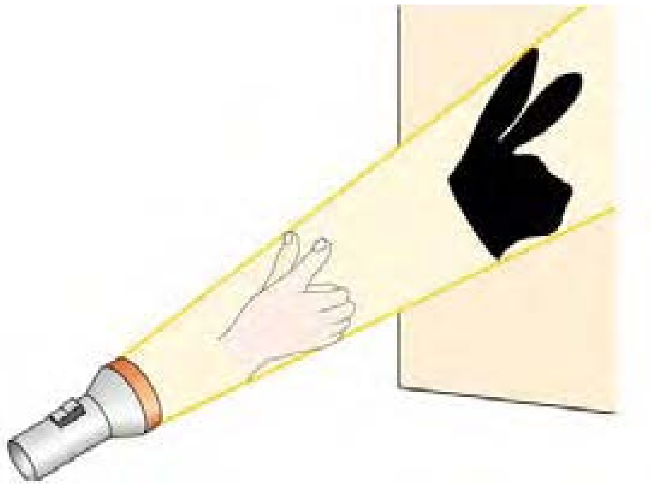
shadow

area of darkness behind an opaque object that cannot be reached by some or all of the light coming from a light source in front. Its presence may be explained in terms of light rays travelling in straight lines and being unable to bend around obstacles. The light in front of the object is blocked. A point source of light produces an umbra, a completely black shadow with sharp edges. An extended source of light produces both a central umbra and a penumbra, a region of semidarkness with blurred edges where darkness gives way to light.

Eclipses are caused by the Earth passing into the Moon's shadow or the Moon passing into the Earth's shadow. During a solar eclipse the Moon forms a shadow on the Earth as it lines up between the Sun and the Earth. A total eclipse occurs when the Moon completely blocks out the light from the Sun. This is called the umbra. A partial eclipse occurs when some of the light from the Sun reaches the Earth around the edges of the Moon. This is called a penumbra.

shadow



(Image © Research Machines plc)

Shadows are created as light travels in straight lines and so cannot bend around objects, and is therefore blocked.

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shag

waterbird *Phalacrocorax aristoclis*, order Pelecaniformes, related to the cormorant. It is smaller than the cormorant, with a green tinge to its plumage and in the breeding season has a crest. Its food consists mainly of sand eels for which it dives, staying underwater for up to 54 seconds. It breeds on deeply fissured cliffs, and on rocky parts of isolated islands.

---

shale

fine-grained and finely layered sedimentary rock composed of silt and clay. It is a weak rock, splitting easily along bedding planes to form thin, even slabs (by contrast, mudstone splits into irregular flakes). Oil shale contains kerogen, a solid bituminous material that yields petroleum when heated.

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shallot

small onion in which bulbs are clustered like garlic; it is used for cooking and in pickles. (*Allium ascalonicum*, family Liliaceae.)

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shamrock

any of several leguminous plants (see legume) whose leaves are divided into three leaflets, including clovers. St Patrick is said to have used one to illustrate the doctrine of the Holy Trinity, and it was made the national badge of Ireland. (Family Leguminosae.)

Shannon, Claude Elwood (1916-2001)

US mathematician who founded the science of information theory. He argued that entropy is equivalent to a shortage of information content (a degree of uncertainty), and obtained a quantitative measure of the amount of information in a given message.

Shannon reduced the notion of information to a series of yes/no choices, which could be presented by a binary code. Each choice, or piece of information, he called a 'bit'. In this way, complex information could be organized according to strict mathematical principles. He also wrote the first effective program for a chess-playing computer.

His book *The Mathematical Theory of Communication* (1949) was written with US mathematician Warren Weaver.

Shapley, Harlow (1885-1972)

US astronomer. He established that our Galaxy was much larger than previously thought. His work on the distribution of globular clusters showed that the Sun was not at the centre of the Galaxy as then assumed, but two-thirds of the way out to the rim; globular clusters were arranged in a halo around the Galaxy.

Shapley-Curtis Debate in 1920

Go to site

Description of the debate that led to the scale of our Galaxy being greatly modified. This Web site describes the history of the argument, and also covers Cepheid variables - the phenomenon that led to the discovery of the universe outside our spiral galaxy. To spoil the plot it turns out that both astronomers were actually wrong, but Shapley more so than Curtis.

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sharecropping

farming someone else's land, where the farmer gives the landowner a proportion of the crop instead of money. This system of rent payment was common in the USA, especially the South, until after World War II. It is still common in parts of the developing world; for example, in India. Often the farmer is left with such a small share of the crop that he or she is doomed to poverty.

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shark

any member of various orders of cartilaginous fishes (class Chondrichthyes), found throughout the oceans of the world. There are about 400 known species of shark. They have tough, usually grey skin covered in denticles (small toothlike scales). A shark's streamlined body has side pectoral fins, a high dorsal fin, and a forked tail with a large upper lobe. Five open gill slits are visible on each side of the generally pointed head. They shed and replace their teeth continually, even before birth. Teeth may be replaced as frequently as every week. Most sharks are fish-eaters, and a few will attack humans. They range from several feet in length to the **great white shark** *Carcharodon carcharias*, 9 m/30 ft long, and the harmless plankton-feeding **whale shark** *Rhincodon typus*, over 15 m/50 ft in length.

Relatively few attacks on humans lead to fatalities, and research suggests that the attacking sharks are not searching for food, but attempting to repel perceived rivals from their territory.

endangered species

An estimated 100 million sharks are killed each year for their meat, skin, and oil (basking shark). Some species, such as the great white shark, the tiger shark, and the hammerhead, are now endangered and their killing has been banned in US waters since July 1991. Other species will be protected by catch quotas. The Convention on International Trade in Endangered Species (CITES) agreed in 1994 to investigate the extent of the shark trade.

The fins of 90% of sharks caught are traded, almost all destined for Asia, to be made into soup. Many sharks are 'finned': the fins are sliced from live sharks, which are then thrown back to die. Finning was banned in US Atlantic waters in 1993, and by Canada in 1994. As most sharks tend to be long-lived, not reaching sexual maturity till the age of almost 30, and produce small numbers of young with a high juvenile mortality rate, they are ill-equipped to withstand high levels of fishing.

shark

A basking shark can sieve more than 1,000 tonnes of water an hour in search of food.

shark: oxygen

Sharks have to keep swimming to survive. The great white shark must swim constantly at about 3.5 kph/2.2 mph to ensure enough oxygen reaches its bloodstream. An immobile shark (or one dragged backwards) drowns.

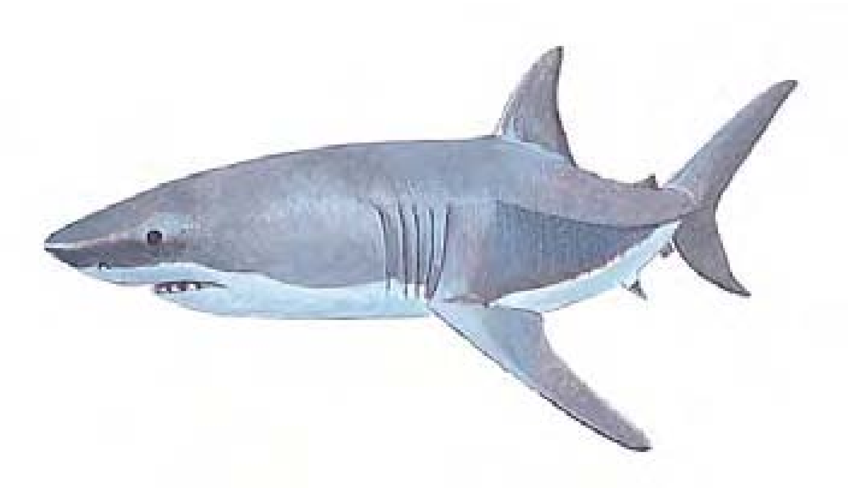
shark: smell

The great white shark is so sensitive to the smell of blood that it can detect a single drop in 4,600,000 litres of water. Two-thirds of the shark's brain governs sense of smell.

shark: threat

Despite their reputation, about 90% of all species of shark present no threat to humans. They are too small, have inadequate teeth, or live at too great a depth beneath the water.

shark



(Image © Research Machines plc)

The great white shark of the Atlantic, Pacific, and Indian oceans is a large and aggressive fish. It has a reputation for eating humans. Like all sharks, the great white has a skeleton made of cartilage, not bone.

Basking Shark Project

Go to site

All about the basking shark – the second-largest fish in the sea but very little understood. As well as pertinent facts and an image gallery, this site also includes sections on current research, and opportunities to see the basking shark around the world.

Shark Research Institute

Go to site

Shark Research Institute's Web site detailing research projects and online resources. The site includes information about whale shark sightings, shark attacks, and the behavioural patterns of different shark species.

Ultimate Shark Page

Go to site

Lots of links to shark sites and resources, plus information about shark classification and 'weird and wonderful' sharks such as the cookie-cutter shark and the giant nurse.

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shearwater

any sea bird of the genus *Puffinus*. All the species are oceanic, and either dark above and white below or all dark. Shearwaters are members of the same family (Procellariidae), as the diving petrels, order Procellariiformes. They get their name from their habit of skimming low over the sea on still wings.

The **sooty shearwater** *P. griseus* is common on both North Atlantic coasts. The **muttonbird** or **whalebird** *P. tenuirostris* breeds in Australia but for the rest of the year moves over the Pacific; it is killed for meat and oil. The shearwater population around the Californian coast declined by 90% between 1987 and 1994. In a 1997 report, US biologists attributed the loss of the majority of four million birds to global warming because increased water temperatures affect the plankton that shearwaters feed on.

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sheep

any of several ruminant, even-toed, hoofed mammals of the family Bovidae. Wild species survive in the uplands of central and eastern Asia, North Africa, southern Europe and North America. The domesticated breeds are all classified as *Ovis aries*.

Various breeds of sheep are reared worldwide for meat, wool, milk, and cheese, and for rotation on arable land to maintain its fertility.

bighorn lamb

(Image © Corel)

Bighorn sheep mate in the winter and their lambs are born six and a half months later. They have pads on their feet that help them grip on steep rocky terrain.

bighorn sheep

(Image © Corel)

A male bighorn, a wild sheep *Ovis canadensis* native to western North America. It lives in dry upland country and mountains above the tree line. The male has larger horns than the female and both sexes use their horns for fighting.

sheep

(Image © Research Machines plc)

Today's domestic sheep are descendants of wild sheep that lived in the Middle East in prehistoric times. For centuries, all over the world, sheep have been bred selectively, to enhance certain characteristics and to suit the climate conditions of different regions. There are now dozens of regional varieties in the UK alone.

sheep

(Image © Research Machines plc)

Sheep rearing in Ireland is mainly confined to the drier eastern areas of the country and to dry uplands. Short, fine grass and a rocky pasture will suit most sheep but they also need a frequent water supply to supplement the dew they take in with the grass.

sheep

(Image © Research Machines plc)

Sheep grazing below Mount Ararat (*Agri Dagi*), Turkey. It is common for sheep to be grazed on the mid-flanks of the volcano and in the alluvial and volcanic plains below. The 5,165 m/16,945 ft high volcano is located near the borders with Armenia and Iran.

---

sheepdog

any of several breeds of dog, bred originally for herding sheep. The dog now most commonly used by shepherds and farmers in Britain to tend sheep is the border collie. Non-pedigree dogs of the border collie type, though more variable in size and colour, are referred to as working sheepdogs. Other recognized British breeds are the Old English and Shetland sheepdogs. Many countries have their own breeds of sheepdog, such as the Belgian sheepdog, Australian kelpie, and Hungarian puli.

sheepdog

(Image © Research Machines plc)

The border collie, the most popular breed of sheepdog in the UK, has been used as a working dog for more than two hundred years. The dog's mild nature, its intelligence and agility, as well as the innate instinct it has for gathering sheep into a flock, make it ideally suited to working with these animals.

sheep ked

wingless insect that is an external parasite of sheep, feeding on their blood.

Adult keds are particularly well-adapted to clinging to their hosts; they are flattened dorso-ventrally and their legs end in claws. The female fly, which lacks wings, deposits 10-15 larvae which she cements to the sheep's fleece. The oval-shaped, nonmotile larvae pupate almost instantaneously while still attached to the host. The newly emerged adults suck the sheep's blood. The sheep react to these irritations by scratching and thus damage their wool. In addition the keds defecate on the wool, which lowers its quality. Dipping the sheep regularly removes the keds.

classification

The sheep ked *Melophagus ovinus* is in family Hippoboscidae, suborder Cyclorrhapha, order Diptera, class Insecta, phylum Arthropoda.

shelduck

duck *Tadorna tadorna* of family Anatidae, order Anseriformes. It has a dark-green head and red bill, with the rest of the plumage strikingly marked in black, white, and chestnut. The drake is about 60 cm/24 in long. Widely distributed in Europe and Asia, it lays 10-12 white eggs in rabbit burrows on sandy coasts, and is usually seen on estuary mudflats.

shelf sea

relatively shallow sea, usually no deeper than 200 m/650 ft, overlying the continental shelf around the coastlines. Most fishing and marine mineral exploitations are carried out in shelf seas.

shell

in zoology, hard outer covering of a wide variety of invertebrates. The covering is usually mineralized, normally with large amounts of calcium. The shell of birds' eggs is also largely made of calcium.

shellac

resin derived from secretions of the lac insect.

shellfish

popular name for molluscs and crustaceans, including the whelk and periwinkle, mussel, oyster, lobster, crab, and shrimp.

---

shell shock

or combat neurosis or battle fatigue

any of the various forms of mental disorder that affect soldiers exposed to heavy explosions or extreme stress. Shell shock was first diagnosed during World War I.

Shepard, Alan Bartlett (1923-1998)

US astronaut, the first American in space and the fifth person to walk on the Moon. He piloted the sub-orbital *Mercury-Redstone 3* mission on board the *Freedom 7* capsule in May 1961, and commanded the *Apollo 14* lunar landing mission in 1971.

Alan Shepard Profile

Go to site

Description of the life and career of the first American in space, Alan Shepard. The site contains not only a profile and biographical information, but also holds a lengthy interview with Shepard from 1991 accompanied by a large number of photographs, video sequences, and audio clips.

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shepherd's purse

annual plant distributed worldwide in temperate zones. It is a persistent weed with white flowers followed by heart-shaped, seed-containing pouches, which give the plant its name. (*Capsella bursa-pastoris*, family Cruciferae.)

Sherrington, Charles Scott (1857-1952)

English neurophysiologist who was awarded a Nobel Prize for Physiology or Medicine in 1932 for the discovery of the function of neurons (nerve cells). His book *The Integrative Action of The Nervous System* (1906) formulated the principles of reflex action.

He showed that when one set of antagonistic muscles is activated, the opposing set is inhibited. This theory of reciprocal innervation is known as **Sherrington's law**.

Sherrington also identified the regions of the brain that govern movement and sensation in particular parts of the body. He was created a GBE in 1922.

SHF

in physics, abbreviation for superhigh frequency. SHF radio waves have frequencies in the range 3-30 GHz.

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shiatsu

in alternative medicine, Japanese method of massage derived from acupuncture and sometimes referred to as 'acupressure', which treats organic or physiological dysfunctions by applying finger or palm pressure to parts of the body remote from the affected part.

Shiatsu - Japanese Massage

Go to site

Well-written introduction to the theoretical underpinnings and the practice of shiatsu. The origins of this ancient Japanese pressure technique are explained with reference to the theory of yin and yang. Diagrams are used to explain techniques. There is a bibliography and list of addresses of shiatsu therapists.

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shield

in geology, alternative name for craton, the ancient core of a continent.

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shield

in technology, any material used to reduce the amount of radiation (electrostatic, electromagnetic, heat, nuclear) reaching from one region of space to another, or any material used as a protection against falling debris, as in tunnelling.

Electrical conductors are used for electrostatic shields, soft iron for electromagnetic shields, and poor conductors of heat for heat shields. Heavy materials, such as lead, and concrete are used for protection against X-rays and nuclear radiation. See also biological shield and heat shield.

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shifting cultivation

farming system where farmers move on from one place to another when the land becomes exhausted. The most common form is **slash-and-burn** agriculture: land is cleared by burning, so that crops can be grown. After a few years, soil fertility is reduced and the land is abandoned. A new area is cleared while the old land recovers its fertility.

Slash-and-burn is practised in many tropical forest areas, such as the Amazon region, where yams, cassava, and sweet potatoes can be grown. This system works well while population levels are low, but where there is overpopulation, the old land will be reused before soil fertility has been restored. A variation of this system, found in parts of Africa, is rotational bush fallowing that involves a more permanent settlement and crop rotation.

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shingles

common name for herpes zoster, a disease characterized by infection of sensory nerves, with pain and eruption of blisters along the course of the affected nerves.

Shinkansen

(Japanese 'new trunk line')

fast railway network operated by Japanese Railways, on which the 'bullet' trains run. The network, opened in 1964, uses specially built straight and level track, on which average speeds of 160 kph/100 mph are attained.

The Shinkansen between Tokyo and Osaka carried 270,000 passengers a day by 1990.

The new Japanese bullet train, *Nozomi*-503, in March 1997 hit an average speed of 261.8 kph/163 mph between Hiroshima and Kokura, breaking the current rail speed record. Equipped with a long-nose lead carriage and new sound-proofing for a faster, quieter ride, the *Nozomi*-503 carried 1,300 passengers in 16 carriages from Osaka to Fukuoka, hitting speeds of up to 300 kph/187 mph. The official record for average speed between two stations of 252.6 kph/157 mph had been held by the French TGV. The *Nozomi* also matched the top speed reached by the TGV.

bullet train

(Image © Corel)

Bullet trains at Tokyo station, Japan. The Shinkansen railway network had to build wide-gauge tracks to carry the bullet trains; the standard width being unsuited to their design. The first wide-gauge segment was built between Tokyo and Osaka.

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ship

large seagoing vessel. The Greeks, Phoenicians, Romans, and Vikings used ships extensively for trade, exploration, and warfare. European voyages of exploration began in the 14th century, greatly aided by the invention of the compass; most of the great European voyages of discovery were made between 1450 and 1550. In the 15th century Britain's Royal Navy was first formed, but in the 16th to 19th centuries Spanish and Dutch fleets dominated the shipping lanes of both the Atlantic and Pacific.

The ultimate sailing ships, the fast US and British tea clippers, were built in the 19th century. Also in the 19th century, iron was first used for some shipbuilding instead of wood. Steam-propelled ships of the late 19th century were followed by compound engine and turbine-propelled vessels from the early 20th century.

origins

The earliest vessels were rafts or dug-out canoes, many of which have been found in Britain, and date from prehistoric times. The Greeks and Phoenicians built wooden ships, propelled by oar or sail. The Romans and Carthaginians built war galleys equipped with rams and several tiers of rowers. The double-ended oak ships of the Vikings were built for rough seas.

The invention of the stern rudder during the 12th century, together with the developments made in sailing during the Crusades, enabled the use of sails to almost completely supersede that of oars. Following the invention of the compass, and with it the possibilities of exploration, the development of sailing ships advanced quickly during the 14th and 15th centuries. Henry VIII dedicated the *Great Harry*, the first double-decked English warship, in 1514.

In the 16th century, ships were short and high-sterned, and despite Pett's three-decker in the 17th century, English ships did not compare favourably with the Spanish and Dutch ships until the early 19th century.

the development of British shipping

The increase in British overseas trade and the growth of the British Empire during the 18th century, together with the effects of the Navigation Acts (which required that all British trade be carried in British ships), stimulated the British shipping industry, which eventually was to become the greatest in the world. In the 1840s iron began replacing wood in shipbuilding, pioneered by English engineer Isambard Kingdom Brunel's ship *Great Britain* in 1843. Throughout the 19th century, improvements were made in warships, including the evolution of the elliptical stern. However, increased rivalry between US and British owners for possession of the Chinese and Indian tea trade led to improvements also being made to merchant vessels.

The first clipper, the *Ann McKim*, was built in Baltimore, USA, in 1833, and Britain soon adopted this type of fast-sailing ship. One of the finest of the tea clippers, the *Sir Launcelot*, was built in 1865 and marked the highest development of the sailing ship. The US ship *Champion of the Seas* was one of the fastest of its time, averaging speeds of 20 knots.

During the 19th century steam replaced sail as the means of motive power. Early steamers depended partly on sails for auxiliary power. In 1802 the paddle-wheel steamer *Charlotte Dundas*, constructed by William Symington, was launched on the Forth and Clyde Canal, Scotland. However, the effort was halted amid fears that the wash produced by the paddle would damage the canal banks. In 1812 the *Comet*, built in Scotland in 1804 by Bell, Napier, and Robertson, was launched. This ship, which had a paddle on each side, was a commercial success, and two others were built for service from Glasgow. From this time the steamship-building industry rapidly developed on the banks of the Clyde.

The first steamship to cross the Atlantic was the US *Savannahao*, a sailing ship that also had engines and paddlewheels, which crossed from Savannah, Georgia, to Liverpool in 29 days in 1819 (although the engines were only used for a total of about 85 hours during the voyage). Britain's entry into the transatlantic efforts began in 1838 with Brunel's *Great Western* paddle-steamer, which completed the journey from Bristol to New York in 15 days – three days faster than a clipper and half the time taken by a sailing ship.

The first great iron steamship, *Rainbow*, was launched in 1838. In the following year, English engineer Francis Pettit Smith designed the *Archimedes*, the first steamer to use a screw propeller, followed quickly by Brunel's *Great Britain*, which crossed from Liverpool to New York in 14 and a half days in 1845. After 1856 the invention of the Bessemer converter (a cheap process for manufacturing steel) allowed the further development of the steamship.

In 1862 the Cunard Company obtained permission to fit mail steamers with propellers, which suffered less from the rolling of the ship, and the paddle-wheel was relegated to comparatively smooth water. The opening of the Suez Canal in 1869, together with the simultaneous introduction of the compound engine, raised steamships to superiority over sailing ships. In 1902 the turbine engine was employed on passenger steamers on the Clyde, and in 1905 was applied to the transatlantic service. This was followed by the introduction of the internal combustion engine.

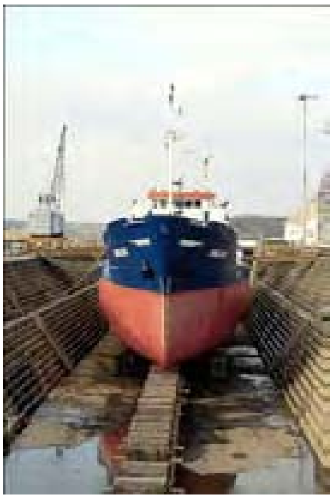
the Blue Riband of the Atlantic

In the early years of the 20th century magnificent ships were built, including the Cunard ship *Mauretania*, the ill-fated *Lusitania* (sunk by a German U-boat in World War I), and the 50,000 ton *Titanic*, which sank on its maiden voyage in 1912. The trophy for the fastest Atlantic crossing, the 'Blue Riband', has been held by many passenger liners, including the *Mauretania* (1909–29), the *Queen Mary* (1936, 1938–52), and the *United States* (1952–89). By 1939 Britain still had the largest merchant fleet in the world. The *Queen Mary* was completed in 1934 and the *Queen Elizabeth* in 1938. However, the world shipbuilding industry suffered from overproduction in the 1930s, and British shipbuilding declined, leading to the Jarrow Crusade in 1936, a protest at the high level of unemployment following the closure of the town's shipyard.

tankers

Following World War II, when reconstruction and industrial development created a great demand for oil, the tanker was developed to carry supplies to the areas of consumption. The shipyards of the world were flooded with orders for tankers; due to economic demands, the size of the tankers became increasingly large. The Suez Canal crisis in 1956, with its disruption of the free flow of the world's oil supplies, focused attention on the possibility of working giant tankers over the Cape route. The prolonged closure of the Suez Canal after 1967 and the great increase in oil consumption led to the development of the very large tanker, or 'supertanker'.

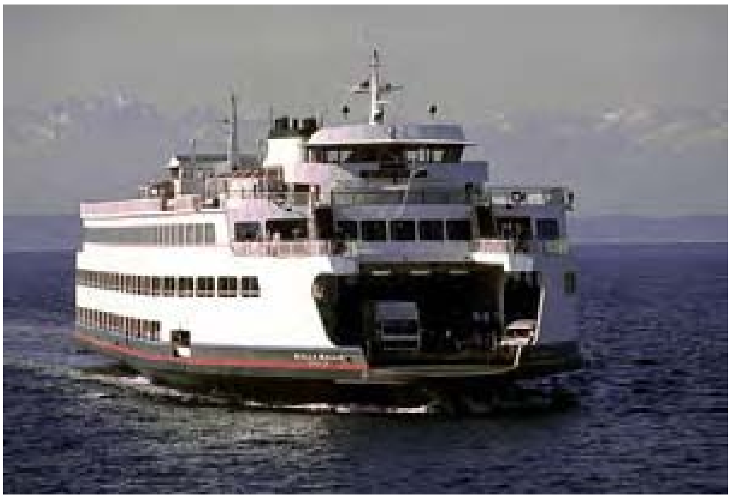
ship



(Image © Corel)

Ship repairs in dry dock in the UK. Ships are brought out of the water to check the condition of the hull, make repairs, and paint the exterior. Dry docks are also used for building new ships.

ship



(Image © Corel)

A vehicle and passenger ferry in Seattle, Washington, USA. The Olympic Mountains can be seen in the background.

ship

(Image © Research Machines plc)

The Gorch Fock is a steel-hulled sailing ship that serves as a training ship for the German Navy. It was built in 1958 at the Hamburg dockyard by the firm of Blohm Voss. Gorch Fock was the alias of the German poet, Johann Kienau, who was born in Hamburg-Finkenwerder in 1880 and died at the Battle of Jutland on 31st May 1916.

ship

(Image © Research Machines plc)

A ship awaiting repair, at Falmouth Docks. The great natural harbour at Falmouth was first exploited in the late 17th century. For more than a hundred years, until the early 19th century, the town was a station for the mail packet service, which carried mail to the Americas and the Mediterranean. Today, the docks are still an important centre for ship repairs, but otherwise the town's main industry is tourism.

Great voyages: key dates

1253-55	Willem van Ruysbroeck of France travels overland to the capital of the Mongolian Empire at Karakorum.
1260-69	The Venetian travellers Nicolo and Maffeo Polo explore central Asia and China.
1271	Marco Polo joins the next expedition to China and stays there in the service of the Khan until 1292. His written account of his experiences does much to inspire European interest in travel.
1325	Giovanni di Montecorvino becomes the first European to visit Tibet, during his travels across Asia.
1325-55	Ibn Battutah, an Arab of Tangier, travels extensively in central Africa, Arabia, and Indonesia.
1340s	Europeans possibly reach Senegal by sea.
1405-33	Zheng He leads Chinese exploration south of China and in the Indian Ocean as far west as Africa.
c. 1430s	Arab merchants begin to gain knowledge of the interior of southern Africa.
1440-60	Prince Henry the Navigator of Portugal sponsors voyages by Portuguese explorers to expand his country's wealth and power.
1440s	Inca explorers start to move outward along the Pacific coast.
1445	A Portuguese expedition under Dinas Dias sails down the African coast as far as Senegal.
1481-95	King John II of Portugal makes discovery of routes to India a priority for Portuguese explorers.
1487	Bartolomeu Diaz, a Portuguese explorer, rounds the Cape of Good Hope (then known as the Cape of Storms) and proves a sea voyage to India is possible.
1492	Christopher Columbus, attempting to reach China from the west, lands in the Bahamas and Hispaniola instead, becoming the first European in the 'West Indies'.
1493-94	Columbus travels again to the Caribbean.
1497	Vasco da Gama reaches India via the Cape and the East African coast.
1497	John Cabot sails westwards from Ireland and lands on Newfoundland. He disappears on a second voyage a year later.
1498	Columbus travels to Trinidad and Venezuela.
1499	Amerigo Vespucci explores the northern part of the South American continent. The area is named 'America' in about 1507.
1500	Pedro Alvarez Cabral runs into the Brazilian coast while heading for India.
1506-08	New maps, such as that of Ruysch, attempt to incorporate knowledge gained from European explorations.
1519-22	One ship of a fleet captained by Magellan achieves the first circumnavigation of the globe - although Magellan dies en route in 1521. The 'Age of Discovery' is often considered to end at this point.
1534	Jacques Cartier navigates the St Lawrence River while searching for a North West Passage.
1553	Willoughby attempts to sail north of Russia to reach China (the North East passage). Other attempts follow.
1577-80	Sir Francis Drake circumnavigates the globe and explores up and down the coast of California.
1610s	Accounts of landings on the Australian coast start to circulate in Europe.

1642	A Dutch sailor, Abel Tasman, explores New Zealand and Tasmania. Later he also sails along the north coast of Australia.

Ships: key dates

8000-7000 BC	Reed boats are developed in Mesopotamia and Egypt; dugout canoes are used in northwest Europe.
4000-3000	The Egyptians use single-masted square-rigged ships on the Nile.
1200	The Phoenicians build keeled boats with hulls made of wooden planks.
1st century BC	The Chinese invent the rudder.
AD 200	The Chinese build ships with several masts.
200-300	The Arabs and Romans develop fore-and-aft rigging that allows boats to sail across the direction of the wind.
800-900	Square-rigged Viking longboats cross the North Sea to Britain, the Faroe Islands, and Iceland.
1090	The Chinese invent the magnetic compass.
1400-1500	Three-masted ships are developed in Western Europe, stimulating voyages of exploration.
1535	A group of Italians use a primitive glass diving bell to explore the wrecks of sunken ships on the bed of Lake Nemi near Rome, Italy.
1596	Visunsin, a Korean naval commander, invents the first ironclad battleship.
1620	Dutch engineer Cornelius Drebbel invents the submarine.
1775	US engineer David Bushnell builds a hand-powered submarine, *Turtle*, with buoyancy tanks.
1777	The first boat with an iron hull is built in Yorkshire, England.
1783	Frenchman Jouffroy d'Abbans builds and tests the first paddle-driven steamboat.
1787	American inventor John Fitch demonstrates the first steamboat in the western hemisphere on the Delaware River at Philadelphia, Pennsylvania.
1797	Fitch applies a screw propeller to his steamboat.
1802	Scottish engineer William Symington launches the first stern paddle-wheel steamer, the *Charlotte Dundas*.
1807	The first practical and economically successful steamboat, the *Clermont*, designed by US engineer and inventor Robert Fulton, sails between New York and Albany.
1811	Fulton designs and builds the *Chancellor Livingston*, a ship 49 m/161 ft long drawing its power from a 60-horsepower steam engine.
1819	US inventor Joseph Francis develops an 'unsinkable' lifeboat with hydrogen-filled buoyancy tanks
1823	US inventor Samuel Morey begins building the *Aunt Sallie*, a boat powered by an early form of internal-combustion engine. The vessel sinks sometime before Morey's death in 1843.
1836	The English inventor Francis Pettit Smith patents the screw propeller in the UK. Shortly afterwards, in the same year, the Swedish inventor John Ericsson also patents a screw propeller.
1837	English engineer Isambard Kingdom Brunel completes the ship *Great Western*, the first steamship built for crossing the Atlantic Ocean regularly.
1838	The steamship *Sirius* makes the first crossing of the Atlantic under steam power alone. It travels from London to New York in 18 days. The steamship *Great Western* makes its maiden voyage later the same year, sailing from Bristol to New York in 15 days.
1845	*Great Britain*, another vessel built by Isambard Kingdom Brunel, becomes the first propeller-driven iron ship to cross the Atlantic.
1845	The first clipper ship, *Rainbow*, is launched in the USA.
1863	*Plongeur*, the first submarine powered by an air-driven engine, is launched in France.
1866	The British clippers *Taeping* and *Ariel* sail, laden with tea, from China to London in 99 days.
1883	German engineer Gottlieb Daimler constructs his first high-speed internal-combustion engine and installs it in a boat.
1897	English engineer Charles Parsons fits a steam turbine to the ship *Turbinia*, making it the fastest boat of the time.
1900	Irish-American John Philip Holland designs the first modern submarine *Holland VI*, fitted with an electric motor for underwater sailing and an internal-combustion engine for surface travel; Enrico Forlanini of Italy builds the first hydrofoil.
1902	The French ship *Petit-Pierre* becomes the first boat to be powered by a diesel engine.
1905	A US inventor, Cameron B Waterman, patents and demonstrates the first outboard motor. In Germany, the first U-boat is launched.
1908	US inventor Elmer Ambrose Sperry patents gyrostabilization, the manipulation of gyroscopes in ships as a means of reducing roll.
1911	Elmer Ambrose Sperry patents the gyrocompass. It is first installed in a merchant ship in 1919.
1912	The liner *Titanic* sinks after a collision with an iceberg in the north Atlantic on its maiden voyage. Designed with separate watertight compartments, the ship is considered unsinkable, but the collision produces a large gash in its side, flooding enough compartments to make it impossible for it to stay afloat.
1948	Swiss-born Belgian Auguste Piccard builds his first bathyscaphe for deep undersea exploration.
1955	The first nuclear-powered submarine, *Nautilus*, is built in the USA; the hovercraft is patented by British inventor Christopher Cockerell.
1959	The first nuclear-powered surface ship, the Soviet ice-breaker *Lenin*, is commissioned; the US *Savannah* becomes the first nuclear-powered merchant (passenger and cargo) ship.
1968	The first supertankers for the bulk transportation of oil and petroleum come into service. A regular hovercraft service across the English Channel comes into operation.
1980	Launch of the first wind-assisted commercial ship for half a century, the Japanese tanker *Shin-Aitoku-Maru*.
1983	German engineer Ortwin Fries invents a hinged ship designed to bend into a V-shape in order to scoop up oil spillages in its jaws.
1986	Launch of the ship *Windstar*. The sails on its four 62-m/204-ft masts are under the control of a computer.
1989	*Gentry Eagle* sets a record for the fastest crossing of the Atlantic in a power vessel, taking 2 days, 14 hours, and 7 minutes.

1990	*Hoverspeed Great Britain*, a wave-piercing catamaran, crosses the Atlantic in 3 days, 7 hours, and 52 minutes, setting a record for the fastest crossing by a passenger vessel. Hoverspeed also begins operating a car ferry service across the English Channel using the catamaran SeaCat. The world's largest car and passenger ferry, the *Silja Serenade*, enters service between Stockholm and Helsinki, carrying 2,500 passengers and 450 cars.
1992	The Japanese propellerless ship *Yamato* driven by magnetohydrodynamics completes its sea trials. The ship uses magnetic forces to suck in and eject sea water like a jet engine.
1997	The biggest cruise ship ever, the *Carnival Destiny*, is launched. It is as long as three football pitches, taller than the Statue of Liberty, and too wide to pass through the Panama Canal. US researchers test a new type of submersible (small submarine) with wings, which can turn, dive, and roll like an aeroplane.
2000	The English cross-Channel car-ferry company Hoverspeed ends its hovercraft service after 22 years. The decade-old SeaCat service continues.
2004	Cunard's *Queen Mary 2*, the new world's largest cruise ship, makes its maiden voyage from Southampton. The *Queen Mary 2* weighs over 151,000 gross tons.
2006	The *Freedom of the Seas*, owned by Royal Caribbean takes over as the world's largest cruise ship.

Hellsmouth Diving and Shipwreck site

Go to site

An introductory guide to diving and diving related topics in the county of Caithness, the most northerly county on the mainland of Scotland. It provides a brief description of the most popular wreck sites with details of how and when the ships sank.

Monsters of the Sea - The Great Ocean Liners of Time

Go to site

Tells the stories of ships such as the *Titanic*, *Aquitania*, and *Lusitania*, through ship specifications, pictures, and supporting text.

Titanic's Lost Sister

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page documents the sinking during World War I of the *Britannic*. You will find information and images about the search and salvage operations, plus a transcript of the *Nova* interview with Dr Robert Ballard, President of the Institute for Exploration. This site provides insight into advances in shipbuilding that followed the wreck of the *Britannic* 's sister ship the *Titanic*, including those safety improvements implemented on the doomed *Britannic* itself, as well as information regarding advances made since World War I. There is also a list of resources for further research.

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shock

in medicine, circulatory failure marked by a sudden fall of blood pressure and resulting in pallor, sweating, fast (but weak) pulse, and sometimes complete collapse. Causes include disease, injury, and psychological trauma.

In shock, the blood pressure falls below that necessary to supply the tissues of the body, especially the brain. Treatment depends on the cause. Rest is needed, and, in the case of severe blood loss, restoration of the normal circulating volume.

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shock absorber

in technology, any device for absorbing the shock of sudden jarring actions or movements. Shock absorbers are used in conjunction with coil springs in most motor-vehicle suspension systems and are usually of the telescopic type, consisting of a piston in an oil-filled cylinder. The resistance to movement of the piston through the oil creates the absorbing effect.

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shock wave

narrow band or region of high pressure and temperature in which the flow of a fluid changes from subsonic to supersonic.

Shock waves are produced when an object moves through a fluid at a supersonic speed. See sonic boom.

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shoebill

or whale-headed stork

large, grey, long-legged, swamp-dwelling African bird *Balaeniceps rex*. Up to 1.5 m/5 ft tall, it has a large wide beak 20 cm/8 in long and more than 10 cm/4 in wide, with which it scoops fish, molluscs, reptiles, and carrion out of the mud. Shoebills occupy largish territories of several square kilometres and build their nests on floating mats of vegetation, approximately 1.5 m in diameter.

In 1998 there were approximately 10,000-15,000 shoebills in Africa. They are the only species in the family Balaenicipitidae of the order Ciconiiformes.

Shoemaker-Levy 9

comet that crashed into Jupiter in July 1994. The fragments crashed at 60 kps/37 mps over the period 16-22 July 1994. The impacts occurred on the far side of Jupiter, but the impact sites came into view of Earth about 25 minutes later. Analysis of the impacts shows that most of the pieces were solid bodies about 1 km/0.6 mi in diameter, but that at least three of them were clusters of smaller objects.

When first sighted on 24 March 1993 by US astronomers Carolyn and Eugene Shoemaker and David Levy, it was found to consist of at least 21 fragments in an unstable orbit around Jupiter. It is believed to have been captured by Jupiter in about 1930, and fragmented by tidal forces on passing within 21,000 km/ 13,050 mi of the planet in July 1992.

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shoot

in botany, the parts of a vascular plant growing above ground, comprising a stem bearing leaves, buds, and flowers. The shoot develops from the plumule of the embryo.

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shooting star

another name for a meteor.

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short circuit

unintended direct connection between two points in an electrical circuit. Resistance is proportional to the length of wire through which current flows. By bypassing the rest of the circuit, the short circuit has low resistance and a large current flows through it. This may cause the circuit to overheat dangerously.

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shoveler

fresh-water duck *Anas clypeata*, family Anatidae, order Anseriformes, so named after its long and broad flattened beak used for filtering out small organisms from sand and mud. The male has a green head, white and brown body plumage, black and white wings, greyish bill, orange feet, and can grow up to 50 cm/20 in long. The female is speckled brown. Spending the summer in northern Europe or North America, it winters further south.

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shrew

insectivorous mammal of the family Soricidae, order Insectivora, found in the Americas and Eurasia. It is mouselike, but with a long nose and pointed teeth. Its high metabolic rate means that it must eat almost constantly.

The **common shrew** *Sorex araneus* is about 7.5 cm/3 in long with a long, supple, pointed snout bearing numerous stiff hairs projecting beyond the lower jaw; its fur is reddish-grey above and greyish beneath. It has glands which secrete a strong, unpleasant odour as a means of defence. It feeds on insects, worms, and often on members of its own kind killed after a fight.

shrew: chromosomes

The number of chromosomes in the cells of common shrews varies from 20-25 in females and 21-27 in males. They are the only mammals not to have a constant number of chromosomes.

shrew: smallest mammal

The smallest terrestrial mammal is the pygmy white-toothed shrew that weighs about 2 g/0.07 oz. Its heart beats about 1,200 times a minute and, to avoid starvation, it must feed at least every 3.5 hours, day and night.

Shrew(-ists) Site

Go to site

Splendid site for the shrew enthusiast that includes images, details of current research, a newsletter, and facts, stories and myths about this animal. There is even a shrew gift shop!

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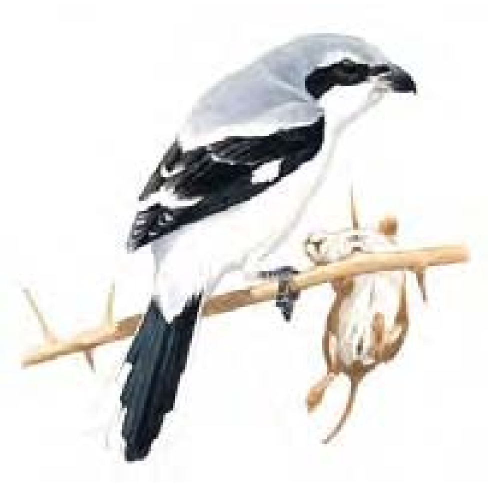
shrike

or butcher-bird

bird of the family Laniidae, of which there are over 70 species, living mostly in Africa, but also in Eurasia and North America. They often impale insects and small vertebrates on thorns. They can grow to 35 cm/14 in long, have grey, black, or brown plumage, sharply clawed feet, and hooked beaks.

shrike



(Image © Research Machines plc)

The great grey shrike. Shrikes are often referred to as 'butcher birds' because of their habit of impaling their prey on thorns in a gruesome larder. Shrikes are found in a variety of habitats in many parts of the world. As well as insects, shrikes will attack and kill small mammals, reptiles, amphibians, and even other birds.

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shrimp

crustacean related to the prawn. It has a cylindrical, semi-transparent body, with ten jointed legs. Some shrimps grow as large as 25 cm/10 in long.

The European common shrimp *Crangon vulgaris* is greenish, translucent, has its first pair of legs ending in pincers, possesses no rostrum (the beaklike structure which extends forwards from the head in some crustaceans), and has comparatively shorter antennae than the prawn.

Synalpheus regalis, a shrimp that lives within sponges in the coral reefs of Belize, was discovered in 1996 to live in social colonies with a structure resembling that of social insects, such as ants. All are the offspring of a single reproductive female; care of young is cooperative; and larger individuals act to defend the colony.

shrimp

The penis of the male Antarctic opossum shrimp is almost the same length as his entire body. Moreover, he has not just one penis but two.

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shrub

perennial woody plant that typically produces several separate stems, at or near ground level, rather than the single trunk of most trees. A shrub is usually smaller than a tree, but there is no clear distinction between large shrubs and small trees.

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shunt

in electrical engineering, a conductor of very low resistance that is connected in parallel to an ammeter in order to enable it to measure larger electric currents. Its low resistance enables it to act like a bypass, diverting most of the current through itself and away from the ammeter.

SI

abbreviation for **Système International d'Unités** (French 'International System of Metric Units'); see SI units.

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sial

in geochemistry and geophysics, the substance of the Earth's continental crust, as distinct from the sima of the ocean crust. The name, now used rarely, is derived from **si**lica and **al**umina, its two main chemical constituents. Sial is often rich in granite.

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siamang

the largest gibbon*Symphalangus syndactylus*, native to Malaysia and Sumatra. Siamangs have a large throat pouch to amplify the voice, making the territorial 'song' extremely loud.

They are black-haired, up to 90 cm/3 ft tall, with very long arms (a span of 150 cm/5 ft).

Siamese fighting fish

beautiful freshwater fish noted for its colour and elaborate behavioural displays. The male builds a nest of bubbles and looks after the eggs.

classification

The Siamese fighting fish *Betta splendens* is in family Belontidae, order Perciformes, class Osteichthyes.

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sick building syndrome

malaise diagnosed in the early 1980s among office workers and thought to be caused by such pollutants as formaldehyde (from furniture and insulating materials), benzene (from paint), and the solvent trichloroethene, concentrated in air-conditioned buildings. Symptoms include headache, sore throat, tiredness, colds, and flu. Studies have found that it can cause a 40% drop in productivity and a 30% rise in absenteeism.

Work on improving living conditions of astronauts showed that the causes were easily and inexpensively removed by potplants in which interaction is thought to take place between the plant and micro-organisms in its roots. Among the most useful are chrysanthemums (counteracting benzene), English ivy and the peace lily (trichloroethene), and the spider plant (formaldehyde).

Effect of selected indoor air pollutants on human health

Studies in Denmark and the USA have linked pollutants found in buildings with human symptoms such as dizziness, headaches, and fatigue. This is known as 'sick building syndrome'. New buildings are typically worse than old buildings, due to the release of chemicals from new furnishings, and reduced air exchange due to air conditioning. Some pollutants have a synergistic or 'cocktail' effect; for example, sulphur dioxide is much more harmful when particulates are present, as coated particles are transported directly to the lungs, where sulphur dioxide causes most harm.

Pollutant	Source	Potential threat
1,1,1-trichloroethane	aerosol sprays	dizziness, irregular breathing
asbestos	pipe insulation, ceiling and wall tiles	lung disease, lung cancer
carbon monoxide	faulty or unvented gas and paraffin heaters, wood stoves	headaches, drowsiness, irregular heartbeat; poisonous
formaldehyde	furniture stuffing, panelling, foam insulation	irritation of eyes, throat, skin, and lungs; dizziness
methylene chloride	paint strippers and thinners	nerve disorders, diabetes
nitrogen oxides	unvented gas and paraffin heaters, wood stoves	irritated lungs, headaches
radon-222	radioactive soil and rock foundations, water supply	lung cancer
styrene	carpets, plastic products	kidney and liver damage
sulphur dioxide	solid fuel heaters	in asthmatics, reduced lung function, chest tightness, and coughing
tetrachloroethylene	dry-cleaning-fluid fumes on clothes and carpets	nerve disorders, liver and kidney damage, cancer threat
tobacco smoke	cigarettes, cigars	lung cancer, respiratory ailments, heart disease

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sickle

harvesting tool of ancient origin characterized by a curving blade with serrated cutting edge and short wooden handle. It was widely used in the Middle East and Europe for cutting wheat, barley, and oats from about 10,000 BC to the 19th century.

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sickle-cell disease

or sickle-cell anaemia

hereditary chronic blood disorder common among people of black African descent; also found in the eastern Mediterranean, parts of the Gulf, and in northeastern India. It is characterized by distortion and fragility of the red blood cells, which are lost too rapidly from the circulation. This often results in anaemia.

People with this disease have abnormal red blood cells (sickle cells), containing defective haemoglobin. The presence of sickle cells in the blood is called **sicklemia**. The disease is caused by a recessive allele.

Those with two copies of the allele suffer debilitating anaemia; those with a single copy paired with the normal allele, suffer with only mild anaemia and have a degree of protection against malaria because fewer normal red blood cells are available to the parasites for infection.

In the USA there were approximately 65,000 African-Americans suffering from sickle-cell disease in 1996; there were about 5,500 British sufferers. Worldwide, 100,000 babies are born with the disease annually. Those born in developing countries are unlikely to survive for long.

Bone marrow transplantation can provide a cure, but the risks (a fatality rate of 10% and a complications rate of 20%) are so great that it is only an option for the severely ill. US researchers announced in April 1995 that patients treated with a drug called hydroxyurea showed a reduction in the number of sickle cells. The drug works by reducing the amount of defective haemoglobin produced, and reviving the production of fetal haemoglobin. Fetal haemoglobin is not affected by sickling. Partial (40%) bone marrow transplants used during early 2001 in sickle-cell treatment trials in the USA also proved successful in combating the disease.

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sidereal period

orbital period of a planet around the Sun, or a moon around a planet, with reference to a background star. The sidereal period of a planet is in effect a 'year' for that planet. A synodic period is a full circle as seen from Earth; for example, the period from new moon to new moon is the Moon's synodic period.

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sidereal time

in astronomy, time measured by the rotation of the Earth with respect to the stars. A sidereal day is the time taken by the Earth to turn once with respect to the stars, namely 23 hours 56 minutes 4 seconds. It is divided into sidereal hours, minutes, and seconds, each of which is proportionally shorter than the corresponding SI unit.

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sidewinder

rattlesnake *Crotalus cerastes* that lives in the deserts of the southwestern USA and Mexico, and moves by throwing its coils into a sideways 'jump' across the sand. It can grow up to 75 cm/30 in long.

Siding Spring Mountain

peak 400 km/250 mi northwest of Sydney, site of the 1.2-m/48-in UK Schmidt Telescope, opened in 1973, and the 3.9-m/154-in **Anglo-Australian Telescope**, opened in 1975, which was the first large telescope to be fully computer-controlled. It is one of the most powerful telescopes in the southern hemisphere.

Mount Stromlo and Siding Spring Observatories

Go to site

Searchable site of Australia's leading observatories. In addition to scientific data of interest only to astronomers, there is general information on current research, downloadable images of space, and information about the observatories.

SIDS

acronym for **sudden infant death syndrome**, the medical name for cot death.

---

siemens

symbol S

SI unit of electrical conductance, the reciprocal of the resistance of an electrical circuit. One siemens equals one ampere per volt. It was formerly called the mho or reciprocal ohm.

---

sievert

symbol Sv

SI unit of radiation dose equivalent. It replaces the rem (1 Sv equals 100 rem). Some types of radiation do more damage than others for the same absorbed dose - for example, an absorbed dose of alpha radiation causes 20 times as much biological damage as the same dose of beta radiation. The equivalent dose in sieverts is equal to the absorbed dose of radiation in grays multiplied by the relative biological effectiveness. Humans can absorb up to 0.25 Sv without immediate ill effects; 1 Sv may produce radiation sickness; and more than 8 Sv causes death.

Sigma Octantis

star closest to the south celestial pole (see celestial sphere), in effect the southern equivalent of Polaris, although far less conspicuous. Situated approximately 1° from the south celestial pole in the constellation Octans, Sigma Octantis is about 270 light years away from the Sun.

---

signal

any sign, gesture, sound, or action that conveys information.

Examples include the use of flags (semaphore), light (traffic and railway signals), radio telephony, radio telegraphy (Morse code), and electricity (telecommunications and computer networks).

The International Code of Signals used by shipping was drawn up by an international committee and published 1931. The codes and abbreviations used by aircraft are dealt with by the International Civil Aviation Organization, established in 1944.

---

signal-to-noise ratio

ratio of the power of an electrical signal to that of the unwanted noise accompanying the signal. It is expressed in decibels.

In general, the higher the signal-to-noise ratio, the better. For a telephone, an acceptable ratio is 40 decibels; for television, the acceptable ratio is 50 decibels.

---

significant figures

figures in a number that, by virtue of their position, express the magnitude of that number to a specified degree of accuracy. In a number, the first significant figure is the first figure that is not a 0. The final significant figure is rounded up if the following digit is greater than 5. For example, 5,463,254 to three significant figures is 5,460,000; 3.462891 to four significant figures is 3.463; 0.00347 to two significant figures is 0.0035.

Sikorsky, Igor Ivan (1889-1972)

Ukrainian-born US engineer. He built the first successful Helicopter in 1939 (commercially produced from 1943). His first biplane flew in 1910, and in 1929 he began to construct multi-engined flying boats.

The first helicopter was followed by a whole series of production designs using one, then two, piston engines. During the late 1950s piston engines were replaced by the newly developed gas-turbine engines.

Igor Sikorsky - One Man, Three Careers

Go to site

Features a large amount of information about Ukranian-born US engineer Igor Sikorsky, including sections on the development of the helicopter, the transoceanic flight, and the construction of the first multiengine aircraft. A number of photos accompany the sections.

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silage

fodder preserved through controlled fermentation in a silo, an airtight structure that presses green crops. It is used as a winter feed for livestock. The term also refers to stacked crops that may be preserved indefinitely.

silage

(Image © Research Machines plc)

Preparing natural materials for the production of silage. Silage is a fodder made of grass, corn, sunflowers, or other leafy material, which is preserved through fermentation in an airtight silo. A common winter feed for livestock, unlike hay silage can be harvested when ready, in almost all weather conditions. It also retains more nutrients per harvested acre when compared with other harvesting systems.

---

silica

silicon dioxide, SiO_2, the composition of the most common mineral group, of which the most familiar form is quartz. Other silica forms are chalcedony, chert, opal, tridymite, and cristobalite.

Common sand consists largely of silica in the form of quartz.

---

silicate

one of a group of minerals containing silicon and oxygen in tetrahedral units of SiO_4, bound together in various ways to form specific structural types. Silicates are the chief rock-forming minerals. Most rocks are composed, wholly or in part, of silicates (the main exception being limestones). Glass is a manufactured complex polysilicate material in which other elements (boron in borosilicate glass) have been incorporated.

Generally, additional cations are present in the structure, especially Al^{3+}, Fe^{2+}, Mg^{2+}, Ca^{2+}, Na^+, K^+, but quartz and other polymorphs of SiO_2 are also considered to be silicates; stishovite (a high-pressure form of SiO_2) is a rare exception to the usual tetrahedral coordination of silica and oxygen.

In **orthosilicates**, the oxygens are all ionically bonded to cations such as Mg^{2+} or Fe^{2+} (as olivines), and are not shared between tetrahedra. All other silicate structures involve some degree of oxygen sharing between adjacent tetrahedra. For example, beryl is a **ring silicate** based on tetrahedra linked by sharing oxygens to form a circle. Pyroxenes are single **chain silicates**, with chains of linked tetrahedra extending in one direction through the structure; amphiboles are similar but have double chains of tetrahedra. In micas, which are **sheet silicates**, the tetrahedra are joined to form continuous sheets that are stacked upon one another.
Framework silicates, such as feldspars and quartz, are based on three-dimensional frameworks of tetrahedra in which all oxygens are shared.

---

silicon

chemical symbol Si

(Latin silex 'flint')

brittle, non-metallic element, atomic number 14, relative atomic mass 28.086. It is the second-most abundant element (after oxygen) in the Earth's crust and occurs in amorphous and crystalline forms. In nature it is found only in combination with other elements, chiefly with oxygen in silica (silicon dioxide, SiO_2) and the silicates. These form the mineral quartz, which makes up most sands, gravels, and beaches.

Pottery glazes and glassmaking are based on the use of silica sands and date from prehistory. Today the crystalline form of silicon is used as a deoxidizing and hardening agent in steel, and has become the basis of the electronics industry because of its semiconductor properties, being used to make 'silicon chips' for microprocessors.

The element was isolated by Swedish chemist Jöns Berzelius in 1823, having been named in 1817 by

Scottish chemist Thomas Thomson by analogy with boron and carbon because of its chemical resemblance to these elements.

silicon chip

integrated circuit with microscopically small electrical components on a piece of silicon crystal only a few millimetres square.

One chip may contain more than a million components. A chip is mounted in a rectangular plastic package and linked via gold wires to metal pins, so that it can be connected to a printed circuit board for use in electronic devices, such as computers, calculators, television sets, car dashboards, and domestic appliances.

silicon chip

The number of transistors on a single silicon chip increased by a factor of 16,000 in the period 1974-98.

Silicon Valley

nickname given to a region of southern California, USA, approximately 32 km/20 mi long, between Palo Alto and San Jose. It is the site of many high-technology electronic firms, whose prosperity is based on the silicon chip. Silicon Valley faces increasing competition from computer companies in Asia.

Revolutionaries of Silicon Valley

Go to site

Joint production of the Tech Museum of Innovation and the *San Jose Mercury News*, this site features interviews with many of Silicon Valley's top pioneers of technology. In addition to text of the interviews, you will find audio clips and an area for offering feedback.

Silicon Valley

Go to site

Brief exploration of the history of California's Silicon Valley, which was named after the brittle metalloid used in the manufacture of microprocessors.

silicosis

chronic disease of miners and stone cutters who inhale silica dust, which makes the lung tissues fibrous and less capable of aerating the blood. It is a form of pneumoconiosis.

silk-screen printing

or serigraphy

method of printing based on stencilling. It can be used to print on most surfaces, including paper, plastic, fabric, and wood. A fine mesh (originally silk) is stretched across a wooden frame to form the screen. An impermeable stencil (either paper or a photosensitized coating) is applied to it, so that the ink passes through to the area beneath only where an image is required. The design can also be painted directly on to the screen with varnish. Once the stencil is attached, the screen is placed on top of fabric. Printing ink or dye is then drawn across, transferring the design to the fabric. A series of screens can be used to add successive layers of colour to the design.

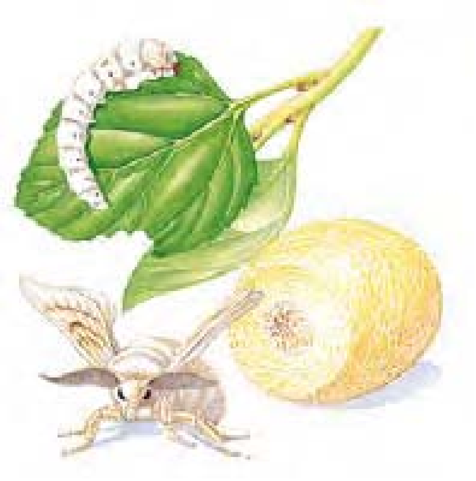
The process was developed in the early 20th century for commercial use and adopted by many artists from the 1930s onwards, most notably US artist Andy Warhol.

silkworm

usually the larva of the **common silkworm moth** *Bombyx mori*. After hatching from the egg and maturing on the leaves of white mulberry trees (or a synthetic substitute), it spins a protective cocoon of fine silk thread 275 m/900 ft long. To keep the thread intact, the moth is killed before emerging from the cocoon, and several threads are combined to form the commercial silk thread woven into textiles.

Other moths produce different fibres, such as **tussah** from *Antheraea mylitta*. The raising of silkworms is called **sericulture** and began in China in about 2000 BC. Chromosome engineering and artificial selection practised in Japan have led to the development of different types of silkworm for different fibres.

silkworm



(Image © Research Machines plc)

Despite its name, the silkworm is in fact the larva of a moth. Various species of the moth families Bombycidae and Saturniidae spin silken cocoons in which to pupate but the Chinese silkworm moth produces so much that it has been the basis of the eastern silk cloth industry for at least 2,000 years. Traditionally, the larvae are fed on white mulberry leaves.

---

sill

sheet of igneous rock created by the intrusion of magma (molten rock) between layers of pre-existing rock. (A dyke, by contrast, is formed when magma cuts *across* layers of rock.) An example of a sill in the UK is the Great Whin Sill, which forms the ridge along which Hadrian's Wall was built.

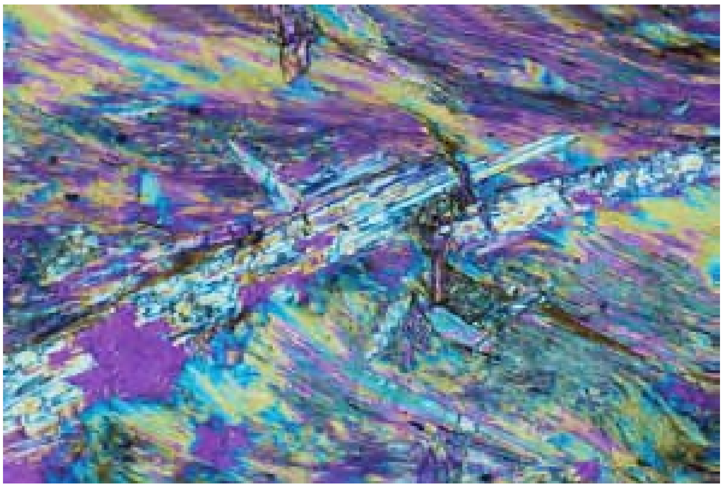
A sill is usually formed of **dolerite**, a rock that is extremely resistant to erosion and weathering, and often forms ridges in the landscape or cuts across rivers to create waterfalls.

---

sillimanite

aluminium silicate, Al_2SiO_5, a mineral that occurs either as white to brownish prismatic crystals or as minute white fibres. It is an indicator of high-temperature conditions in metamorphic rocks formed from clay sediments. Andalusite, kyanite, and sillimanite are all polymorphs of Al_2SiO_5.

sillimanite



(Image © Corel)

Sillimanite through a polarized microscope. Sillimanite is a translucent mineral that forms in metamorphic rocks.

---

silo

in farming, an airtight tower in which silage is made by the fermentation of freshly cut grass and other forage crops. In military technology, a silo is an underground chamber for housing and launching a ballistic missile.

silt

sediment intermediate in coarseness between clay and sand; its grains have a diameter of 0.002-0.02 mm/0.00008-0.0008 in. Silt is usually deposited in rivers, and so the term is often used generically to mean a river deposit, as in the silting-up of a channel.

Silurian Period

period of geological time 439-409 million years ago, the third period of the Palaeozoic era. Silurian sediments are mostly marine and consist of shales and limestone. Luxuriant reefs were built by coral-like organisms. The first land plants began to evolve during this period, and there were many ostracoderms (armoured jawless fishes). The first jawed fishes (called acanthodians) also appeared.

---

silver

chemical symbol Ag

white, lustrous, extremely malleable and ductile, metallic element, atomic number 47, relative atomic mass 107.868. Its chemical symbol comes from the Latin *argentum*. It occurs in nature in ores and as a free metal; the chief ores are sulphides, from which the metal is extracted by smelting with lead. It is the best metallic conductor of both heat and electricity; its most useful compounds are the chloride and bromide, which darken on exposure to light and are the basis of photographic emulsions.

Silver is used ornamentally, for jewellery and tableware, for coinage, in electroplating, electrical contacts, and dentistry, and as a solder. It has been mined since prehistory; its name is an ancient non-Indo-European one, *silubr*, borrowed by the Germanic branch as *silber*.

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silverfish

wingless insect, a type of bristletail.

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silver plate

silverware made by depositing a layer of silver on another metal, usually copper, by the process of electroplating.

---

sima

in geochemistry and geophysics, the substance of the Earth's oceanic crust, as distinct from the sial of the continental crust. The name, now used rarely, is derived from **si**lica and **ma**gnesia, its two main chemical constituents.

---

simple harmonic motion

SHM

oscillatory or vibrational motion in which an object (or point) moves so that its acceleration towards a central point is proportional to its distance from it. A simple example is a pendulum (provided its motion is restricted to small amplitudes). This also demonstrates another feature of SHM, that the maximum deflection is the same on each side of the central point.

A graph of the varying distance with respect to time is a sine curve, a characteristic of the oscillating current or voltage of an alternating current (AC), which is another example of SHM.

---

simultaneous equations

two or more algebraic equations that contain two or more unknown quantities that may have a unique solution. For example, in the case of two linear equations with two unknown variables, such as:

(i) $x + 3y = 6$

and

(ii) $3y - 2x = 4$

the solution will be those unique values of x and y that are valid for both equations. Linear simultaneous equations can be solved by using algebraic manipulation to eliminate one of the variables, coordinate geometry, or matrices (see matrix).

For example, by using algebra, both sides of equation (i) could be multiplied by 2, which gives $2x + 6y = 12$. This can be added to equation (ii) to get $9y = 16$, which is easily solved: $y = 16/9$. The variable x can now be found by inserting the known y value into either original equation and solving for x. Another method is by plotting the equations on a graph, because the two equations represent straight lines in coordinate geometry and the coordinates of their point of intersection are the values of x and y that are true for both of them. A third method of solving linear simultaneous equations involves manipulating matrices. If the equations represent either two parallel lines or the same line, then there will be no solutions or an infinity of solutions, respectively.

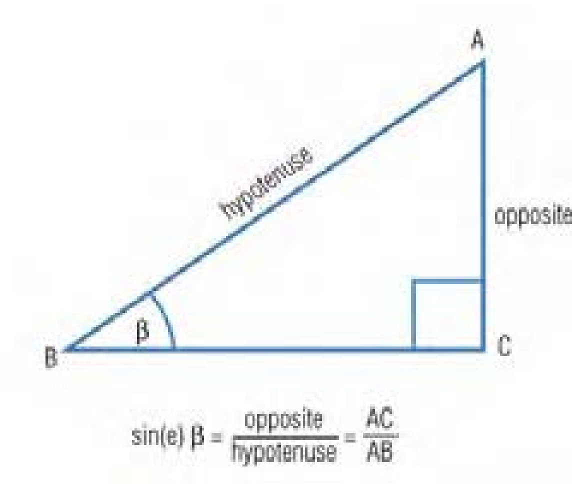
---

sine

sin

in trigonometry, a function of an angle in a right-angled triangle that is defined as the ratio of the length of the side opposite the angle to the length of the hypotenuse (the longest side). This function can be used to find either angles or sides in a right-angled triangle.

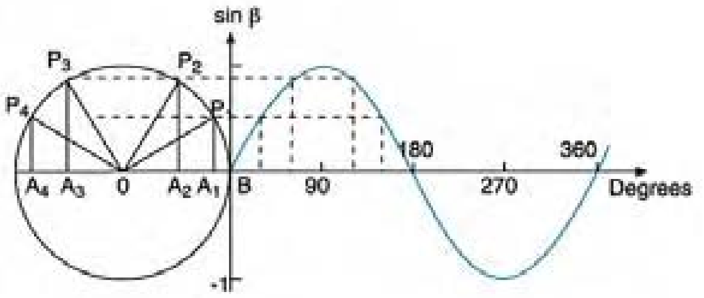
sine



(Image © Research Machines plc)

The sine is a function of an angle in a right-angled triangle found by dividing the length of the side opposite the angle by the length of the hypotenuse (the longest side). Sine (usually abbreviated sin) is one of the fundamental trigonometric ratios.

sine



(Image © Research Machines plc)

(left) The sine of an angle; (right) constructing a sine wave. The sine of an angle is a function used in the mathematical study of the triangle. If the sine of angle β is known, then the hypotenuse can be found given the length of the opposite side, or the opposite side can be found from the hypotenuse. Within a circle of unit radius (left), the height P_1A_1 equals the sine of angle P_1OA_1. This fact and the equalities below the circle allow a sine curve to be drawn, as on the right.

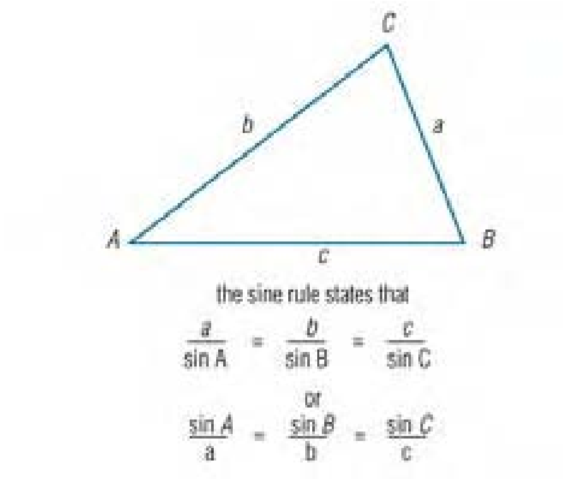
---

sine rule

in trigonometry, a rule that relates the sides and angles of a triangle, stating that the ratio of the length of each side and the sine of the angle opposite is constant (twice the radius of the circumscribing circle). If the sides of a triangle are *a*, *b*, and *c*, and the angles opposite are *A*, *B*, and *C*, respectively, then the sine rule may be expressed as

$a/\sin A = b/\sin B = c/\sin C$

sine rule


C
b
a
A
B
c
the sine rule states that
$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$
or
$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$

(Image © Research Machines plc)

The sine rule relates the sides and angles of a triangle, stating that the ratio of the length of each side and the sine of the angle opposite is constant.

---

sine wave

or sine curve

in physics, graph demonstrating properties that vary sinusoidally. It is obtained by plotting values of angles against the values of their sines. Examples include simple harmonic motion, such as the way alternating current (AC) electricity varies with time.

Singer, Isaac Merrit (1811-1875)

US inventor of domestic and industrial sewing machines. Within a few years of opening his first factory in 1851, he became the world's largest sewing-machine manufacturer (despite infringing the patent of Elias Howe), and by the late 1860s more than 100,000 Singer sewing machines were in use in the USA alone.

Single European Act

act signed in 1986 (and in force from July 1987) to establish a single European market, defined as an area without frontiers in which free movement of goods, services, people, and capital is ensured.

The act was the first major revision of the Treaties of Rome. It provided for greater involvement of the European Parliament in the decision-making process, and the introduction of qualified majority voting in the Council of Ministers (now the Council of the European Union) for some policy areas. In addition, it included provisions concerning collaboration in research and development and in environmental policy.

---

singularity

in astrophysics, point in space-time at which the known laws of physics break down. A singularity is predicted to exist at the centre of a black hole, where infinite gravitational forces compress the infalling mass of a collapsing star to infinite density. According to the Big Bang model of the origin of the universe, the expansion of the universe began from a singularity.

---

sinus

in biology, a sinus is a narrow cavity in the body. The paranasal sinuses in the skull communicate with the nose. Bacterial infection of these sinuses results in pain and inflammation and requires treatment with an antibiotic. Other examples of sinuses include the cavities in the membrane covering the brain through which the blood circulates.

---

sinusitis

painful inflammation of one of the sinuses, or air spaces, that surround the nasal passages. Most cases clear with antibiotics and nasal decongestants, but some require surgical drainage.

Sinusitis most frequently involves the maxillary sinuses, within the cheek bones, producing pain around the eyes, toothache, and a nasal discharge.

Childhood Infections - Sinusitis

Go to site

Useful information about sinusitis. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection, how it can be treated both at home and professionally, and what to do should the symptoms occur.

siphon

tube in the form of an inverted U with unequal arms. When it is filled with liquid and the shorter arm is placed in a tank or reservoir, liquid flows out of the longer arm provided that its exit is below the level of the surface of the liquid in the tank.

Theoretically a siphon can work in a vacuum, using a liquid that does not boil away and that has a cohesion (tensile strength) great enough to keep the column of liquid in the shorter arm unbroken. In practice, using ordinary, impure water, which has a low cohesion, the siphon relies on the atmospheric pressure on the reservoir surface to raise liquid to the height of the apex of the tube, replacing that falling from the long arm. This means that a siphon cannot raise water above about 76 cm/30 in, the height of a column of water that balances atmospheric pressure.

siphonogamy

plant reproduction in which a pollen tube grows to enable male gametes to pass to the ovary without leaving the protection of the plant.

Siphonogamous reproduction is found in all angiosperms and most gymnosperms, and has enabled these plants to reduce their dependency on wet conditions for reproduction, unlike the zoidogamous plants (see zoidogamy).

Sirius

or the Dog Star or Alpha Canis Majoris

brightest star in the night sky, 8.6 light years from the Sun in the constellation Canis Major. Sirius is a double star: Sirius A is a white star with a mass 2.3 times that of the Sun, a diameter 1.8 times that of the Sun, and a true luminosity of 23 Suns. It is orbited every 50 years by a white dwarf, Sirius B, also known as the Pup.

Sirius B is an eighth-magnitude companion which is sometimes known as 'the Dark Companion' as it was first detected in the 19th century by German astronomer Friedrich Bessel from its gravitational effect on the proper motion of Sirius A. 'Dog Star' is the alternative name for Sirius, dating back to ancient Egypt. The unpleasantness of the hot summer season known as the 'dog days' was attributed to the influence of Sirius being in conjunction with the Sun. Sirius B was seen for the first time in 1862 but it was only in the 1920s that it was recognized as the first known example of a white dwarf.

sirocco

hot, normally dry and dust-laden wind that blows from the deserts of North Africa across the Mediterranean into southern Europe. It occurs mainly in the spring. The name 'sirocco' is also applied to any hot oppressive wind.

sisal

strong fibre made from various species of agave, such as *Agave sisalina*.

siskin

North American finch *Carduelis pinus* with yellow markings or greenish-yellow bird *Carduelis spinus* about 12 cm/5 in long, found in Eurasia. They are members of the finch family Fringillidae, order Passeriformes.

sitatunga

herbivorous antelope *Tragelaphus spekei* found in several swamp regions in Central Africa. Its hooves are long and splayed to help progress on soft surfaces. It grows to about 1.2 m/4 ft high at the shoulder; the male has thick horns up to 90 cm/3 ft long.

Males are dark greyish-brown, females and young are chestnut, all with whitish markings on the rather shaggy fur.

SI units

French Système International d'Unités

standard system of scientific units used by scientists worldwide. Originally proposed in 1960, it replaces the m.k.s., c.g.s., and f.p.s. systems. It is based on seven basic units: the metre (m) for length, kilogram (kg) for mass, second (s) for time, ampere (A) for electrical current, kelvin (K) for temperature, mole (mol) for amount of substance, and candela (cd) for luminosity.

SI prefixes

To avoid the use of zeros in large or small numbers, prefixes are added to each of the International System of Units (SI) units to indicate multiples and submultiples of ten.

Multiple	Prefix	Symbol	Example
1,000,000,000,000,000,000,000,000 (10^{24})	yotta-	Y	Ym (yottametre)
1,000,000,000,000,000,000,000 (10^{21})	zetta-	Z	ZHz (zettahertz)
1,000,000,000,000,000,000 (10^{18})	exa-	E	Eg (exagram)
1,000,000,000,000,000 (10^{15})	peta-	P	PJ (petajoule)
1,000,000,000,000 (10^{12})	tera-	T	TV (teravolt)
1,000,000,000 (10^{9})	giga-	G	GW (gigawatt)
1,000,000 (10^{6})	mega-	M	MHz (megahertz)
1,000 (10^{3})	kilo-	k	kg (kilogram)
100 (10^{2})	hecto-	h	hm (hectometre)
10 (10^{1})	deca-	da	daN (decanewton)
1/10 (10^{-1})	deci-	d	dC (decicoulomb)
1/100 (10^{-2})	centi-	c	cm (centimetre)
1/1,000 (10^{-3})	milli-	m	mm (millimetre)
1/1,000,000 (10^{-6})	micro-	μ	μF (microfarad)
1/1,000,000,000 (10^{-9})	nano-	n	nm (nanometre)
1/1,000,000,000,000 (10^{-12})	pico-	p	ps (picosecond)
1/1,000,000,000,000,000 (10^{-15})	femto-	f	frad (femtoradian)
1/1,000,000,000,000,000,000 (10^{-18})	atto-	a	aT (attotesla)
1/1,000,000,000,000,000,000,000 (10^{-21})	zepto-	z	zs (zeptosecond)
1/1,000,000,000,000,000,000,000,000 (10^{-24})	yocto-	y	ym (yoctometre)

SI units

The table lists the International System of Units (SI) units.

Quantity	SI unit	Symbol
Base units		
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature, thermodynamic	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd
Derived units		
absorbed radiation dose	gray	Gy
electric capacitance	farad	F
electric charge	coulomb	C
electric conductance	siemens	S
energy or work	joule	J
force	newton	N
frequency	hertz	Hz
illuminance	lux	lx
inductance	henry	H
luminous flux	lumen	lm
magnetic flux	weber	Wb
magnetic flux density	tesla	T

plane angle	radian	rad
potential difference	volt	V
power	watt	W
pressure	pascal	Pa
radiation dose equivalent	sievert	Sv
radiation exposure	roentgen	R
radioactivity	becquerel	Bq
resistance	ohm	Ω
solid angle	steradian	sr
sound intensity	decibel	dB
temperature	degree Celsius	°C

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skate

any of several species of flatfish of the ray group. The common skate *Raja batis* is up to 1.8 m/6 ft long and greyish, with black specks. Its egg cases ('mermaids' purses') are often washed ashore by the tide.

---

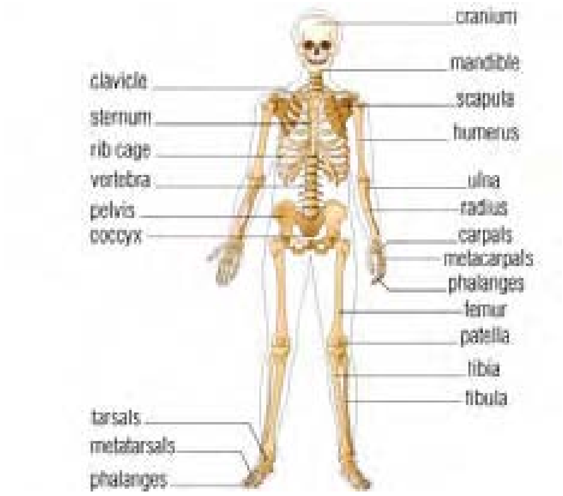
skeleton

framework of bones that supports and gives form to the body, protects its internal organs, and provides anchorage points for its muscles. It is composed of about 200 bones. Each bone is made of a mineral, calcium phosphate, and protein. Bones of the skeleton are joined to each other by ligaments. In the human body, walking, running, arm and leg movements, hand actions, and even just standing, are all achieved by the operation of muscles attached to bones of the skeleton. Movement of the body is brought about by the moveable joints of the body. The elbow joint is a good example. Muscles are attached to bones by tendons, and contractions of the muscle bring about movement.

The skeleton may be composed of bone and cartilage (vertebrates), chitin (arthropods), calcium carbonate (molluscs and other invertebrates), or silica (many protists). The human skeleton is composed of 206 bones, with the vertebral column (spine) forming the central supporting structure.

A skeleton may be internal, forming an endoskeleton, or external, forming an exoskeleton, as in the shells of insects or crabs. Another type of skeleton, found in invertebrates such as earthworms, is the hydrostatic skeleton. This gains partial rigidity from fluid enclosed within a body cavity. Because the fluid cannot be compressed, contraction of one part of the body results in extension of another part, giving peristaltic motion.

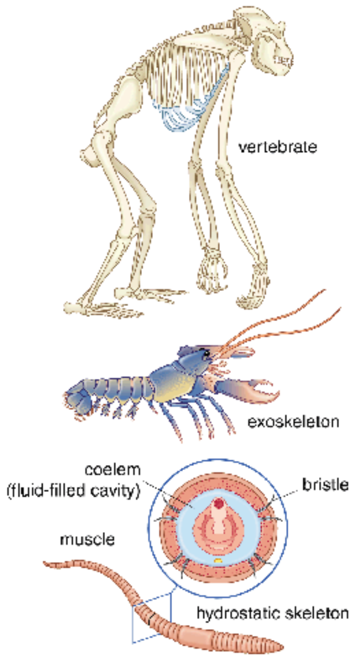
skeleton



(Image © Research Machines plc)

The human skeleton is made up of 206 bones and provides a strong but flexible supportive framework for the body.

skeleton



(Image © Research Machines plc)

Different types of skeleton. Vertebrate skeletons (top) are made of bone and cartilage and provide a scaffold for the flesh. Only in certain parts (for example the skull and the rib cage) are organs encased totally. A gorilla is shown here. Invertebrates may have an exoskeleton, made of chitin, as in insects and crustacea, such as the lobster (middle). The exoskeleton totally encases the animal and is periodically moulted to allow growth. Molluscs, worms, and other 'soft' invertebrates have a hydrostatic 'skeleton' that supports the body and facilitates locomotion. A cross-section of the fluid-filled cavity of an earthworm is shown below.

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skin

covering of the body of a vertebrate. In mammals, the outer layer (epidermis) is dead and its cells are constantly being rubbed away and replaced from below; it helps to protect the body from infection and to prevent dehydration. The lower layer (dermis) contains blood vessels, nerves, hair roots, and sweat and sebaceous glands (producing oil), and is supported by a network of fibrous and elastic cells. The medical speciality concerned with skin diseases is called dermatology.

The skin helps to protect the body from drying out. It is waterproof and covered with dry, dead cells, so little water is lost from skin cells. However, water is lost from a human body when the body sweats. The skin helps to regulate body temperature. Body temperature is monitored and controlled by the thermoregulatory centre in the brain. This centre has special cells sensitive to the temperature of blood flowing through the brain (receptors). Temperature receptors in the skin also send nerve impulses to this centre giving information about skin temperature.

If the body temperature is too high blood vessels supplying the skin capillaries expand (dilate) so that more blood flows through the capillaries and more heat is lost. To further assist heat loss sweat glands release sweat, which cools the body as it evaporates.

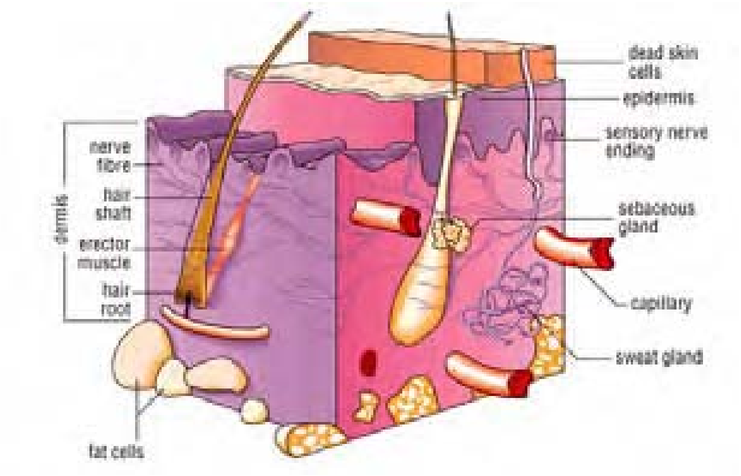
If the body temperature is too low blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries.

Other than measuring the temperature, the skin senses the environment in several other ways. Some receptors in the skin are sensitive to touch and pressure. If they are stimulated, nerve impulses are sent to the brain carrying information. It also protects the body from disease-causing organisms, which find it hard to penetrate the skin.

skin

Each person sheds an average of 18 kg/40lb of skin in a lifetime. The outer layer of skin - the epidermis - consists entirely of dead cells that fall off and are replaced by the level below.

skin



(Image © Research Machines plc)

The skin of an adult man covers about 1.9 sq m/20 sq ft; a woman's skin covers about 1.6 sq m/17 sq ft. During our lifetime, we shed about 18 kg/40 lb of skin.

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skin graft

in medicine, an operation in which large areas of damaged skin are replaced by skin from other areas of the body, usually from the arm or the thigh.

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skink

lizard of the family Scincidae, a large family of about 700 species found throughout the tropics and subtropics. The body is usually long and the legs are reduced. Some skinks are legless and rather snakelike. Many are good burrowers, or can 'swim' through sand, like the **sandfish** genus *Scincus* of North Africa. Some skinks lay eggs, others bear live young.

Skinks include the **three-toed skink** *Chalcides chalcides* of southern Europe and northwest Africa, up to 40 cm/16 in long, of which half is tail, and the **stump-tailed skink** *Tiliqua rugosa* of Australia, which stores fat in its triangular tail, looks the same at either end, and feeds on fruit as well as small animals. A new skink genus was identified in the rainforest of the Philippine Islands and described in 1997. There are two species of **moist forest skink** *Parvoscinus*. They lack external ear openings and females have only one oviduct and lay a single egg.

Skinner, B(urrhus) F(rederic) (1904-1990)

US psychologist. He was a radical behaviourist who rejected mental concepts, seeing the organism as a 'black box' where internal processes are not significant in predicting behaviour. He studied operant conditioning (influencing behaviour patterns by reward or punishment) and held that behaviour is shaped and maintained by its consequences.

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skua

dark-coloured gull-like seabird, living in Arctic and Antarctic waters. Skuas can grow up to 60 cm/2 ft long, with long, well-developed wings and short, stout legs; in colour they are greyish above and white below. They are aggressive scavengers, and seldom fish for themselves but force gulls to disgorge their catch, and also eat chicks of other birds. Skuas are in the family Stercorariidae, order Charadriiformes.

The largest species is the **great skua** *Stercorarius skua* of the North Atlantic, 60 cm/2 ft long and dark brown on the upper parts.

Antarctic skuas *Catharacta antarctica* nest near the penguin colonies they feed on, and are as aggressive in defending their own nests as they are in defending their local penguin colony from other predators. They fly north during the Antarctic winter.

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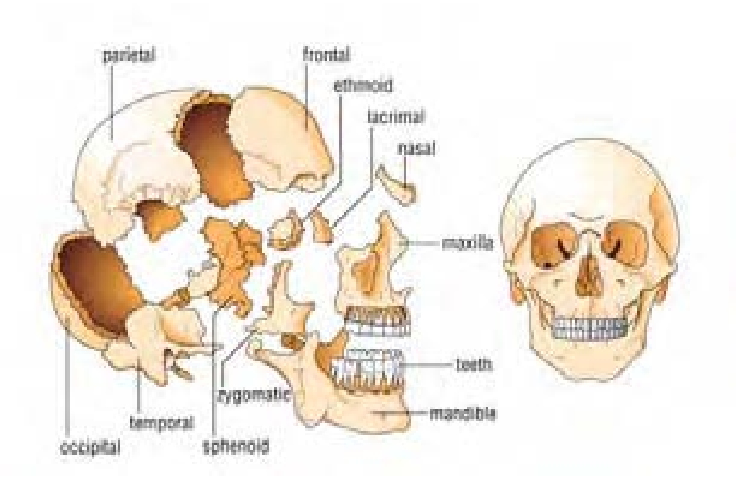
skull

in vertebrates, the collection of flat and irregularly shaped bones (or cartilage) that enclose the brain and the organs of sight, hearing, and smell, and provide support for the jaws. In most mammals, the skull consists of 22 bones joined by fibrous immobile joints called sutures. The floor of the skull is pierced by a large hole (*foramen magnum*) for the spinal cord and a number of smaller apertures through which other nerves and blood vessels pass.

The skull comprises the cranium (brain case) and the bones of the face, which include the upper jaw, enclosing the sinuses, and form the framework for the nose, eyes, and the roof of the mouth cavity. The lower jaw is hinged to the middle of the skull at its lower edge. The opening to the middle ear is located near the jaw hinge. The plate at the back of the head is jointed at its lower edge with the upper section of the spine. Inside, the skull has various shallow cavities into which fit different parts of the brain.

skull



(Image © Research Machines plc)

The skull is a protective box for the brain, eyes, and hearing organs. It is also a framework for the teeth and flesh of the face. The cranium has eight bones: occipital, two temporal, two parietal, frontal, sphenoid, and ethmoid. The face has 14 bones, the main ones being two maxillae, two nasal, two zygoma, two lacrimal, and the mandible.

skull

To remember the bones of the skull:

Old **p**eople **f**rom **T**exas **e**at **s**piders

Occipital, **p**arietal, **f**rontal, **t**emporal, **e**phnoid, **s**phenoid

---

skunk

North American mammal of the weasel family. The common skunk *Mephitis mephitis* has a long, arched body, short legs, a bushy tail, and black fur with white streaks on the back. In self-defence, it discharges a foul-smelling fluid.

Skunk and Opossum Page

Go to site

Lively site providing all the information you could possibly want about skunks and opossums – photos, a guide to identifying their tracks, common misconceptions, advice on keeping them as pets, stories featuring the animals, and even a recipe!

Skylab

US space station, launched on 14 May 1973, made from the adapted upper stage of a Saturn V rocket. At 75 tonnes, it was the heaviest object ever put into space and had a length of 25.6 m/84 ft. *Skylab* contained a workshop for carrying out experiments in weightlessness, an observatory for monitoring the Sun, and cameras for photographing the Earth's surface.

Damaged during launch, it had to be repaired by the first crew of astronauts. Three crews, each of three astronauts, occupied *Skylab* for periods of up to 84 days, at that time a record duration for human space flight. *Skylab* finally fell to Earth on 11 July 1979, dropping debris on Western Australia.

Skylab

(Image © NASA)

Observations made by astronauts aboard *Skylab* enabled a huge advance in our understanding of solar phenomena. Here a solar prominence is captured in ultraviolet light by the solar coronagraph operated by US astronaut Owen Garriot of the *Skylab 3* mission.

skylark

a type of lark.

slag

in chemistry, the molten mass of impurities that is produced in the smelting or refining of metals.

The slag produced in the manufacture of iron in a blast furnace floats on the surface above the molten iron. It contains mostly silicates, phosphates, and sulphates of calcium. When cooled, the solid is broken up and used as a core material in the foundations of roads and buildings.

slaked lime

common name for calcium hydroxide.

slash and burn

or shifting cultivation

simple agricultural method whereby natural vegetation is cut and burned, and the clearing then farmed for a few years until the soil loses its fertility, whereupon farmers move on and leave the area to regrow. Although this is possible with a small, widely dispersed population, as in the Amazon rainforest for example, it becomes unsustainable with more people and is now a cause of deforestation.

slate

fine-grained, usually grey metamorphic rock that splits readily into thin slabs along its cleavage planes. It is the metamorphic equivalent of shale.

Slate is highly resistant to atmospheric conditions and can be used for writing on with chalk (actually gypsum). Quarrying slate takes such skill and time that it is now seldom used for roof and sill material except in restoring historic buildings.

slate

(Image © Research Machines plc)

Slate tiles are a traditional roof covering in many parts of the UK. They are nailed to long batons of wood fixed at intervals across the roof area, which is normally lined for protection against the weather.

sleep

state of natural unconsciousness that occurs at regular intervals in most mammals and birds, though there is considerable variation in the amount of time spent sleeping. Sleep differs from hibernation in that it occurs daily rather than seasonally, and involves less drastic reductions in metabolism. The function of sleep is unclear. People deprived of sleep become irritable, uncoordinated, forgetful, hallucinatory, and even psychotic.

In humans, sleep is linked with hormone levels and specific brain electrical activity, including delta waves, quite different from the brain's waking activity. REM (rapid eye movement) phases, associated with dreams, occur at regular intervals during sleep, when the eyes move rapidly beneath closed lids.

Species that do not have distinct periods of sleep (most invertebrates and fishes, for example) have short intervals of reduced activity throughout a given 24-hour period. Extensive periods of sleep may have developed to make animals inconspicuous at times when they would be vulnerable to predators.

US researchers into REM sleep showed in 1998 that platypuses experience more REM (dream) sleep than any other animal. It had previously been thought that dreaming had evolved only in placental mammals.

sleep requirements

Smaller mammals tend to sleep longer than larger ones. Bats sleep for about 20 hours a day and squirrels for 15, whereas as elephants need only about 4 hours and giraffes are happy with just 2 hours of sleep a night.

sleeping pill

any sedative that induces sleep; in small doses, such drugs may relieve anxiety.

sleeping sickness

infectious disease of tropical Africa, a form of trypanosomiasis. Early symptoms include fever, headache, and chills, followed by anaemia and joint pains. Later, the disease attacks the central nervous system, causing drowsiness, lethargy, and, if left untreated, death. Sleeping sickness is caused by either of two trypanosomes, *Trypanosoma gambiense* or *T. rhodesiense*. Control is by eradication of the tsetse fly, which transmits the disease to humans. Out of the 1 million people in Africa who become infected with the sleeping sickness, 100,000 people die each year from the disease, it was reported in 2000.

Sleeping sickness in cattle is called nagana.

slide rule

mathematical instrument with pairs of logarithmic sliding scales, used for rapid calculations, including multiplication, division, and the extraction of square roots. It has been largely superseded by the electronic calculator.

It was invented in 1622 by the English mathematician William Oughtred. A later version was devised by the French army officer Amédée Mannheim (1831-1906).

slime mould

or myxomycete

extraordinary organism that shows some features of fungus and some of protozoa. Slime moulds are not closely related to any other group, although they are often classed, for convenience, with the fungi. There are two kinds, cellular slime moulds and plasmodial slime moulds, differing in their complex life cycles.

Cellular slime moulds go through a phase of living as single cells, looking like amoebae, and feed by engulfing the bacteria found in rotting wood, dung, or damp soil. When a food supply is exhausted, up to 100,000 of these amoebae form into a colony resembling a single sluglike animal and migrate to a fresh source of bacteria. The colony then takes on the aspect of a fungus, and forms long-stalked fruiting bodies which release spores. These germinate to release amoebae, which repeat the life cycle. The best studied model species from this group is *Dictyostelium discoidum*.

Plasmodial slime moulds have a more complex life cycle involving sexual reproduction. They form a slimy mass of protoplasm with no internal cell walls, which slowly spreads over the bark or branches of trees.

slime mould

Single-celled slime moulds can clump together to form a multicellular organism when times get tough. If food is becoming scarce, the unicellular slime mould releases a chemical to attract others. As they group together, they begin to produce spores that can then be dispersed to more fruitful areas.

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sloe

fruit of the blackthorn bush.

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sloth

slow-moving South American mammal, about 70 cm/2.5 ft long, family Bradypodidae, order Edentata. Sloths are greyish brown and have small rounded heads, rudimentary tails, and prolonged forelimbs. Each foot has long curved claws adapted to clinging upside down from trees. On the ground the animals cannot walk, but drag themselves along. They are vegetarian.

The hair is brown, long, coarse and shaggy. An alga lives in it, and in damp weather turns the hair green, which helps the animal to blend in with its leafy background. Sloths are nocturnal animals. They usually live alone in the treetops, eating leaves. They give birth to one young at a time, which spends its first few weeks clinging to its mother's hair.

sloth: number of toes

The two-toed sloth has three toes on its hind legs. It is only on each front leg that it has one less toe than a three-toed sloth.

sloth: waste disposal

Even the bowels of the sloth work slowly. It defecates on a weekly basis, descending discreetly to the ground to do so. For its safety the sloth needs to spend as little time on the ground as possible, but this strategy means it also avoids revealing its position by the give-away sounds of excrement crashing through the trees.

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slow-worm

harmless species of lizard *Anguis fragilis*, once common in Europe, now a protected species in Britain. Superficially resembling a snake, it is distinguished by its small mouth and movable eyelids. It is about 30 cm/1 ft long, and eats worms and slugs.

SLR

abbreviation for **single-lens reflex**, a type of camera in which the image can be seen through the lens before a picture is taken.

A small mirror directs light entering the lens to the viewfinder.

When a picture is taken the mirror moves rapidly aside to allow the light to reach the film. The SLR allows different lenses, such as close-up or zoom lenses, to be used because the photographer can see exactly what is being focused on.

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slug

soft-bodied land-living gastropod (type of mollusc) related to the snails, but without a shell, or with a much reduced shell. All slugs have a protective coat of slime and a distinctive head with protruding tentacles. The eyes are at the end of the tentacles, which are also used to smell and locate food. Slugs eat dead animal matter and plants; some species are carnivorous and eat other slugs, snails, and earthworms.

Slugs are hermaphrodite (having both male and female organs). They can fertilize themselves, but usually mate with another. Slugs can live for up to three years, and are invertebrates (animals without backbones).

behaviour

Water can quickly be lost from the slug's body, so, to prevent drying out, slugs normally come out to feed only at night or when it is wet. During dry weather they shelter in crevices, hide under rocks or go underground. The slug moves by gliding its flattened body (foot) over the ground, leaving a slimy mucus trail.

types of slug

Land slugs belong to two groups, the roundbacks and the keeled slugs. Roundbacks, such as the slugs found in gardens, are usually about 2-3cm/0.7-1 in long and have soft fleshy sausage-shaped bodies. Keeled slugs, such as the great grey slug, are usually longer, growing up to 20 cm/6.4 in long, and they have a ridge or keel along their backs.

classification

Slugs belong to the animal phylum Mollusca (molluscs), class Gastropoda (slugs and snails). There are over 40,000 species of gastropod and most land and freshwater slugs belong to a group called the pulmonates. The great number of land species include the common garden slug (*Arion hortensis*) and the great grey slug (*Limax maximus*).

slug

Slug slime is so viscous that a slug can crawl along a sharp razor blade without harm.

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smack

slang term for heroin, an addictive depressant drug.

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small arms

one of the two main divisions of firearms: guns that can be carried by hand. The first small arms were portable handguns in use in the late 14th century, supported on the ground and ignited by hand. Today's small arms range from breech-loading single-shot rifles and shotguns to sophisticated automatic and semiautomatic weapons.

The matchlock, which evolved during the 15th century, used a match of tow and saltpetre gripped by an S-shaped lever, which was rocked towards the touch hole with one finger, enabling the gun to be held, aimed, and fired in much the same way as today. Front and back sights, followed by a curved stock that could be held against the shoulder (in the hackbut or hookgun), gave increased precision. The difficulty of keeping a match alight in wet weather was overcome by the introduction of the wheel lock, in about 1515, in which a shower of sparks was produced by a spring-drawn steel wheel struck by iron pyrites. This cumbersome and expensive mechanism evolved into the simpler flintlock in about 1625, operated by flint striking steel and in general use for 200 years until a dramatic advance, the 'percussion cap', invented in 1810 by a sport-loving Scottish cleric, Alexander Forsyth (1769-1843), removed the need for external igniters. From then on, weapons were fired by a small explosive detonator placed behind or within the base of the bullet, struck by a built-in hammer.

The principles of rifling, breech-loading, and the repeater, although known since the 16th century, were not successfully exploited until the 19th century. It was known that imparting a spin made the bullet's flight truer, but the difficulty of making the bullet bite the grooves had until then prevented the use of rifling. The Baker rifle, issued to the British Rifle Brigade in 1800, was loaded from the front of the barrel (muzzle) and had a mallet for hammering the bullets into the grooves. The first breechloader was von Dreyse's 'needle gun', issued to the Prussian army in 1842, in which the detonator was incorporated with the cartridge. Breechloaders were used during the American Civil War and were in general use by 1870, being quicker, and sweeping the barrel out after each firing. An early rifle with bolt action was the Lee-Metford of 1888, followed by the Lee-Enfield, both having a magazine beneath the breech, containing a number of cartridges. A modified model is still used by the British army. US developments favoured the repeater (such as the Winchester) in which the fired case was extracted and ejected, the hammer cocked, and a new charge inserted into the chamber, all by one reciprocation of a finger lever. In the semiautomatic, part of the explosion energy performs the same operations: the Garand, long used by the US army, is of this type. Completely automatic weapons were adopted during World War II. Improvements since then have concentrated on making weapons lighter and faster-firing, as with the M-16, extensively used by US troops in the Vietnam War.

Small Is Beautiful

book by E F Schumacher, published in 1973, which argues that the increasing scale of corporations and institutions, concentration of power in fewer hands, and the overwhelming priority being given to economic growth are both unsustainable and disastrous to environment and society.

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smallpox

acute, highly contagious viral disease, marked by aches, fever, vomiting, and skin eruptions leaving pitted scars. Widespread vaccination programmes have wiped out this often fatal disease.

Smallpox was probably first brought to Europe by the returning crusaders, and as sea travel developed it was carried to the New World by explorers and settlers. It was common in Europe until the development of vaccination by Edward Jenner about 1800, and remained so in Asia, where a virulent form of the disease (*variola major*) was fatal to 30% of victims until the World Health Organization (WHO) campaign from 1967, which resulted in its virtual disappearance by 1980. The campaign was estimated to have cost $300 million/£200 million, and is the organization's biggest health success to date.

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smart card

plastic card with an embedded microprocessor and/or memory. It can store, for example, personal data, identification, and bank-account details, to enable it to be used as a credit or debit card. The card can be loaded with credits, which are then spent electronically, and reloaded as needed. Possible other uses range from hotel door 'keys' to passports and mobile telephone SIM (Subscriber Identity Module) cards.

The smart card was invented by French journalist Juan Moreno in 1974. Smart cards now have as much computing power as the leading personal computers of 1990.

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smart drug

any drug or combination of nutrients (vitamins, amino acids, minerals, and sometimes herbs) said to enhance the functioning of the brain, increase mental energy, lengthen the span of attention, and improve the memory. As yet there is no scientific evidence to suggest that these drugs have any significant effect on healthy people.

Some smart drugs consist of food additives which are precursors of the neurotransmitter acetylcholine. Most, however, are experimental drugs devised by pharmaceutical companies to treat aspects of dementia, in particular, memory loss. The description is also applied to existing drugs claimed to improve mental performance but which are legally prescribed for other purposes. These include beta-blockers (prescribed for some heart disease), phenytoin (epilepsy), and L-dopa (Parkinson's disease).

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smart fluid

or electrorheological fluid

liquid suspension that solidifies to form a jellylike solid when a high-voltage electric field is applied across it and that returns to the liquid state when the field is removed. Most smart fluids are zeolites or metals coated with polymers or oxides.

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smell

sense that responds to certain molecules in the air. It works by having receptors for particular chemical groups, into which the airborne chemicals must fit to trigger a message to the brain.

A sense of smell is used to detect food and to communicate with other animals (see pheromone and scent gland). Humans can distinguish between about 10,000 different smells. Aquatic animals can sense chemicals in water, but whether this sense should be described as 'smell' or 'taste' is debatable. See also nose.

smell

Human mothers can identify their babies by smell alone.

Mystery of Smell

Go to site

As part of a much larger site called 'Seeing, Hearing, and Smelling the World', here is a page examining the way our sense of smell works. It is divided into four sections called 'The vivid world of odours', 'Finding the odourant receptors', 'How rats and mice - and probably humans - recognize odours', and 'The memory of smells'. This site makes good use of images and animations to help with the explanations, so it is best viewed with an up-to-date browser.

Secret Sense in the Human Nose?

Go to site

As part of a much larger site called 'Seeing, Hearing, and Smelling the World', here is a page examining the way our sense of smell detects odours of which we are not aware. It is divided into three sections called 'Sniffing out social and sexual signals', 'Triggers of innate behaviour', and 'Pheromones and mammals'. This site makes good use of images and animations to help with the explanations, so it is best viewed with an up-to-date browser.

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smelling salts

mixture of ammonium carbonate, bicarbonate, and carbamate together with other strong-smelling substances, formerly used as a restorative for dizziness or fainting.

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smelt

small fish, usually marine, although some species are freshwater.

They occur in Europe and North America. The most common European smelt is the sparling *Osmerus eperlanus*.

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smelting

processing a metallic ore in a furnace to produce the metal. Oxide ores such as iron ore are smelted with coke (carbon), which reduces the ore into metal and also provides fuel for the process.

A substance such as limestone is often added during smelting to facilitate the melting process and to form a slag, which dissolves many of the impurities present.

Smith, William (1769-1839)

English geologist. He produced the first geological maps of England and Wales, setting the pattern for geological cartography. Often called the founder of stratigraphical geology, he determined the succession of English strata across the whole country, from the Carboniferous up to the Cretaceous. He also established their fossil specimens.

Working as a canal engineer, he observed while supervising excavations that different beds of rock could be identified by their fossils, and so established the basis of stratigraphy.

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smog

natural fog containing impurities, mainly nitrogen oxides (NO_x) and volatile organic compounds (VOCs) from domestic fires, industrial furnaces, certain power stations, and internal-combustion engines (petrol or diesel). It can cause substantial illness and loss of life, particularly among chronic bronchitics, and damage to wildlife.

photochemical smog is mainly prevalent in the summer as it is caused by chemical reaction between strong sunlight and vehicle exhaust fumes. Such smogs create a build-up of ozone and nitrogen oxides which cause adverse symptoms, including coughing and eye irritation, and in extreme cases can kill.

The London smog of 1952 lasted for five days and killed more than 4,000 people from heart and lung diseases. The use of smokeless fuels, the treatment of effluent, and penalties for excessive smoke from poorly maintained and operated vehicles can be effective in reducing smog but it still occurs in many cities throughout the world.

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smokeless fuel

fuel that does not give off any smoke when burned, because all the carbon is fully oxidized to carbon dioxide (CO_2). Natural gas, oil, and coke are smokeless fuels.

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smoker

hot fissure in the ocean floor, known as a hydrothermal vent.

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smoking

method of preserving fresh oily meats (such as pork and goose) or fish (such as herring and salmon). Before being smoked, the food is first salted or soaked in brine, then hung to dry. Meat is hot-smoked over a fast-burning wood fire, which is covered with sawdust, producing thick smoke and partly cooking the meat. Fish may be hot-smoked or cold-smoked over a slow-burning wood fire, which does not cook it.
Modern refrigeration techniques mean that food does not need to be smoked to help it keep, so factory-smoked foods tend to be smoked just enough to give them a smoky flavour, with colours added to give them the appearance of traditionally smoked food.

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smoking

inhalation (breathing in) of the fumes from burning substances, generally tobacco in the form of cigarettes. The practice is habit-forming and dangerous to health, since carbon monoxide and other toxic materials result from the combustion process. Smoking is addictive (see addiction) because of the presence of the drug nicotine in the smoke. A direct link between lung cancer and tobacco smoking was established in 1950; the habit is also linked to respiratory and coronary heart diseases. In the West, smoking is now forbidden in many public places because even **passive smoking** – breathing in fumes from other people's cigarettes – can be harmful. Some illegal drugs, such as crack and opium, are also smoked. In 2001, it was estimated that there were 1.1 billion smokers worldwide.

Carbon monoxide in the smoke combines with haemoglobin and reduces the amount of oxygen that the blood can carry. The link between lung cancer and tobacco smoking was established in 1950, but it is now known that all forms of cancer are more common in a person who smokes. A variety of diseases of breathing and circulation are also common in smokers. Bronchitis and emphysema are typical problems for the long-term smoker (see lung). The degeneration of arteries is more likely in smokers. This results in coronary heart disease and increased risk of heart attack. Smokers are 25 times as likely to develop lung cancer, have 2–3 times the risk of heart attack and 50% will die prematurely as a result of smoking. The habit causes 4 million premature deaths annually worldwide.

Action on Smoking and Health (ASH)

Go to site

Appropriately named ASH (Action on Smoking and Health) Web site highlighting the challenge to the tobacco industry for institutional change. The opening page contains recent news on action against the tobacco industry. The rest of the site is accessible through the extremely comprehensive list of areas on the left-hand-side menu and covers such topics as tips for giving up smoking, ASH policy and agenda, and other UK smoking-related links.

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smooth muscle

involuntary muscle capable of slow contraction over a period of time. It is present in hollow organs, such as the intestines, stomach, bladder, and blood vessels. Its presence in the wall of the alimentary canal allows slow rhythmic movements known as peristalsis, which cause food to be mixed and forced along the gut. Smooth muscle has a microscopic structure distinct from other forms.

---

smooth snake

common nonvenomous snake found in southern and central Europe. It grows to a length of 60 cm/24 in, and it is brownish-red or grey in colour, with dark-brown spots along its back. It is ovoviviparous, producing live young that free themselves from their shells immediately.

classification

The smooth snake *Coronella austriaca* is in family Colubridae, suborder Serpentes, order Squamata, class Reptilia.

SMS

abbreviation for short message service

service for sending and receiving text messages (see text messaging) to and from mobile phones and other communication devices. SMS was created when it was incorporated into the Global System for Mobiles (GSM) digital mobile phone standard. The limited number of characters allowed per text message led to the evolution of a distinct form of abbreviated language (for example, 'u' for 'you' and 'c' for 'see'). It is also possible to deliver an SMS message through an Internet Web site, called an SMS gateway.

The text can comprise a combination of characters, numbers, and symbols. The shortest messages are those based on the international UCS2 coding system used in countries that need more then the standard 8-bit American Standard Code for Information Interchange (ASCII) to code their character set.

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smut

in botany, any of a group of parasitic fungi (see fungus) that infect flowering plants, particularly cereal grasses. (Order Ustilaginales.)

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snail

air-breathing gastropod mollusc with a spiral shell. There are thousands of species, on land and in water. The typical snails of the genus *Helix* have two species in Europe. The common garden snail *H. aspersa* is very destructive to plants.

Snails are hermaphrodite and, before mating, produce a mucus covered calcerous 'love dart' that pierces the skin of their mate. The mucus contains a pheromone that makes the female reproductive canal less hostile to sperm.

snail

When under attack from predators some pond snails expel all their blood to enable them to withdraw deeper into their shells.

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snake

reptile of the suborder Serpentes of the order Squamata, which also includes lizards. Snakes are characterized by an elongated limbless body, possibly evolved because of subterranean ancestors. However, a team of US and Israeli palaeontologists rediscovered a fossil collection in 1996 which suggested that snakes evolved from sea-dwelling predators.

One of the striking internal modifications is the absence or greatly reduced size of the left lung. The skin is covered in scales, which are markedly wider underneath where they form. There are 3,000 species found in the tropical and temperate zones, but none in New Zealand, Ireland, Iceland, and near the poles. Only three species are found in Britain: the adder, smooth snake, and grass snake.

locomotion

In all except a few species, scales are an essential aid to locomotion. A snake is helpless on glass where scales can effect no 'grip' on the surface; progression may be undulant, 'concertina', or creeping, or a combination of these.

senses

Detailed vision is limited at a distance, though movement is immediately seen; hearing is restricted to ground vibrations (sound waves are not perceived); the sense of touch is acute; besides the sense of smell through the nasal passages, the flickering tongue picks up airborne particles which are then passed to special organs in the mouth for investigation; and some (rattlesnakes) have a cavity between eye and nostril which is sensitive to infrared rays (useful in locating warm-blooded prey in the dark).

reproduction

Some are oviparous and others ovoviviparous, that is, the eggs are retained in the oviducts until development is complete; in both cases the young are immediately self-sufficient.

species

The majority of snakes belong to the Colubridae family, and are chiefly harmless, such as the common grass snake of Europe, but this family includes the deadly African boomslang *Dispholidus typus*. The venomous families include the Elapidae, comprising the true cobras, the New World coral snakes, and the Australian taipan, copper-head, and death adder; the Viperidae (see viper); and the Hydrophiidae, aquatic sea-snakes.

Among the more primitive snakes are the Boidae, which still show links with lizards and include the boa constrictor, anaconda, and python. These kill by constriction but their victims are usually comparatively small animals.

All snakes are carnivorous, and often camouflaged for better concealment in hunting as well as for their own protection.

treatment of snakebite

There are 50,000-100,000 deaths from snake bites worldwide annually, it was announced in September 2000. The serums used to treat snakebites are called antivenins. Antivenins are produced by injecting animals (horses and sheep are used) with venom, extracting their blood, now containing antibodies to the venom, and removing the red blood cells. However, in addition to the desired venom antibodies, many other antibodies and proteins are contained within the serum. These often cause 'serum sickness' in the patient, as a result of a severe allergenic reaction.

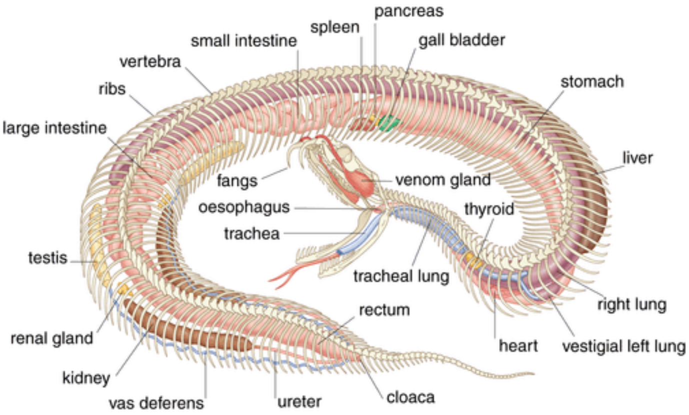
As antivenins are expensive to prepare and store, and specific to one snake species, experiments have been carried out using more widely valid treatments, for example, trypsin, a powerful protein-degrading enzyme, effective against the cobra/mamba group.

In 1993 Japanese and Brazilian researchers independently identified a protein in the blood of a venomous snake that neutralizes its own venom. In laboratory tests in Australia, this protein, named *Notechis scutatus* inhibitor (NSI) after the tiger snake from the whose blood it was isolated, was effective against the venom of six other snakes.

snake

The world's rarest snake is the Antiguan racer, with only 50 remaining in the wild in 1997.

snake


pancreas
spleen
small intestine
gall bladder
vertebra
ribs
stomach
large intestine
liver
fangs
venom gland
oesophagus
thyroid
trachea
testis
tracheal lung
right lung
rectum
renal gland
heart
vestigial left lung
kidney
cloaca
vas deferens
ureter

(Image © Research Machines plc)

The anatomy of a snake (male). A snake's skeleton contains over 400 spinal bones. Its internal organs lie in the linear body cavity enclosed by the ribs.

Jason's Snakes and Reptiles

Go to site

Detailed guide to the care of snakes and reptiles. This site also includes a wide-range of useful links, and is illustrated throughout.

Rat Snake

Go to site

Illustrated guide to the rat snake including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

---

snake fly

elongate insect found in wooded regions, among flowers or tree-trunks. More than 80 species are known.

The adult insects have an unusually long prothorax (region immediately behind the head) which forms a kind of 'neck' and the entire body is elongate, ending in a drawn out slender egg-laying apparatus (ovipositor), hence their name. The female inserts the eggs, with its long ovipositor, into slits in the bark of trees, especially of conifers. The larva forages under the loose bark, preying on soft-bodied insects.

classification

The snake fly is in family Raphidiidae, in suborder Megaloptera of order Neuroptera, class Insecta, phylum Arthropoda.

---

snapdragon

perennial herbaceous plant belonging to the figwort family, with spikes of brightly coloured two-lipped flowers. (*Antirrhinum majus*, family Scrophulariaceae.)

Snapdragon

Go to site

Detailed description of the snapdragon flower. Information about how to grow the plant is accompanied by a colour photograph.

---

snapper

one of a number of tropical, carnivorous fish, about 60 cm/24 in or more in length. Many are red, but the species come in many colours. They are valuable edible fishes, especially the red snapper *Lutjanus blackfordi*.

classification

Snappers are in the family Lutjanidae of order Perciformes, class Osteichthyes.

---

snellen

unit expressing the visual power of the eye.

Snel's law of refraction

in optics, the rule that when a ray of light passes from one medium to another, the sine of the angle of incidence divided by the sine of the angle of refraction is equal to the ratio of the indices of refraction in the two media. For a ray passing from medium 1 to medium 2: $n_2/n_1 = \sin i/\sin r$ where n_1 and n_2 are the refractive indices of the two media. The law was devised by the Dutch physicist, Willebrord Snel (1591-1626).

---

snipe

marsh bird of the family Scolopacidae, order Charadriiformes closely related to the woodcock. Snipes use their long, straight bills to probe marshy ground for worms, insects, and molluscs. Their nests are made on the grass, and they lay four eggs.

The cry of the birds resembles the sound 'scape-scape', and during the breeding season they make a peculiar drumming or bleating noise in their downward flight. A gamebird, the snipe has a swift and darting flight, making it a difficult target.

---

snoring

loud noise during sleep made by vibration of the soft palate (the rear part of the roof of the mouth), caused by streams of air entering the nose and mouth at the same time. It is most common when the nose is partially blocked.

Sleep apnoea causes loud snoring that wakes the sufferer repeatedly throughout the night, causing chronic tiredness.

Snowdon, Anthony Charles Robert Armstrong-Jones, 1st Earl of Snowdon (1930-)

English photographer. He is especially known for his portraits. He was consultant to the Council of Industrial Design and editorial adviser to *Design Magazine* from 1961 to 1987; artistic adviser to *Sunday Times* Publications from 1962 to 1990; and photographer for the *Telegraph Magazine* from 1990. He has also made several films for television. He was married to Princess Margaret 1960-78. He was created earl in 1961.

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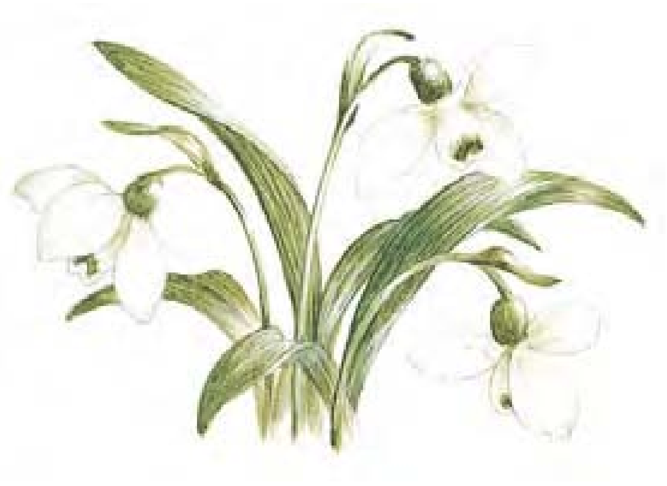
snowdrop

small bulbous European plant; its white bell-shaped hanging flowers, tinged with green, are among the first to appear in early spring. (*Galanthus nivalis*, family Amaryllidaceae.)

snowdrop



(Image © Research Machines plc)

Snowdrops flower in the early spring when snow may still be on the ground in the woodlands and shrubland of Europe. The small drooping flowers hang about 15 cm/6 in above the ground. They have six petals, the three inner ones having a green patch.

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snow leopard

a type of leopard.

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soap

mixture of the sodium salts of various fatty acids: palmitic, stearic, and oleic acid. It is made by the action of sodium hydroxide (caustic soda) or potassium hydroxide (caustic potash) on fats of animal or vegetable origin. Soap makes grease and dirt disperse in water in a similar manner to a detergent.

Soap was mentioned by Galen in the 2nd century for washing the body, although the Romans seem to have washed with a mixture of sand and oil. Soap was manufactured in Britain from the 14th century, but better-quality soap was imported from Castile or Venice. The Soapmakers' Company, London, was incorporated in 1638. Soap was taxed in England from the time of Cromwell in the 17th century to 1853.

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soapstone

compact, massive form of impure talc.

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social behaviour

in zoology, behaviour concerned with altering the behaviour of other individuals of the same species. Social behaviour allows animals to live harmoniously in groups by establishing hierarchies of dominance to discourage disabling fighting. It may be aggressive or submissive (for example, cowering and other signals of appeasement), or designed to establish bonds (such as social grooming or preening).

The social behaviour of mammals and birds is generally more complex than that of lower organisms, and involves relationships with individually recognized animals. Thus, courtship displays allow individuals to choose appropriate mates and form the bonds necessary for successful reproduction. In the social systems of bees, wasps, ants, and termites, an individual's status and relationships with others are largely determined by its biological form, as a member of a caste of workers, soldiers, or reproductives; see eusociality.

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sociobiology

study of the biological basis of all social behaviour, including the application of population genetics to the evolution of behaviour. It builds on the concept of inclusive fitness, contained in the notion of the 'selfish gene'. Contrary to some popular interpretations, it does not assume that all behaviour is genetically determined.

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soda ash

former name for sodium carbonate.

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soda lime

powdery mixture of calcium hydroxide and sodium hydroxide or potassium hydroxide, used in medicine and as a drying agent.

Soddy, Frederick (1877-1956)

English physical chemist who pioneered research into atomic disintegration and coined the term isotope. He was awarded the Nobel Prize for Chemistry in 1921 for investigating the origin and nature of isotopes.

The displacement law, introduced by Soddy in 1913, explains the changes in atomic mass and atomic number for all the radioactive intermediates in the decay processes.

After his chemical discoveries, Soddy spent some 40 years developing a theory of 'energy economics', which he called 'Cartesian economics'. He argued for the abolition of debt and compound interest, the nationalization of credit, and a new theory of value based on the quantity of energy contained in a thing.

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sodium

chemical symbol Na

soft, waxlike, silver-white, metallic element, atomic number 11, relative atomic mass 22.989. Its chemical symbol comes from the Latin *natrium*. It is one of the alkali metals (in Group 1 of the periodic table) and has a very low density, being light enough to float on water. It is the sixth-most abundant element (the fourth-most abundant metal) in the Earth's crust. Sodium is highly reactive, oxidizing rapidly when exposed to air and reacting violently with water. It is one of the most reactive metals in the reactivity series of metals. Its most familiar compound is sodium chloride (common salt), which occurs naturally in the oceans and in salt deposits left by dried-up ancient seas.

---

sodium carbonate

or soda ash; Na_2CO_3

anhydrous white solid. The hydrated, crystalline form ($Na_2CO_3.10H_2O$) is also known as washing soda.

It is made by the Solvay process and used as a mild alkali, as it is hydrolysed in water:

$$CO_3{}^{2-}{}_{(aq)} + H_2O_{(l)} \rightarrow HCO_3{}^{-}{}_{(aq)} + OH^{-}{}_{(aq)}$$

It is used to neutralize acids, in glass manufacture, and in water softening.

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sodium chloride

or common salt or table salt; NaCl

white, crystalline compound found widely in nature. The crystals are cubic in shape. It is a typical ionic solid with a high melting point (801°C/1,474°F); it is soluble in water, insoluble in organic solvents, and is a strong electrolyte when molten or in aqueous solution. Found in concentrated deposits as the mineral halite, it is widely used in the food industry as a flavouring and preservative, and in the chemical industry in the manufacture of sodium, chlorine, and sodium carbonate.

Chlorine and sodium hydroxide are produced by the electrolysis of brine, a solution of sodium chloride in water. Salt for use in the food industry includes added iodine to reduce the incidence of the iodine deficiency diseases such as goitre and cretinism.

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sodium hydrogencarbonate

chemical name for bicarbonate of soda.

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sodium hydroxide

or caustic soda; NaOH

commonest alkali. The solid and the solution are corrosive. It is used to neutralize acids, in the manufacture of soap, and in drain and oven cleaners. It is prepared industrially from sodium chloride by the electrolysis of concentrated brine.

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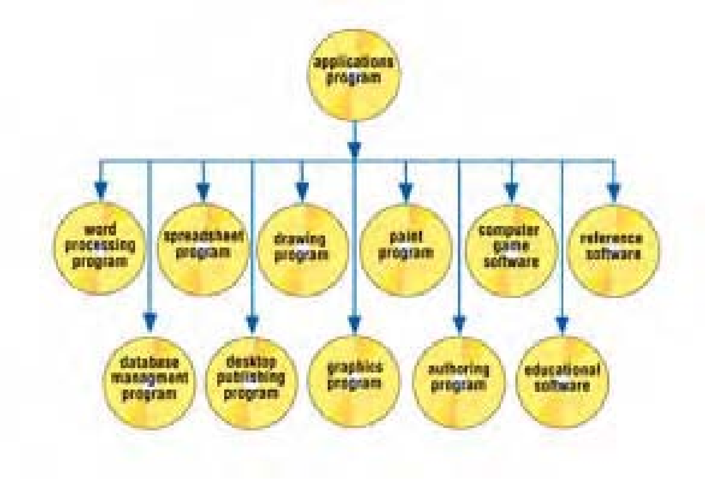
software

in computing, a collection of programs and procedures for making a computer perform a specific task, as opposed to hardware, the physical components of a computer system. Software is created by programmers and is either distributed on a suitable medium, such as CD-ROM, or built into the computer in the form of firmware. Examples of software include operating systems, compilers, and applications such as payroll or word processing programs. No computer can function without some form of software.

To function, computers need two types of software: application software and systems software. **Application software**, such as a payroll system or a word processor, is designed for the benefit of the end user. **Systems software** performs tasks related to the operation and performance of the computer system itself. For example, a systems program might control the operation of the display screen, or control and organize backing storage.

software


applications program
word processing program
spreadsheet program
drawing program
paint program
computer game software
reference software
database managment program
desktop publishing program
graphics program
authoring program
educational software

(Image © Research Machines plc)

The various types of software application program that are available for computer systems.

soft water

water that contains very few dissolved metal ions such as calcium (Ca^{2+}) or magnesium (Mg^{2+}). It lathers easily with soap, and no scale is formed inside kettles or boilers. It has been found that the incidence of heart disease is higher in soft-water areas.

softwood

any coniferous tree (see conifer), or the wood from it. In general this type of wood is softer and easier to work, but in some cases less durable, than wood from flowering (or angiosperm) trees.

SOHO

abbreviation for Solar and Heliospheric Observatory.

soil

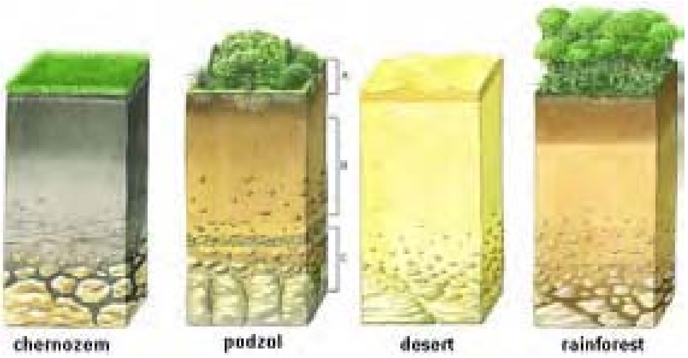
loose covering of broken rocky material and decaying organic matter overlying the bedrock of the Earth's surface. It is composed of minerals (formed from physical weathering and chemical weathering of rocks), organic matter (called humus) derived from decomposed plants and organisms, living organisms, air, and water. Soils differ according to climate, parent material, rainfall, relief of the bedrock, and the proportion of organic material. The study of soils is **pedology**.

Soils influence the type of agriculture employed in a particular region – light well-drained soils favour arable farming, whereas heavy clay soils give rise to lush pasture land. Plant roots take in nutrients (in the form of ions) dissolved in the water in soil. The main elements that plants need to absorb through their roots are nitrogen, phosphorus, and potassium.

soil

A handful of soil contains up to 5,000 species of bacteria.

soil


chernozem
podzol
desert
rainforest

(Image © Research Machines plc)

Common types of soil profile.

soil

To remember the chief constituents of soil:

All **h**airy **m**en **w**ill **b**uy **r**azors

Air, **h**umus, **m**ineral salts, **w**ater, **b**acteria, **r**ock particles

Soil pH - What It Means

Go to site

Explanation of soil pH. The Web site also describes how to measure the pH of soil using simple experimental equipment, and goes on to describe methods that may be used to modify the acidity of alkalinity of soil.

soil creep

gradual movement of soil down a slope in response to gravity. This eventually results in a mass downward movement of soil on the slope.

Evidence of soil creep includes the formation of terracettes (steplike ridges along the hillside), leaning walls and telegraph poles, and trees that grow in a curve to counteract progressive leaning.

soil depletion

decrease in soil quality over time. Causes include loss of nutrients caused by overfarming, erosion by wind, and chemical imbalances caused by acid rain.

soil erosion

wearing away and redistribution of the Earth's soil layer. It is caused by the action of water, wind, and ice, and also by improper methods of agriculture. If unchecked, soil erosion results in the formation of deserts (desertification). It has been estimated that 20% of the world's cultivated topsoil was lost between 1950 and 1990.

If the rate of erosion exceeds the rate of soil formation (from rock and decomposing organic matter), then the land will become infertile. The removal of forests (deforestation) or other vegetation often leads to serious soil erosion, because plant roots bind soil, and without them the soil is free to wash or blow away, as in the American dust bowl. The effect is worse on hillsides, and there has been devastating loss of soil where forests have been cleared from mountainsides, as in Madagascar.

Improved agricultural practices such as contour ploughing are needed to combat soil erosion. Windbreaks, such as hedges or strips planted with coarse grass, are valuable, and organic farming can reduce soil erosion by as much as 75%.

Soil degradation and erosion are becoming as serious as the loss of the rainforest. It is estimated that more than 10% of the world's soil lost a large amount of its natural fertility during the latter half of the 20th century. Some of the worst losses are in Europe, where 17% of the soil is damaged by human activity such as mechanized farming and fallout from acid rain. In Mexico and Central America, 24% of soil is highly degraded, mostly as a result of deforestation.

soil erosion

(Image © Garret Nagle)

Signs that heavy machinery has caused ground compaction (also called ponding). Natural vegetation has been removed, reducing the amount of water that is intercepted or captured as it passes through the soil. The soil is compacted, and becomes impermeable (does not let water in). The result is an increase in overland runoff (water flowing over the surface), causing an increase in soil erosion and flooding.

Soil Erosion - Causes and Effects

Go to site

Detailed page from the Canadian Ontario Ministry of Agriculture on the causes and effects of erosion. The site provides a good summary of the various factors affecting the rate and magnitude of soil erosion including rainfall intensity, slope gradient and length, and vegetation.

soil mechanics

branch of engineering that studies the responses of soils with different water and air contents, to loads. Soil is investigated during construction work to ensure that it has the mechanical properties necessary to support the foundations of dams, bridges, and roads.

sol

colloid of very small solid particles dispersed in a liquid that retains the physical properties of a liquid.

solan goose

another name for the gannet.

Solar and Heliospheric Observatory

SOHO

space probe built by the European Space Agency and launched by NASA on 2 December 1995 to study the solar wind of atomic particles streaming towards the Earth from the Sun. It also observes the Sun in ultraviolet and visible light, and measures slight oscillations on the Sun's surface that can reveal details of the structure of the Sun's interior.

The US$1.2 billion probe is positioned towards the Sun, 1.5 million km/938,000 mi from Earth. SOHO's hydrazine fuel froze in June 1998 causing contact with it to be lost. Ground control at the Goddard Space Flight Center finally regained command of SOHO in September 1998, when SOHO was turned so that its solar power arrays faced the Sun. SOHO has been in continuous use since that time. It broadcasts daily images of the Sun, which are accessible to the public via the Internet. On 28 October 2003, it observed a spectacular solar flare that required two of its instruments to be temporarily shut down to avoid damage.

Solar and Heliospheric Observatory

Go to site

News, images, and background on the mission of the Solar and Heliospheric Observatory (SOHO) to study the Sun's structure, its outer atmosphere, and the particles that make up the solar wind. The site has available for download the SOHO screen saver, which automatically updates your desktop with the latest images of the Sun.

solar cycle

variation of activity on the Sun over an 11-year period indicated primarily by the number of sunspots visible on its surface. The next period of maximum activity is expected round 2011.

solar energy

energy derived from the light and heat from the Sun. The amount of energy falling on just 1 sq km/0.4 sq mi is about 4,000 megawatts, enough to heat and light a small town.
Solar heaters usually consist of concave mirrors or reflective parabolic surfaces that concentrate the Sun's rays onto a black (heat-absorbing) panel containing pipes through which air or water is circulated, either by thermal convection or by a pump. The heat energy of the air or water is converted into electrical energy via a turbine and a generator. Hot water for industrial and domestic use can be produced by circulating water through panels, the water absorbing heat from the Sun as it passes through the panels.

Solar energy may also be harnessed indirectly using **solar cells** (photovoltaic cells) made of panels of semiconductor material (usually silicon), which generate electricity when illuminated by sunlight. Although it is difficult to generate a high output from solar energy compared to sources such as nuclear or fossil fuels, it is a major non-polluting and renewable energy source used as far north as Scandinavia as well as in the southwestern USA and in Mediterranean countries.

One Life for Solar Power

Go to site

Massive solar energy resource that contains a number of articles on solar energy. It asks readers to consider why solar power is not more widespread, given that it is a can provide energy without the 'pollution and hazards associated with...exhaustible sources'.

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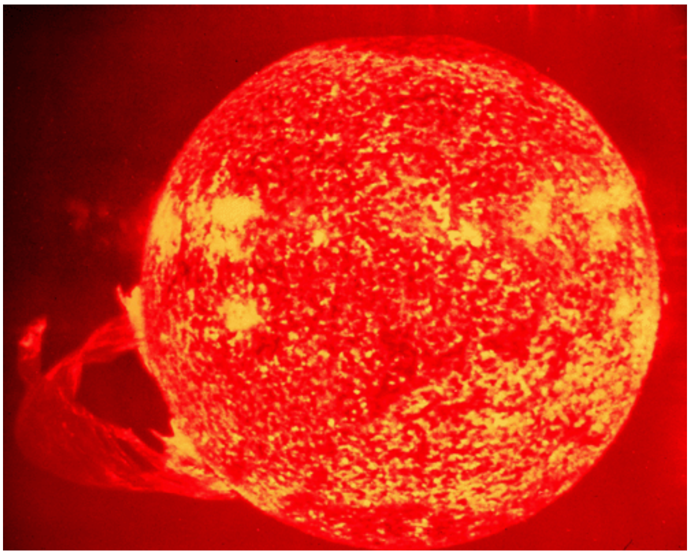
solar flare

brilliant eruption on the Sun above a sunspot, thought to be caused by release of magnetic energy. Flares reach maximum brightness within a few minutes, then fade away over about an hour. They eject a burst of atomic particles into space at up to 1,000 kps/600 mps. When these particles reach Earth they can cause radio blackouts, disruptions of the Earth's magnetic field, and auroras.

solar flare



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

A huge solar flare (bottom left of the Sun's disc) sends atomic particles in enormous quantities and at great speed into the Solar System. Flares are associated with sunspots, areas on the surface of the Sun that are visibly darker and measurably much cooler. Like sunspots, therefore, flares fluctuate in number according to an apparent 11-year cycle.

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solar pond

natural or artificial 'pond', such as the Dead Sea, in which salt becomes more soluble in the Sun's heat. Water at the bottom becomes saltier and hotter, and is insulated by the less salty water layer at the top. Temperatures at the bottom reach about 100°C/212°F and can be used to generate electricity.

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solar radiation

radiation given off by the Sun, consisting mainly of visible light, ultraviolet radiation, and infrared radiation, although the whole spectrum of electromagnetic waves is present, from radio waves to X-rays. High-energy charged particles, such as electrons, are also emitted, especially from solar flares. When these reach the Earth, they cause magnetic storms (disruptions of the Earth's magnetic field), which interfere with radio communications.

Solar Energy: Basic Facts

Go to site

Quick guide to this renewable energy source. Taken from a series of fact sheets published by the Solar Energy Society, this page explains concepts such as solar water heating, photovoltaics, and passive solar architecture. Find out why solar power works better in Scotland than in the south of France.

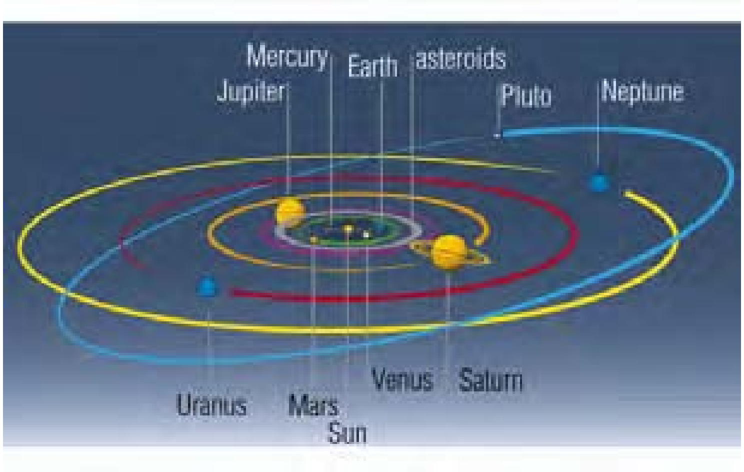
Solar System

Sun (a star) and all the bodies orbiting it: the nine planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto), their moons, and smaller objects such as asteroids and comets. The Sun contains 99.86% of the mass of the Solar System. The planets orbit the Sun in elliptical paths, and in the same direction as the Sun itself rotates. The planets nearer the Sun have shorter orbital times than those further away since the distance they travel in each orbit is less, and their orbital speeds are higher.

The inner planets (Mercury, Venus, Earth, and Mars) have solid, rocky surfaces; relatively slow periods of rotation (Mercury takes 59 days to complete one rotation, Venus 243 days, Earth nearly 24 hours, and Mars 24.5 hours); very few natural satellites; and diameters up to 13,000 km/8,000 mi. Venus can be seen with the unaided eye, appearing in the evening as the brightest 'star' in the sky. In contrast, the outer planets (Jupiter, Saturn, Uranus, and Neptune) have denser, gaseous atmospheres composed mainly of hydrogen and helium; fast periods of rotation (Jupiter takes 10 hours for one rotation, Saturn nearly 10.5 hours, Uranus 11 hours, and Neptune 16 hours); and many natural satellites (Jupiter and Saturn have more than 30 between them, Uranus has 15, and Neptune has 13). Uranus, Neptune, and Pluto were discovered after the development of the telescope.

Beyond the orbit of Neptune lies the Kuiper belt, a disc of small bodies, of which Pluto may be the largest member. Still farther beyond this is the Oort cloud, extending into the interstellar regions in all directions, consisting of slow-moving dormant comets. Some of these are occasionally perturbed gravitationally and plunge into the inner Solar System.

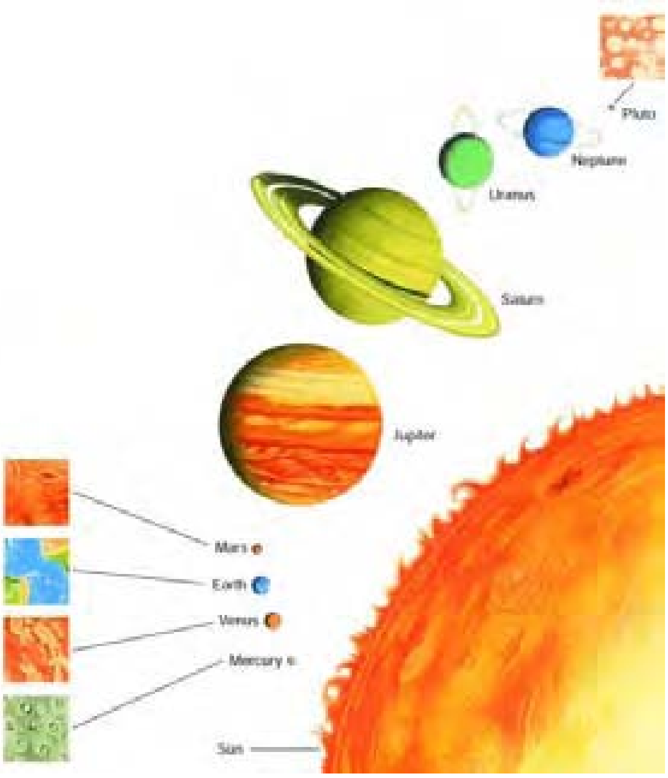
Solar System



(Image © Research Machines plc)

Most of the objects in the Solar System lie close to the plane of the ecliptic. The planets are tiny compared to the Sun (not shown to scale). If the Sun were the size of a basketball, the planet closest to the Sun, Mercury, would be the size of a mustard seed 15 m/48 ft from the Sun. The most distant planet, Pluto, would be a pinhead 1.6 km/1 mi away from the Sun. The Earth, which is the third planet out from the Sun, would be the size of a pea 32 m/100 ft from the Sun.

Solar System



(Image © Research Machines plc)

The planets of the Solar System in order and to scale. Surface detail is included for the smallest planets. To remember the order of planets moving away from the Sun, the mnemonic '**M**y **v**ery **e**ducated **m**other **j**ust **s**erved **u**s **n**ine **p**ies' may be useful.

Earth View

Go to site

Real-time picture of the Earth, showing night and day regions. This site provides a variety of links to other Earth- and space-related sites, including a Moon view and views from any satellite orbiting the Earth. Zooming-in and panning controls are also provided, offering close-up detail of different countries.

Nine Planets

Go to site

Multimedia tour of the Solar System, with descriptions of each of the planets and major moons. In addition, there are appendices on such topics as astronomical names and how they are assigned, the origin of the Solar System, and hypothetical planets.

Planetary Image Finders

Go to site

Page dedicated to listing the best sources of high-resolution, often unprocessed images of each planet or moon in the Solar System.

Satellites of the Outer Planets

Go to site

Detailed and highly comprehensive page about the satellites of the outer planets. With links to separate pages for every satellite covered, this is more of a resource to dip into than read from start to finish. Images of each satellite are also provided, plus links to a special three-dimensional tour of the Solar System.

Solar System Live

Go to site

Take a look at the entire Solar System as it might be seen at different times and dates or from different viewpoints.

Sun

Go to site

Short history of the Sun, and an insight into its context within the contemporary universe. This site is mainly text-based but includes the odd dramatic picture, making this a useful site.

Views of the Solar System

Go to site

Educational tour of the Solar System. It contains information and statistics about the planets, moons, asteroids, comets, and meteorites found within the Solar System, and is supported by images.

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solar time

time of day as determined by the position of the Sun in the sky.

Apparent solar time, the time given by a sundial, is not uniform because of the varying speed of the Earth in its elliptical orbit.
Mean solar time is a uniform time that coincides with apparent solar time at four instants through the year. The difference between them is known as the equation of time, and is greatest in early November when the Sun is more than 16 minutes fast on mean solar time. Mean solar time on the Greenwich meridian is known as Greenwich Mean Time and is the basis of civil timekeeping.

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solar wind

stream of atomic particles, mostly protons and electrons, from the Sun's corona, flowing outwards at speeds of between 300 kps/200 mps and 1,000 kps/600 mps.

The fastest streams come from 'holes' in the Sun's corona that lie over areas where no surface activity occurs. The solar wind pushes the gas of comets' tails away from the Sun, and 'gusts' in the solar wind cause geomagnetic disturbances and auroras on Earth. Other planets are also affected: the European Space Agency's probe Mars Express (to be launched in 2003) will investigate how the solar wind affects that planet's atmosphere.

solder

any of various alloys used when melted for joining metals such as copper, its common alloys (brass and bronze), and tin-plated steel, as used for making food cans.

Soft solders (usually alloys of tin and lead, sometimes with added antimony) melt at low temperatures (about 200°C/392°F), and are widely used in the electrical industry for joining copper wires. Hard (or brazing) solders, such as silver solder (an alloy of copper, silver, and zinc), melt at much higher temperatures and form a much stronger joint. Printed circuit boards for computers are assembled by soldering.

A necessary preliminary to making any solder joint is thorough cleaning of the surfaces of the metal to be joined (to remove oxide) and the use of a flux (to prevent the heat applied to melt the solder from reoxidizing the metal).

sole

flatfish found in temperate and tropical waters. The **common sole** *Solea solea*, also called **Dover sole**, is found in the southern seas of northwestern Europe. Up to 50 cm/20 in long, it is a prized food fish, as is the **sand** or **French sole** *Pegusa lascaris* further south.

solenodon

rare insectivorous shrewlike mammal, genus *Solenodon*. There are two species, one each on Cuba and Hispaniola. They are about 30 cm/12 in long with a 25 cm/10 in naked tail, shaggy hair, long, pointed snouts, and strong claws, and they produce venomous saliva. They are slow-moving, come out mostly at night, and eat insects, worms, and other invertebrate animals. They are threatened with extinction owing to introduced predators.

solenoid

coil of wire, usually cylindrical, in which a magnetic field is created by passing an electric current through it (see electromagnet). This field can be used to temporarily magnetize, and so move, an iron rod placed on its axis. Mechanical valves attached to the rod can be operated by switching the current on or off, so converting electrical energy into mechanical energy. Solenoids are used to relay energy from the battery of a car to the starter motor by means of the ignition switch.

The solenoid has a magnetic field, one end being the north pole and the other end the south pole. A solenoid behaves as any other magnet; by changing the direction of the current the position of the north and south poles can be switched. If a larger current is passed through the coil it becomes a stronger magnet.

solid

in physics, a state of matter that holds its own shape (as opposed to a liquid, which takes up the shape of its container, or a gas, which totally fills its container). According to the kinetic theory of matter, the atoms or molecules in a solid are packed closely together in a regular arrangement, and are not free to move but merely vibrate about fixed positions, such as those in crystal lattices.

solidification

change of state from liquid (or vapour) to solid that occurs at the freezing point of a substance.

solid-state circuit

electronic circuit in which all the components (resistors, capacitors, transistors, and diodes) and interconnections are made at the same time, and by the same processes, in or on one piece of single-crystal silicon. The small size of this construction accounts for its widespread use in all areas of electronics. See intergrated circuit.

solifluction

movement (flow) of topsoil that has become saturated with water. It is an important process of transportation in periglacial environments where water released by the spring thaw cannot percolate downwards because the ground below is permanently frozen (permafrost). The saturated topsoil may then flow slowly downhill to form a **solifluction lobe**.

Solomon's seal

any of a group of perennial plants belonging to the lily family, native to Europe and found growing in moist, shady woodland areas. They have drooping bell-like white or greenish-white flowers which appear just above the point where the leaves join the arching stems, followed by blue or black berries. (Genus *Polygonatum*, family Liliaceae.)

solstice

either of the days on which the Sun is farthest north or south of the celestial equator each year. In the northern hemisphere, the **summer solstice**, when the Sun is farthest north, occurs around 21 June and the **winter solstice** around 22 December.

solubility

measure of the amount of solute (usually a solid or gas) that will dissolve in a given amount of solvent (usually a liquid) at a particular temperature. Solubility may be expressed as grams of solute per 100 grams of solvent or, for a gas, in parts per million (ppm) of solvent.

solute

substance that is dissolved in another substance (see solution).

solution

two or more substances mixed to form a single, homogenous phase. One of the substances is the **solvent** and the others (**solutes**) are said to be dissolved in it.

The constituents of a solution may be solid, liquid, or gaseous. The solvent is normally the substance that is present in greatest quantity; however, if one of the constituents is a liquid this is considered to be the solvent even if it is not the major substance.

solution

or dissolution

in earth science, process by which the minerals in a rock are dissolved in water. Solution is one of the processes of erosion as well as weathering (in which the breakdown of rock occurs without transport of the dissolved material). An example of this is when weakly acidic rainfall dissolves calcite.

Solution commonly affects limestone and chalk, which are both formed of calcium carbonate. It can occur in coastal environments along with corrasion and hydraulic action, producing features like the white cliffs of Dover, as well as fluvial (river) environments, like the one that formed Cheddar Gorge.

Solution is also responsible for the weathering of many buildings, monuments and other structures.

Solvay process

industrial process for the manufacture of sodium carbonate.

It is a multistage process in which carbon dioxide is generated from limestone and passed through brine saturated with ammonia. Sodium hydrogencarbonate is isolated and heated to yield sodium carbonate. All intermediate by-products are recycled so that the only ultimate by-product is calcium chloride.

solvent

substance, usually a liquid, that will dissolve another substance (see solution). Although the commonest solvent is water, in popular use the term refers to low-boiling-point organic liquids, which are harmful if vapour from them is breathed in as a result of their use in a confined space, or from skin contact with the liquid. They can give rise to respiratory problems, liver damage, and neurological complaints.

Typical organic solvents are petroleum distillates (in glues), xylol (in paints), alcohols (for synthetic and natural resins such as shellac), esters (in lacquers, including nail varnish), ketones (in cellulose lacquers and resins), and chlorinated hydrocarbons (in paint stripper and dry-cleaning fluids). The fumes of some solvents, when inhaled (glue-sniffing), affect mood and perception. In addition to damaging the brain and lungs, repeated inhalation of solvent from a plastic bag can cause death by asphyxiation.

sonar

acronym for SOund Navigation And Ranging

method of locating underwater objects by the reflection of ultrasonic waves. The time taken for an acoustic beam to travel to the object and back to the source enables the distance to be found since the velocity of sound in water is known. Sonar devices, or **echo sounders**, were developed in 1920, and are the commonest means of underwater navigation.

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sone

unit of subjective loudness. A tone of 40 decibels above the threshold of hearing with a frequency of 1,000 hertz is defined as one sone; any sound that seems twice as loud as this has a value of two sones, and so on. A loudness of one sone corresponds to 40 phons.

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sonic boom

noise like a thunderclap that is heard when an aircraft passes overhead faster than the speed of sound. It happens as the cone-shaped shock wave caused by the plane moves over the ground.

Sony

Japanese electronics company that produced the Walkman, the first easily portable cassette player with headphones, in 1980. It diversified into entertainment by the purchase of CBS Records in 1988 and Columbia Pictures in 1989. Sony made the 3.5-in disk drives for the Apple Macintosh in 1984, and also manufactures microchips and games consoles, among many other products.

During the 1970s Sony developed the Betamax video-cassette format, which technicians rated as more advanced than the rival VHS system developed by the Matsushita Corporation, but the latter eventually triumphed in the marketplace. Sony's late former senior executive, Akio Morita, was co-author of *A Japan That Can Say No* (1989) and sequels.

In 2006 sales were $64 billion, and there were about 150,000 employees.

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sorbic acid

$CH_3CH{=}CHCH{=}CHCOOH$

tasteless acid found in the fruit of the mountain ash (genus *Sorbus*) and prepared synthetically. It is widely used in the preservation of food – for example, cider, wine, soft drinks, animal feeds, bread, and cheese.

Sørensen, Søren Peter Lauritz (1868-1939)

Danish chemist who in 1909 introduced the concept of using the pH scale as a measure of the acidity of a solution. On Sørensen's scale, still used today, a pH of 7 is neutral; higher numbers represent alkalinity, and lower numbers acidity.

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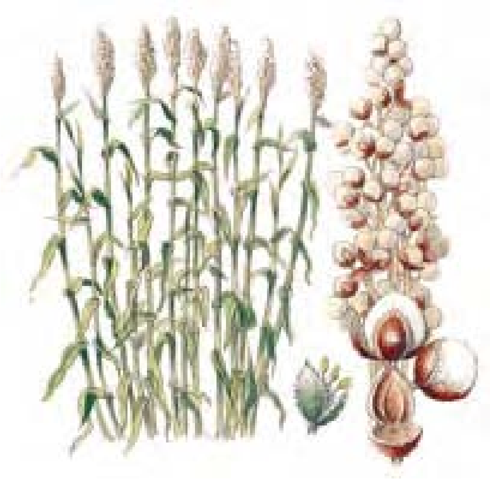
sorghum

or great millet or Guinea corn

any of a group of cereal grasses native to Africa but cultivated widely in India, China, the USA, and southern Europe. The seeds are used for making bread. Durra is a member of the genus. (Genus *Sorghum*.)

Around 58 million tonnes of sorghum are grown worldwide on 44 million hectares. It is vulnerable to the fungus ergot, which can destroy whole crops. In 1994 a simple fungicidal spray of garlic and water was found to be nearly 100% successful in combatting ergot.

sorghum



(Image © Research Machines plc)

Sorghum is a type of grass that was originally cultivated in Africa to provide grain for animal fodder and to make flour for bread or porridge. There are other kinds of sorghums which have been used to provide hay, molasses or syrup, and even brushes and brooms.

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sorrel

(Old French sur 'sour')

any of several plants belonging to the buckwheat family. *R. acetosa* is grown for its bitter salad leaves. Dock plants are of the same genus. (Genus *Rumex*, family Polygonaceae.)

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sorting

in computing, arranging data in sequence. When sorting a collection, or file, of data made up of several different fields, one must be chosen as the **key field** used to establish the correct sequence. For example, the data in a company's mailing list might include fields for each customer's first names, surname, address, and telephone number. For most purposes the company would wish the records to be sorted alphabetically by surname; therefore, the surname field would be chosen as the key field.

The choice of sorting method involves a compromise between running time, memory usage, and complexity. Those used include **selection sorting**, in which the smallest item is found and exchanged with the first item, the second smallest exchanged with the second item, and so on; **bubble sorting**, in which adjacent items are continually exchanged until the data are in sequence; and **insertion sorting**, in which each item is placed in the correct position and subsequent items moved down to make a place for it.

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sorus

in ferns, a group of sporangia, the reproductive structures that produce spores. They occur on the lower surface of fern fronds.

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sound

physiological sensation received by the ear, originating in a vibration causing sound waves. The sound waves are pressure variations in the air and travel in every direction, spreading out as an expanding sphere. Sound energy cannot travel in a vacuum.

All sound waves in air travel with a speed dependent on the temperature; under ordinary conditions, this is about 330 m/1,080 ft per second. The pitch of the sound depends on the number of vibrations imposed on the air per second (frequency), but the speed is unaffected. The loudness of a sound is dependent primarily on the amplitude of the vibration of the air.

How Ultrasound Works

Go to site

This site gives an insight into how ultrasound works, and where and why it is used. It contains an example of an ultrasound image of a fetus. There are further links provided to other sections of the site, explaining the medical uses of ultrasound.

How We Perceive Sound: The Ear

Go to site

Details of the workings of the ear. The user can click on a part of the diagram of the ear to find out what it is and how it works. This is a very clearly laid out site with easy-to-understand definitions.

Physics and Psychophysics of Music

Go to site

Course notes from an Australian University, covering all aspects of physics and sound. The site covers the basics such as 'Definitions of sound' and 'Frequency of a sound wave', and leads on to advanced issues like 'The psychophysics of loudness'.

Physics of Sound

Go to site

Exploration of the speed of sound. This site deals with the different speeds that occur in solids, liquids, and gases. The equation for calculating speed and the calculation of differences between different materials is defined. A 'Check your understanding' section tests the areas covered in the text, and answers are available from the pull-down menus under each question.

Range of Human Hearing

Go to site

All about sound and hearing. The first page is a brief outline of the upper limits of human hearing in the domains of frequency and intensity. The user can then follow the links in the text for pages containing further definitions of terms, such as sound pressure and waves.

Wizard's Lab: Sound and Waves

Go to site

Hosted by a wizard, these pages introduce sound and waves. There are several lessons detailing the properties and characteristics of sound waves. After each topic there is a summary, and there is a link to a quiz, and to other physics topics. The style is informal, but this helps explain the principles clearly. In addition the user can listen to RealAudio while reading the text.

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sound barrier

concept that the speed of sound, or sonic speed (about 1,220 kph/760 mph at sea level), constitutes a speed limit to flight through the atmosphere, since a badly designed aircraft suffers severe buffeting at near sonic speed owing to the formation of shock waves. US test pilot Chuck Yeager first flew through the 'barrier' in 1947 in a Bell X-1 rocket plane. Now, by careful design, such aircraft as Concorde can fly at supersonic speed with ease, though they create in their wake a sonic boom.

Faster Than Sound

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *Nova*, this page commemorates the 50-year anniversary of test pilot Chuck Yeager's breaking the sound barrier in his X-1, the so-called 'bullet with wings'. Hear audio clips of Yeager and others who worked on the project describing those fast-paced days. Learn about the design of the X-1 rocket and the secret history behind the X-1 programme. You can also find out what causes a sonic boom and learn about the latest attempts to beat speed records on land, water, and in the air. You can download a transcript of the television programme, and there is a list of resources.

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sound synthesis

the generation of sound (usually music) by electronic synthesizer.

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sound therapy

in alternative medicine, treatment based on the finding that human blood cells respond to sound frequencies by changing colour and shape, and the hypothesis that therefore sick or rogue cells can be healed or harmonized by sound. Although sound therapy in some form can claim a history dating back to ancient times, modern sound theory was developed and researched in the 1990s by French musician and acupuncturist Fabien Maman and US physicist Joel Sternheimer. It was claimed that sound frequencies applied to acupuncture points are as effective as needles.

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soundtrack

band at one side of a movie film on which the accompanying sound is recorded. Usually it takes the form of an optical track (a pattern of light and shade). The pattern is produced on the film when signals from the recording microphone are made to vary the intensity of a light beam. During playback, a light is shone through the track on to a photocell, which converts the pattern of light falling on it into appropriate electrical signals. These signals are then fed to loudspeakers to recreate the original sounds.

source language

in computing, the language in which a program is written, as opposed to machine code, which is the form in which the program's instructions are carried out by the computer. Source languages are classified as either high-level languages or low-level languages, according to whether each notation in the source language stands for many or only one instruction in machine code.

Programs in high-level languages are translated into machine code by either a compiler or an interpreter program. Low-level programs are translated into machine code by means of an assembler program. The program, before translation, is called the **source program**; after translation into machine code it is called the **object program**.

souring

change that occurs to wine on prolonged exposure to air. The ethanol in the wine is oxidized by the air (oxygen) to ethanoic acid. It is the presence of the ethanoic (acetic) acid that produces the sour taste:

$$CH_3CH_2OH_{(aq)} + O_{2(g)} \rightarrow CH_3COOH_{(aq)} + H_2O_{(1)}$$

Milk turns sour with the production of lactic acid, brought about by bacterial action.

Southern Cross

popular name for the constellation Crux.

southern lights

common name for the aurora australis.

Southern Ocean

corridor linking the Pacific, Atlantic, and Indian oceans, all of which receive cold polar water from the world's largest ocean surface current, the Antarctic Circumpolar Current, which passes through the Southern Ocean.

soybean

leguminous plant *Glycine max*, native to East Asia, in particular Japan and China. Originally grown as a food crop for animals, it is increasingly used for human consumption in cooking oils and margarine, as a flour, soy milk, soy sauce, or processed into tofu, miso, or textured vegetable protein (TVP).

Soy is the richest natural vegetable food. The dried bean is 18-22% fat, 35% carbohydrate, and one hectare of soy beans yields 357 lb/162 kg of protein (compared with 20 lb/9 kg per hectare for beef). There are more than 1,000 varieties. The plant has been cultivated in Asia for about 5,000 years, and first became known in Europe when brought back from Japan by the German botanist Engelbert Kaenfer in 1692. Today the USA produces more soybeans than Asia.

Miso is soybeans fermented with cereal grains, water, and salt, used in soups and sauces; **soy sauce** is beans fermented with salt; and **tamari** is similar to soy sauce but stronger, having been matured for up to two years.

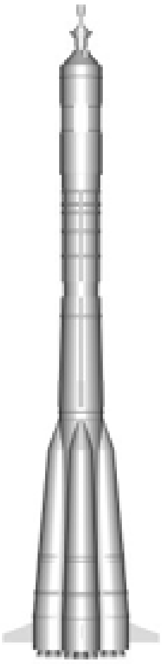
Soyuz

(Russian 'union')

Soviet (later Russian) series of spacecraft, capable of carrying up to three cosmonauts. It is the longest serving crewed spacecraft in the world. *Soyuz* spacecraft consist of three parts: a rear section containing engines; the central crew compartment; and a forward compartment for working and living space. Although the craft were originally used for independent space fight, from 1998 the *Soyuz* ferried crews and components to the *International Space Station* (*ISS*), scheduled for completion in 2006. When NASA grounded its space shuttles after the 2003 *Columbia* space shuttle disaster, the *Soyuz* craft assumed all of the flights to the *ISS* until the shuttles' return in July 2005.

Soyuz 1 crashed on its first flight in April 1967, killing the lone pilot, Vladimir Komarov. Yet in 1968 *Soyuz 3* had the first crewed rendezvous and possible docking by a cosmonaut; in 1969 the flights of *Soyuz 6*, *Soyuz 7*, and *Soyuz 8* marked the first time three spacecraft and seven astronauts had been put into Earth orbit simultaneously; and in 1971 *Soyuz 11* linked up with the first space station, *Salyut 1* (see *Salyut*), although three cosmonauts died on re-entry due to loss of pressure in the spacecraft caused by a faulty valve. In 1975 the *Apollo-Soyuz* Test Project resulted in a successful docking of the two spacecraft in orbit. Among the crews ferried up to space stations have been guest cosmonauts from other countries.

Soyuz



(Image © Research Machines plc)

The Soyuz rocket is used to launch the crewed *Soyuz* spacecraft, which delivers cosmonauts to the *International Space Station*.

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space

or outer space

void that exists beyond Earth's atmosphere. Above 120 km/75 mi, very little atmosphere remains, so objects can continue to move quickly without extra energy. The space between the planets is not entirely empty, but filled with the tenuous gas of the solar wind as well as dust. Highly rarefied gas, dust, and high-energy subatomic particles also exist in the space between galaxies and between clusters of galaxies.

Space flight: key dates

1903	Russian scientist Konstantin Tsiolkovsky publishes the first practical paper on astronautics
1926	US engineer Robert Goddard launches the first liquid-fuel rocket
1937-45	In Germany, Wernher von Braun develops the V2 rocket
4 October 1957	The USSR launches the first space satellite, Sputnik 1, into Earth orbit
3 November 1957	The USSR launches Sputnik 2, which carries a dog called Laika; she dies on board after seven days
1958	Explorer 1, the first US satellite, discovers the Van Allen radiation belts
12 April 1961	The USSR launches the first crewed spaceship, *Vostok 1*, with Soviet cosmonaut Yuri Gagarin on board. Before landing he completes a single orbit of 89.1 minutes at an altitude of 142-175 km/88-109 mi
5 May 1961	Alan Shepard, of the USA, makes a 15-minute sub-orbital flight reaching an altitude of 185 km/115 mi aboard the *Mercury* capsule *Freedom 7*
20 February 1962	John Glenn in *Friendship 7* becomes the first US astronaut to orbit the Earth
July 1962	Telstar, a US communications satellite, sends the first live television transmission between the USA and Europe
16-19 June 1963	Soviet cosmonaut Valentina Tereshkova becomes the first woman in space, making 48 orbits of the Earth in *Vostok 6*
18 March 1965	Soviet cosmonaut Alexei Leonov performs the first space walk, outside the spacecraft *Voskhod 2*
27 January 1967	US astronauts Gus Grissom, Edward White, and Roger Chaffee die during a simulated countdown when a flash fire sweeps through the cabin of *Apollo 1*
24 April 1967	Vladimir Komarov is the first person to be killed on a space mission, when his ship, *Soyuz 1* (USSR), crash-lands on the Earth
20 July 1969	US astronaut Neil Armstrong of *Apollo 11* becomes the first person to walk on the Moon
April 1970	The *Apollo 13* mission to the Moon is cut short after an on-board explosion; all three astronauts survive the return to Earth

November 1970	Luna 17 (USSR) is launched; its space probe, Lunokhod, takes photographs and makes soil analyses of the Moon's surface
1971	Cosmonauts Georgi Dobrovolsky, Viktor Patsayev, and Vladislav Volkov, aboard the *Soyuz 11* mission, are the first people to die in space when their cabin depressurizes during re-entry
April 1971	The Soviet *Salyut 1*, the first orbital space station, is established; it is later visited by the *Soyuz 11* crewed spacecraft
1973	*Skylab 2*, the first US orbital space station, is established
1975	The crafts *Apollo 18* of the USA and *Soyuz 19* of the USSR make a joint flight and link up in space
1979	The European Space Agency's satellite launcher, Ariane 1, is launched
1981	The first reusable crewed spacecraft, the US space shuttle *Columbia*, is launched
18 June 1983	The US space shuttle *Challenger* carries the first five-person crew into orbit, including Sally Ride, the first US woman in space
28 November 1983	The space shuttle *Columbia*, with a crew of six, launches the European experimental platform *Spacelab*
1984	Soviet cosmonaut Svetlana Savitskaya, one of the crew of the *Soyuz* T-12, becomes the first woman to walk in space
28 January 1986	The US space shuttle *Challenger* explodes shortly after take-off, killing all seven crew members
February 1986	The Russian space station *Mir* is launched into orbit and is visited by its first crew.
1988	The US shuttle programme resumes with the launch of *Discovery*
15 November 1988	The Soviet shuttle *Buran* is launched from the rocket Energiya
December 1988	Soviet cosmonauts Musa Manarov and Vladimir Titov in the space station *Mir* complete a whole year - actually 365 days 59 minutes - in space
April 1990	The US Hubble Space Telescope is launched from Cape Canaveral
August 1990	The US space probe Magellan, launched in 1989, reaches Venus and begins mapping the planet in detail
5 April 1991	The Gamma-Ray Observatory is launched from the space shuttle *Atlantis* to survey the sky at gamma-ray wavelengths
18 May 1991	Helen Sharman, the first Briton in space, is launched with Anatoli Artsebarsky and Sergei Krikalev to the *Mir* space station, returning to Earth on 26 May in *Soyuz* flight TM-11 with Viktor Afanasyev and Musa Manarov
1992	European satellite Hipparcos, launched in 1989 to measure the position of 120,000 stars, fails to reach geostationary orbit and goes into a highly elliptical orbit, swooping to within 500 km/308 mi of the Earth every ten hours. The satellite is later retrieved
	Astronauts aboard the space shuttle *Endeavour* successfully carry out a mission to replace the Hubble Space Telescope's solar panels and repair its mirror
October 1992	LAGEOS-2 (Laser Geodynamics Satellite) is released from the space shuttle *Columbia* into an orbit so stable that it will still be circling the Earth in billions of years
1994	Japan's heavy-lifting H-2 rocket is launched successfully, carrying an uncrewed shuttle craft
1995	The US space shuttle *Atlantis* docks with *Mir*, exchanging crew members
4 June 1996	The Ariane 5 rocket disintegrates almost immediately after takeoff, destroying four Cluster satellites
1997	Astronauts aboard the US space shuttle *Discovery* carry out a second service mission to improve the performance of the Hubble Space Telescope
	Mir undergoes increasing difficulties, following a collision with a cargo ship that depressurized one of its modules, *Spektr*
October 1998	NASA launches the space probe Deep Space 1 to explore interplanetary space
November 1998	A Russian Proton rocket lifts *Zarya*, the first module of the *International Space Station* (*ISS*) into Earth orbit. The *ISS* is an international project involving 15 countries, including the USA and Russia
1999	The Russian space agency abandons the problem-ridden *Mir* space station
	NASA loses two important Mars probes, Mars Climate Orbiter and Mars Polar Lander
July 1999	The US space shuttle *Columbia* launches the Chandra X-Ray Observatory
November 1999	A space shuttle crew aboard *Discovery* carry out another servicing mission on the Hubble Space Telescope to fix faulty gyroscopes
December 1999	The European Space Agency (ESA) launches its X-Ray Multi-Mirror Mission Observatory atop an Ariane 5 rocket; it is later renamed Newton
2000	A Dutch-based company, MirCorp, takes over the *Mir* space station with support from the Russian government
November 2000	The first crew of scientists move into the *ISS*
NASA terminates its X-33 experimental spaceship programme	
23 March 2001	The *Mir* space station is finally decommissioned and deliberately brought down into the Pacific Ocean
April 2001	Dennis Tito, 60, visits the *ISS* as the first space tourist
	Canadarm 2 is installed on the *ISS*
1 February 2003	The space shuttle *Columbia* breaks up on re-entry, killing all seven crew, including the first Israeli astronaut Ilan Ramon
15 October 2003	Yang Liwei becomes the first Chinese astronaut with the launch of *Shenzhou-5*
July 2005	Nasa resumes space shuttle flights, launching *Discovery*. However, further problems lead to the shuttle fleet being grounded again.

October 2005	China's second manned space mission, Shenzou VI ends successfully, with plans for further missions in 2007

Ask the Space Scientist

Go to site

Well-organized NASA site with answers to questions about astronomy and space. The site endeavours to send a reply to any question about space and astronomy within three days. There are useful links to question archives, general files, and other space-related sites.

Space.com

Go to site

Latest news on space exploration, plus space quizzes, games, and other fun stuff. The site also includes a children's page with activities.

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space adaptation syndrome

alternative term for space sickness.

Spacelab

small space station built by the European Space Agency (ESA), carried in the cargo bay of the US space shuttle, in which it remained throughout each flight, returning to Earth with the shuttle. *Spacelab* consisted of a pressurized module in which astronauts could work, and a series of pallets, open to the vacuum of space, on which equipment was mounted. *Spacelab* was used for astronomy, Earth observation, and experiments utilizing the conditions of weightlessness and vacuum in orbit.

The first *Spacelab* mission lasted from 28 November to 8 December 1983. Three other missions were flown between 1983 and 1985. The first crewed mission managed by a nation other than the USA or USSR was a German *Spacelab* mission, **D1 Spacelab**. It carried a record crew of eight, and lasted from 30 October to 6 November 1985 aboard the space shuttle *Challenger*. *Spacelab* life sciences missions were flown in June 1991 and October 1993; a life science and microgravity mission was flown in June-July 1996. *Spacelab* was used in 25 shuttle flights, but was finally decommissioned in 1998.

Spacelab

Go to site

Space shuttle reference manual with a chapter describing in detail the make-up and operation of the *Spacelab* pressurized experiment module.

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space probe

any instrumented object sent beyond Earth to collect data from other parts of the Solar System and from deep space. The first probe was the Soviet Lunik 1, which flew past the Moon in 1959. The first successful planetary probe was the US Mariner 2, which flew past Venus in 1962, using a transfer orbit. The first space probe to leave the Solar System was Pioneer 10 in 1983. Space probes include Galileo, Giotto, Magellan, Mars Observer, Ulysses, the Moon probes, and the Mariner, Pioneer, Viking, and Voyager series.

Space probes: key dates

13 September 1959	Luna 2 hits the Moon, the first craft to do so
10 October 1959	Luna 3 photographs the far side of the Moon
14 December 1962	Mariner 2 flies past Venus; launch date 26 August 1962
31 July 1964	Ranger 7 hits the Moon, having sent back 4,316 pictures before impact
14 July 1965	Mariner 4 flies past Mars; launch date 28 November 1964
3 February 1966	Luna 9 achieves the first soft landing on the Moon, having transmitted 27 close-up panoramic photographs; launch date 31 January 1966
2 June 1966	Surveyor 1 lands softly on the Moon and returns 11,150 pictures; launch date 30 May 1965
13 November 1971	Mariner 9 enters orbit of Mars; launch date 30 May 1971
3 December 1973	Pioneer 10 flies past Jupiter; launch date 3 March 1972
29 March 1974	Mariner 10 flies past Mercury; launch date 3 November 1973
22 October 1975	Venera 9 lands softly on Venus and returns its first pictures; launch date 8 June 1975
20 July 1976	Viking 1 first lands on Mars; launch date 20 August 1975
3 September 1976	Viking 2 transmits data from the surface of Mars
20 August 1977	Voyager 2 is launched
5 September 1977	Voyager 1 is launched. With a faster trajectory, it will reach Jupiter sooner than Voyager 2
4 December 1978	Pioneer-Venus 1 orbits Venus; launch date 20 May 1978
5 March 1979	Voyager 1 encounters Jupiter

9 July 1979	Voyager 2 encounters Jupiter
12 November 1980	Voyager 1 reaches Saturn
25 August 1981	Voyager 2 flies past Saturn
1 March 1982	Venera 13 transmits its first colour pictures of the surface of Venus; launch date 30 October 1981
10 October 1983	Venera 15 maps the surface of Venus from orbit; launch date 2 June 1983
2 July 1985	The European Space Agency (ESA) probe Giotto is launched to Halley's comet
24 January 1986	Voyager 2 encounters Uranus
13-14 March 1986	Giotto meets Halley's comet, closest approach 596 km/370 mi, at a speed 50 times faster than that of a bullet
4 May 1989	Magellan launches from space shuttle *Atlantis* on a 15-month cruise to Venus across 15 million km/9 million mi of space
25 August 1989	Voyager 2 reaches Neptune (4,400 million km/2,700 million mi from Earth), approaching it to within 4,850 km/3,010 mi
18 October 1989	Galileo is launched from space shuttle *Atlantis* for a six-year journey to Jupiter
10 August 1990	Magellan arrives at Venus and transmits its first pictures on 16 August 1990
6 October 1990	The ESA probe Ulysses is launched from space shuttle *Discovery*, to study the Sun
29 October 1991	Galileo makes the closest-ever approach to an asteroid, Gaspra, flying within 1,600 km/990 mi
8 February 1992	Ulysses flies past Jupiter at a distance of 380,000 km/236,000 mi from the surface, just inside the orbit of Io and closer than 11 of Jupiter's 16 moons
10 July 1992	Giotto flies at a speed of 14 kps/8.5 mps to within 200 km/124 mi of comet Grigg-Skjellerup, 12 light years (240 million km/150 million mi) away from Earth
25 September 1992	Mars Observer is launched from Cape Canaveral, the first US mission to Mars for 17 years
10 October 1992	Pioneer Venus 1 burns up in the atmosphere of Venus
21 August 1993	Contact is lost with Mars Observer three days before it is due to drop into orbit around Mars
28 August 1993	Galileo flies past the asteroid Ida
December 1995	Galileo's probe enters the atmosphere of Jupiter. It radios information back to the orbiter for 57 minutes before it is destroyed by atmospheric pressure
17 February 1996	NASA's Near-Earth Asteroid Rendezvous (NEAR) is launched to study Eros
1997	Galileo begins orbiting Jupiter's moons. It takes photographs of Europa for a potential future landing site, and detects molecules containing carbon and nitrogen on Callisto, suggesting that life once existed there
17 June 1997	The US NEAR spacecraft flies within 1,200 km/746 mi of the asteroid Mathilde, taking high-resolution photographs and revealing a 25-km/15.5-mi crater covering the 53-km/33-mi asteroid
4 July 1997	The NASA Mars Pathfinder becomes the third spacecraft to soft land on Mars. It deploys a micro-roving vehicle called Sojourner. The Mars Pathfinder images are posted on Internet Web sites and accessed by millions of people all over the world
11 September 1997	NASA's Mars Global Surveyor enters orbit around the Red Planet to begin a highly successful mission which continues into 2000, taking high-resolution images of almost the entire Martian surface, as well as gathering vital climate data
15 October 1997	The NASA-ESA Cassini-Huygens mission gets underway with the successful launch of a Titan IV Centaur booster from Cape Canaveral. Cassini will enter orbit around Saturn in July 2004 and will deploy the ESA Huygens spacecraft to land on Titan, the largest moon of the ringed planet
1998	Analysis of high-resolution images from the Galileo spacecraft suggests that the icy crust of Europa, Jupiter's fourth-largest moon, may hide a vast ocean warm enough to support life
6 January 1998	NASA's Lunar Prospector is launched by an Athena 2 rocket from Cape Canaveral and enters orbit around the Moon to conduct a comprehensive survey of the Moon's chemical composition, including a discovery, announced in March 1998, that there could be frozen water beneath the surface of the polar regions. Lunar Prospector later impacts the south pole of the Moon on 31 July 1999 but no trace of water is found in the resulting impact plume
April 1998	Daniel Goldin, the administrator of NASA, gives the go-ahead for the development of the fourth and last Great Observatory series spacecraft, the Space Infrared Telescope Facility, to be launched in 2001. The Great Observatory series includes the Hubble Space Telescope which was launched in 1990
4 July 1998	Japan launches its first probe to explore Mars using an M5 booster from Kagoshima. Called Planet B or Nozomi, the spacecraft was scheduled to reach the Red Planet via fly-bys of the Moon in October and December 1998 and a fly-by of the Earth in October 1999 but will not reach Mars until 2003 due to flight-path deviations
24 October 1998	The first spacecraft in NASA's New Millennium programme, called Deep Space 1, is launched aboard a Delta II booster from Cape Canaveral, to demonstrate a range of new technologies needed for future Solar System exploration, including ion propulsion and 'intelligent spacecraft' systems during a flight that featured a fly-by of an asteroid in 1999
11 December 1998	The Mars Climate Orbiter is launched by a Delta II from Cape Canaveral as part of NASA's long-term exploration of Mars. However, due to a metric-imperial value data error - made during the manufacture of the spacecraft - the craft makes a wrong approach to Mars and crashes into the Martian surface during the planned orbital insertion burn on 23 September 1999
3 January 1999	The second Mars '99 programme spacecraft, the Mars Polar Lander, is launched by another Delta II from Cape Canaveral but is also lost (on 6 December 1999) as it attempts to make a soft landing in a region close to the Red Planet's south pole. The dual loss of the Mars missions is a major blow to NASA and to the future exploration of Mars
7 April 1999	ESA's Mars Express mission is given formal approval with a contract to build the Mars orbiting spacecraft. Mars Express will be launched in 2003, entering orbit in December of that year. A UK 'piggy-back' spacecraft, Beagle 2, will land on the Martian surface
June 1999	NASA gives formal approval to the development of the Next-Generation Space Telescope (NGST) to succeed the Hubble Space Telescope and to be launched in about 2008. NASA also says that Hubble will remain operational until 2010 and may be brought back to Earth aboard a space shuttle
23 July 1999	The space shuttle *Columbia* STS-93 is launched and deploys the Chandra X-Ray Observatory, NASA's third Great Observatory series spacecraft, into orbit

July 1999	NASA gives approval for two new *Discovery* programme spacecraft: Messenger, which will make two close fly-bys of the planet Mercury in 2008, the first such mission since Mariner 10 in 1974; and Deep Impact, a mission to penetrate the comet P/Tempel 1 in July 2005
10 December 1999	ESA's X-Ray Multi-Mirror telescope is launched by an Arianespace Ariane 5 booster from Kourou, French Guiana
7 February 2000	NASA's Stardust spacecraft, en route to the comet Wild 2 in 2004, collects its first samples of interstellar dust, which are due to be returned to Earth in 2006, along with samples of comet dust from Wild 2
14 February 2000	NASA's NEAR spacecraft becomes the first to orbit an asteroid - Eros. NEAR takes thousands of high-resolution images and makes detailed scientific observations during a year-long mission
March 2000	NASA scientists announce that they may have to crash the Galileo probe in order to prevent it from contaminating Europa, one of Jupiter's moons, with microbes from Earth. They believe their best chance of locating extraterrestrial life within our Solar System is on Europa
4 June 2000	NASA's Gamma-Ray Observatory is deliberately de-orbited by the space agency as a precaution after gyroscope control problems
22 June 2000	Images from the Mars Global Surveyor revealing 'water gullies' on the planet are released by NASA
July 2000	NASA announces that twin Mars Exploration Rover missions will be launched in 2003 to land at separate locations on the Red Planet in 2004
September 2000	ESA approves the BepiColombo mission to explore the planet Mercury, to be launched in 2009
December 2000	As NASA's Cassini spacecraft flies past Jupiter en route to Saturn, making observations of Jupiter, the first dual-space exploration of a planet is conducted, with the Galileo Jupiter orbiter
January 2001	Contact with the first deep-space interplanetary explorer, Pioneer 10, is lost. The spacecraft, which explored Jupiter in 1973, was over 11 billion km/7 billion mi from Earth
12 February 2001	NASA's NEAR makes a spectacular finale to its mission at the asteroid Eros by making a carefully thruster-controlled soft landing on the surface. The originally unplanned manoeuvre makes the craft the first to land on an asteroid
March 2001	NASA budget cuts threaten to cancel the only planned mission to explore the final planet in the solar system, Pluto. The Pluto Kuiper Express, to fly past Pluto and its moon, Charon, and to explore the region beyond Pluto in which other objects orbit the Sun, was to have reached Pluto by 2020
7 April 2001	NASA's Mars Odyssey is successfully launched by a Delta rocket from Cape Canaveral. The craft reached Mars on 24 October 2001, and attained its working orbit around the planet in January 2002. The probe carries instruments designed to examine from orbit the chemical make-up of the planet's surface, and it is hoped that the information gathered may help to determine whether life has ever existed on Mars
2 June 2003	ESA launches its Mars Express Orbiter carrying the British-built lander Beagle 2
July 2003	NASA launches two Mars Exploration Rovers, Spirit and Opportunity
25 December 2003	ESA's Beagle 2 lander descends from the Mars Express Orbiter towards the Isidis Planitia region on the Martian surface. However, transmission is lost and further contact proves impossible
January 2004	NASA's rovers Spirit and Opportunity successfully descend by parachute to the Martian surface
March 2004	NASA's Opportunity rover discovers evidence that its landing site on the flat Meridiani Planum region of Mars was previously covered in water. The accompanying Spirit rover on the opposite side of the planet finds that water had once existed in the Gusev Crater. The continuing success of the mission leads NASA to extend original three-month schedule by a further five months
January 2005	ESA's Huygens probe successfully lands on Titan, sending back images
April 2006	The Venus Express probe reaches Venus and goes into orbit around it

space shuttle

in full space shuttle orbiter

reusable crewed spacecraft developed by NASA to reduce the cost of using space for commercial, scientific, and military purposes. The orbiter, the part that goes into space, is 37.2 m/122 ft long and weighs 68 tonnes. The prototype, *Enterprise*, was first flown on 12 August 1977. The first true shuttle, *Columbia*, was launched on 12 April 1981. After leaving its payload in space, the space shuttle can be flown back to Earth to land on a special runway 4.5 km/2.8 mi long and 91 m/300 ft wide, and is then available for reuse.

Four space shuttles were built initially: *Columbia*, *Challenger*, first launched on 4 April 1983, *Discovery* on 30 August 1984, and *Atlantis* on 3 October 1985. The rocket boosters were redesigned after *Challenger* was destroyed in a mid-air explosion in 1986, killing its seven astronauts. Flights resumed in September 1988. A replacement orbiter, *Endeavour*, was built, making its first flight in May 1992. The break-up of *Columbia* on re-entry on 1 February 2003 killed all seven astronauts aboard. NASA then halted all flights and established the *Columbia* Accident Investigation Board which recommended 15 safety changes. The first subsequent flight of a shuttle, *Discovery*, took place on 26 July 2005. When the flights were halted, there had been 113 shuttle flights.

The USSR produced *Buran*, a shuttle of similar size and appearance to the US one. It was launched on its first and only flight, without a crew, by the Energiya rocket on 15 November 1988. The Buran programme was abandoned almost immediately, and the craft that had flown into orbit was destroyed by the collapse of its hangar in 2002. Another craft, intended for test purposes, has been put on display in Australia and Bahrain. There is no prospect of returning Buran to service.

space shuttle

(Image © Corel)

Orbiter of the US space shuttle *Discovery* landing on a runway. Unlike previous spacecraft, the shuttle can be used again and again because the orbiter has a protective outer shell to prevent it from burning up during re-entry into the Earth's atmosphere.

space shuttle

(Image © Corel)

The vertical launch of a space shuttle from Cape Canaveral. The shuttle orbiter, its two huge fuel boosters, and its central fuel tank are clearly visible. The boosters break away after take-off and parachute down into the sea where they are recovered. The central fuel tank is partly discarded once empty.

NASA Shuttle Web

Go to site

Official NASA site for all shuttle missions. There is extensive technical and non-technical information, both textual and graphic. Questions can be sent to shuttle crew members during missions. There is an extensive list of Frequently Asked Questions. There are helpful links to related sites and even a plain-English explanation of NASA's bewildering jargon and acronyms.

Picture Gallery

Go to site

Small but spectacular collection of radar images taken from the space shuttle *Endeavour* in 1994 and offered by NASA. The collection also includes 3D images, videos, and animations. The high-technology enthusiast will also find ample details on the imaging radar system used for the project.

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space sickness

or space adaptation syndrome

feeling of nausea, sometimes accompanied by vomiting, experienced by about 40% of all astronauts during their first few days in space. It is akin to travel sickness, and is thought to be caused by confusion of the body's balancing mechanism, located in the inner ear, by weightlessness. The sensation passes after a few days as the body adapts.

space station

any large structure designed for human occupation in space for extended periods of time. Space stations are used for carrying out astronomical observations and surveys of Earth, as well as for biological studies and the processing of materials in weightlessness. The first space station was the Soviet *Salyut 1*, launched in 1971. In 1973, NASA launched *Skylab*. The core of the Soviet space station *Mir* was launched in 1986. In 1998, the first component of the *International Space Station*, being constructed by the USA, Russia, and 14 other nations, was launched. The first crew arrived at ISS in November 2000 under the command of NASA astronaut Bill Shepherd.

spacesuit

protective suit worn by astronauts and cosmonauts during launch and in space. During launch it acts as a high-altitude pressure suit and also guards against depressurization in the vacuum of space. A spacesuit has to be worn outside the spacecraft during extravehicular activity. It provides an insulated, air-conditioned cocoon in which a person can live and work for hours at a time while outside the spacecraft. Inside the suit is a cooling garment that keeps the body at a comfortable temperature even during vigorous work. The suit provides air to breathe and removes exhaled carbon dioxide and moisture. The suit's outer layers insulate the occupant from the extremes of hot and cold in space (-150°C/-240°F in the shade to 180°C/350°F in sunlight), and from the impact of small meteorites.

space-time

in physics, combination of space and time used in the theory of relativity. When developing relativity, Albert Einstein showed that time was in many respects like an extra dimension (or direction) to space. Space and time can thus be considered as entwined into a single entity, rather than two separate things.

Space-time is considered to have four dimensions: three of space and one of time. In relativity theory, events are described as occurring at points in space-time. The **general theory of relativity** describes how space-time is distorted by the presence of material bodies, an effect that we observe as gravity.

Light Cone: An Illuminating Introduction to Relativity

Go to site

Informal and entertaining site introducing space-time. Easy-to-digest tutorials, illustrated with simple diagrams and animations, explain the concepts and how they have evolved.

Spacetime Wrinkles

Go to site

Masses of space-time information from the National Center for Supercomputing Applications at the University of Illinois. There are also illustrated easy-to-follow tutorials organized by theme, and lots of video clips and animations.

spadix

in botany, an inflorescence consisting of a long, fleshy axis bearing many small, stalkless flowers. It is partially enclosed by a large bract or spathe. A spadix is characteristic of plants belonging to the family Araceae, including the arum lily *Zantedeschia aethiopica*.

spaniel

any of several breeds of small and medium-sized gundog, characterized by large, drooping ears and a wavy, long, silky coat. Spaniels are divided into two groups: those that are still working gundogs - Clumber, cocker, Irish water, springer, and Sussex - and the toy breeds that are kept as pets - including the Japanese, King Charles, papillon, and Tibetan.

The working breeds usually have docked tails.

Spanish fly

alternative name for a European blister beetle*Lytta vesicatoria*, once used in powdered form as a dangerous diuretic and supposed aphrodisiac.

spark chamber

electronic device for recording tracks of charged subatomic particles, decay products, and rays. At its simplest, it consists of two smooth threadlike electrodes that are positioned 1-2 cm/0.5-1 in apart, the space between being filled with a mixture of neon and helium gas. Sparks jump through the gas along the ionized path created by the radiation. More usually, the detector consists of a stack of condenser plates between which the sparks jump. The sparks mark out the path of the charged particle. See particle detector.

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spark plug

plug that produces an electric spark in the cylinder of a petrol engine to ignite the fuel mixture. It consists essentially of two electrodes insulated from one another. High-voltage (18,000 V) electricity is fed to a central electrode via the distributor. At the base of the electrode, inside the cylinder, the electricity jumps to another electrode earthed to the engine body, creating a spark. See also ignition coil.

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sparrow

any of a family (Passeridae) of small Old World birds of the order Passeriformes with short, thick bills, but applied particularly to the different members of the genus *Passer* in the family Ploceidae, order Passeriformes.

Many members of the New World family Emberizidae, which includes warblers, orioles, and buntings, are also called sparrows; for example, the North American song sparrow *Melospize melodia*.

sparrow

The size of the male house sparrow's black bib is determined by its testosterone levels. The higher the level, the larger the bib.

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sparrow hawk

alternate (but no longer correct) name for the American kestrel. The name now only refers to a small woodland hawk*Accipiter nisus* found in Eurasia and North Africa. It has a long tail and short wings. The male grows to 11 in/28 cm long, and the female 15 in/38 cm. It hunts small birds and mice.

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spasm

in medicine, a sudden, involuntary contraction of a muscle or of a hollow organ with a muscular wall.

A **tonic spasm** describes a spasm in which the contraction persists for some time followed by sudden or gradual relaxation, whilst **clonic spasm** is characterized by a series of contractions and relaxations of the muscle. Cramps are spasms that affect the limbs and colic describes spasms of the stomach and intestinal walls.

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spastic

term applied generally to limbs with impaired movement, stiffness, and resistance to passive movement, and to any body part (such as the colon) affected with spasm.

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spathe

in flowers, the single large bract surrounding the type of inflorescence known as a spadix. It is sometimes brightly coloured and petal-like, as in the brilliant scarlet spathe of the flamingo plant *Anthurium andreanum* from South America; this serves to attract insects.

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spearmint

perennial herb belonging to the mint family, with aromatic leaves and spikes of purple flowers; the leaves are used for flavouring in cookery. (*Mentha spicata*, family Labiatae.)

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speciation

emergence of a new species during evolutionary history. One cause of speciation is the geographical separation of populations of the parent species, followed by reproductive isolation and selection for different environments so that they no longer produce viable offspring when they interbreed. Other causes are assortative mating and the establishment of a polyploid population.

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species

in biology, a distinguishable group of organisms that resemble each other or consist of a few distinctive types (as in polymorphism), and that can all interbreed to produce fertile offspring. Species are the lowest level in the system of biological classification.

Related species are grouped together in a genus. Within a species there are usually two or more separate populations, which may in time become distinctive enough to be designated subspecies or varieties, and could eventually give rise to new species through speciation. Around 1.4 million species have been identified so far, of which 750,000 are insects, 250,000 are plants, and 41,000 are vertebrates. In tropical regions there are roughly two species for each temperate-zone species. It is estimated that one species becomes extinct every day through habitat destruction.

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specific gravity

alternative term for relative density.

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specific heat capacity

quantity of heat required to raise unit mass (1 kg) of a substance by one kelvin (1 K). The unit of specific heat capacity in the SI system is the joule per kilogram per kelvin (J kg^{-1} K^{-1}).

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specific latent heat

heat that changes the physical state of a unit mass (one kilogram) of a substance without causing any temperature change.

The **specific latent heat of fusion** of a solid substance is the heat required to change one kilogram of it from solid to liquid without any temperature change. The **specific latent heat of vaporization** of a liquid substance is the heat required to change one kilogram of it from liquid to vapour without any temperature change.

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speckle interferometry

technique whereby large telescopes can achieve high resolution of astronomical objects despite the adverse effects of the atmosphere through which light from the object under study must pass. It involves the taking of large numbers of images, each under high magnification and with short exposure times. The pictures are then combined to form the final picture. The technique was introduced by the French astronomer Antoine Labeyrie in 1970.

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spectacles

another name for eyeglasses, worn to correct or assist defective vision.

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spectator ion

in a chemical reaction that takes place in solution, an ion that remains in solution without taking part in the chemical change. For example, in the precipitation of barium sulphate from barium chloride and sodium sulphate, the sodium and chloride ions are spectator ions.

$BaCl_{2\ (aq)} + Na_2SO_{4\ (aq)} \rightarrow BaSO_{4\ (s)} + 2NaCl_{(aq)}$

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spectral classification

in astronomy, classification of stars according to their surface temperature and luminosity, as determined from their spectra. Stars are assigned a spectral type (or class) denoted by the letters O, B, A, F, G, K, and M, where O stars (about 40,000 K/39,700°C/71,500°F) are the hottest and M stars (about 3,000 K/2,700°C/5,000°F) are the coolest.

Each letter may be further divided into ten subtypes, B0, B1, B2, and so on. Stars are also assigned a luminosity class denoted by a Roman numeral attached to the spectral type: I (supergiants), II (bright giants), III (giants), IV (subgiants), V (main sequence), VI (subdwarfs), or VII (white dwarfs). The Sun is classified as type G2V. See also Hertzsprung-Russell diagram.

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spectrometer

in physics and astronomy, instrument used to study the composition of light emitted by a source. The range, or spectrum, of wavelengths emitted by a source depends upon its constituent elements, and may be used to determine its chemical composition.

The simpler forms of spectrometer analyse only visible light. A **collimator** receives the incoming rays and produces a parallel beam, which is then split into a spectrum by either a diffraction grating or a prism mounted on a turntable. As the turntable is rotated each of the constituent colours of the beam may be seen through a **telescope**, and the angle at which each has been deviated may be measured on a circular scale. From this information the wavelengths of the colours of light can be calculated. Spectrometers are used in astronomy to study the electromagnetic radiation emitted by stars and other celestial bodies. The spectral information gained may be used to determine their chemical composition, or to measure the red shift or blue shift of light caused by the movement of astronomical objects towards or away from the Earth.

spectrometry

in analytical chemistry, a technique involving the measurement of the spectrum of energies (not necessarily electromagnetic radiation) emitted or absorbed by a substance.

spectroscopy

study of spectra (see spectrum) associated with atoms or molecules in the solid, liquid, or gaseous phase. Spectroscopy can be used to identify unknown compounds and is an invaluable tool in science, medicine, and industry (for example, in checking the purity of drugs).

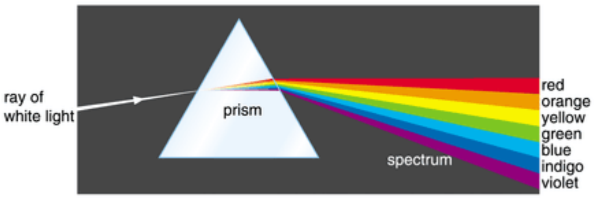
Emission spectroscopy is the study of the characteristic series of sharp lines in the spectrum produced when an element is heated. Thus an unknown mixture can be analysed for its component elements. Related is **absorption spectroscopy**, dealing with atoms and molecules as they absorb energy in a characteristic way. Again, dark lines can be used for analysis. More detailed structural information can be obtained using **infrared spectroscopy** (concerned with molecular vibrations) or **nuclear magnetic resonance (NMR) spectroscopy** (concerned with interactions between adjacent atomic nuclei). **Supersonic jet laser beam spectroscopy** enables the isolation and study of clusters in the gas phase. A laser vaporizes a small sample, which is cooled in helium, and ejected into an evacuated chamber. The jet of clusters expands supersonically, cooling the clusters to near absolute zero, and stabilizing them for study in a mass spectrometer.

spectrum

plural spectra

in physics, the pattern of frequencies or wavelengths obtained when electromagnetic radiations are separated into their constituent parts. Visible light is part of the electromagnetic spectrum and most sources emit waves over a range of wavelengths that can be broken up or 'dispersed'; white light can be separated (for example, using a triangular prism) into red, orange, yellow, green, blue, indigo, and violet. The visible spectrum was first studied by English physicist Isaac Newton, who showed in 1666 how white light could be broken up into different colours.

spectrum



(Image © Research Machines plc)

A prism (a triangular block of transparent material such as plastic, glass, or silica) is used to split a ray of white light into its spectral colours.

spectrum

To remember the order of colours:

Richard **o**f **Y**ork **g**ained **b**attles **i**n **v**ain or **R**oll **o**ut **y**our **G**uinness, **b**oys, **i**n **v**ats or **R**eal **o**ld **y**okels **g**uzzle **b**eer **i**n **v**olume

Red, **o**range, **y**ellow, **g**reen, **b**lue, **i**ndigo, **v**iolet

speculum

plural specula

medical instrument to aid examination of an opening into the body; for example, the nose or vagina. The speculum allows the opening to be widened, permitting the passage of instruments. Many specula also have built-in lights to illuminate the examined cavity.

The earliest recorded vaginal speculum was used by Greek physician Archigenes in the 2nd century AD.

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speech disorder

in medicine, condition that makes speech difficult or impossible. Speech disorders occur for a variety of physical and psychological reasons. Congenital defects, such as cleft palate, require surgical correction before speech is intelligible.

Deafness is the most frequent cause of dumbness, the inability to pronounce the sounds that make up words. A combination of training in lip reading, speech therapy, psychotherapy, and specialist education may be required in children with congenital deafness. Stroke, head injury, and some severe psychiatric disorders may be responsible for speech disorders in adults.

A child may have difficulties in understanding language or self-expression if the language development area of the brain develops abnormally and specialist education and speech therapy may then be required.

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speech recognition

or voice input

in computing, any technique by which a computer can understand ordinary speech. Spoken words are divided into 'frames', each lasting about one-thirtieth of a second, which are converted to a wave form. These are then compared with a series of stored frames to determine the most likely word. Research into speech recognition started in 1938, but the technology did not become sufficiently developed for commercial applications until the late 1980s.

Discrete word recognition required a short pause between words. This was replaced in the early years of the 21st century by **continuous speech recognition**, which allows the use of normal but carefully articulated speech.

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speech recognition software

computing system that enables data to be input by voice. A microphone connects to the sound card in the computer which converts the analogue signals of the voice to digital signals which can then be processed. Examples include Dragon Naturally Speaking, IBM's Via Voice, Philip's SpeechMagic, and iListen from MacSpeech Inc.

The user must read sample sentences to the computer on first use to familiarize it with individual pronunciation. Early software was very inaccurate and slow but by the early 21st century speeds of 160 words per minute with 95–99% accuracy were achievable.

Speech Recognition

Go to site

List of speech recognition materials on the Internet. There are links to articles, speech recognition in the news, user groups, and mailing lists and information on dictation software for Windows, Apple, and Unix systems.

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speech synthesis

or voice output

computer-based technology for generating speech. A speech synthesizer is controlled by a computer, which supplies strings of codes representing basic speech sounds (phonemes); together these make up words. Speech-synthesis applications include children's toys, car and aircraft warning systems, and talking books for the blind.

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speed

common name for amphetamine, a stimulant drug.

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speed

rate at which an object moves, or how fast an object moves. The average speed v of an object may be calculated by dividing the distance s it has travelled by the time t taken to do so, and may be expressed as:

$v = s / t$

The usual units of speed are metres per second or kilometres per hour.

Speed is a scalar quantity in which direction of motion is unimportant (unlike the vector quantity velocity, in which both magnitude and direction must be taken into consideration). Movement can be described by using motion graphs. Plotting distance against time in a distance-time graph allows the total distance covered to be worked out.

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speed of light

speed at which light and other electromagnetic waves travel in a vacuum. Its value is 299,792,458 m per second/186,282 mi per second but for most calculations 3×10^8 m s^{-1} (300 million metres per second) suffices. In glass the speed of light is two-thirds of its speed in air, about 200 million metres per second. The speed of light is the highest speed possible, according to the theory of relativity, and its value is independent of the motion of its source and of the observer. It is impossible to accelerate any material body to this speed because it would require an infinite amount of energy.

Speed of Light: Measuring the

as swift as light

The speed of light in a vacuum, c, is a fundamental constant of nature. It occurs in many scientific equations, such as Einstein's famous $E = mc^2$. Numerous attempts have been made to determine c as accurately as possible.

first estimates

The first reasonable estimate was made in 1675 by a young Danish astronomer, Ole Roemer, at the Royal Observatory in Paris. Roemer was studying the motion of Jupiter's moons, which take between 1.7 and 16.7 days to orbit Jupiter. The orbital time of a moon can be measured by timing its eclipse by Jupiter's shadow. Roemer noticed that the interval between successive eclipses gradually decreased when Jupiter and the Earth were approaching one another and increased when they were receding. He explained this by assuming that light travels through space at a finite though very great speed. Thus if Jupiter is approaching the Earth, the time the light from a moon takes to reach the Earth will gradually decrease as Jupiter and the Earth get closer, and the interval between eclipses will appear to decrease. From the differences in orbital times and the known rates of motion of Jupiter and the Earth, Roemer estimated that the speed of light must be about 300,000 km/186,400 mi per second.

In 1728 British Astronomer Royal James Bradley (1693-1762) made another estimate using a different approach. Tradition has it that Bradley devised his method while sailing on the River Thames. He noticed how the apparent wind direction depended on the boat's movement and the windspeed. Bradley reasoned that if starlight was regarded as a wind blowing earthwards, its direction should appear to change throughout the year as the Earth moved round the Sun. By observing the change he was able to calculate the speed of light and verify Roemer's result.

laboratory measurements

The first laboratory measurement was made by French physicist Armand Fizeau in 1849. He used a bright beam of light which travelled to a distant mirror and was reflected back along its path. Using a partly silvered mirror, he could look along the light path and see the reflected beam. A large square-toothed wheel in front of the mirror cut the beam into a sequence of flashes as it turned. The speed of rotation could be carefully controlled. With the wheel spinning, Fizeau could only see a flash of light if it passed through the gap between two teeth. He increased the speed of the wheel until the first gap coincided with the returning flash. It was then simple, using the known rotation speed and the dimensions of the teeth, to calculate how long it had taken the tooth to move out of the beam path. The light had travelled 17.2 km/10.7 mi, there were 720 equal teeth in the wheel, and the wheel speed was 12.6 revolutions per second. Fizeau's result, therefore, for the speed of light was 313,300 km/194,700 mi per second.

A year later another French physicist, Léon Foucault, improved on Fizeau's experiment. A beam of light was reflected by a rotating mirror, travelled to a distant mirror and then returned to the rotating mirror. The rotating mirror had turned a little, so the returned beam appeared to be in a slightly different position from when it set out. This change could be measured accurately with a micrometer and used to calculate the rotation speed of the mirror more accurately than in Fizeau's experiment. Foucault used a baseline of only 20 m/65 ft, but achieved a slightly more accurate result: 298,000 km/185,200 mi per second.

all done by mirrors

In 1926 US physicist Albert Michelson (1852-1931) refined Foucault's experiment. He used a much longer baseline, starting at the Mount Wilson Observatory and travelling to a mirror on nearby Mount San Antonio. The baseline was measured precisely by the US Coast and Geodetic Survey as 35,385.53 m/116,135.3 ft, accurate to within 3 mm/0.1 in. Michelson used a multi-sided octagonal mirror which could be spun at 550 revolutions per second. The exact speed was measured by stroboscopic comparison with an electrically driven tuning fork.

Light from an electric arc passed through a narrow slit and was reflected from one facet of the rotating mirror. The beam travelled to the Mount San Antonio station, was reflected from a flat mirror and returned to Mount Wilson. For the reflection to be observed, the octagonal mirror had to have made one-eighth of a rotation while the light travelled along the baseline and returned. The round trip took 0.00023 seconds when the mirror spun at 528 revolutions per second. The calculated speed of light, after correction for slowing of the beam by air along its path, was 299,863 km/186,335 mi per second. In 1929 Michelson repeated the experiment inside a long excavated tube, to eliminate the uncertainty caused by variations in air density along the path. His result was *c* = 299,774 km/186,280 mi per second: within 0.006% of the modern value.

speed of light

To remember the speed of light:

The speed of light is 299,792,458 m/s, which can be remembered from the number of letters in each word of the following phrase:
We guarantee certainty, clearly referring to this light mnemonic

---

speed of sound

speed at which sound travels through a medium, such as air or water. In air at a temperature of 0°C/32°F, the speed of sound is 331 m/1,087 ft per second. At higher temperatures, the speed of sound is greater; at 18°C/64°F it is 342 m/1,123 ft per second. It is also affected by the humidity of the air. It is greater in liquids and solids; for example, in water it is about 1,440 m/4,724 ft per second, depending on the temperature.

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speedometer

instrument attached to the transmission of a vehicle by a flexible drive shaft, which indicates the speed of the vehicle in miles or kilometres per hour on a dial easily visible to the driver.

---

speedwell

any of a group of flowering plants belonging to the snapdragon family. Of the many wild species, most are low-growing with small bluish flowers. (Genus *Veronica*, family Scrophulariaceae.)

---

speleology

scientific study of caves, their origin, development, physical structure, flora, fauna, folklore, exploration, mapping, photography, cave-diving, and rescue work.
Potholing, which involves following the course of underground rivers or streams, has become a popular sport.

Speleology first developed in France in the late 19th century, where the Société de Spéléologie was founded in 1895.

Caves and Caving in the UK

Go to site

Extensive site about caving in the UK. It includes a map of the best areas and extensively linked text with sections on caving conservation and legal aspects, as well as how to get started.

---

sperm

or semen

fluid containing the male gametes (sperm cells) of animals. Usually, each sperm cell has a head capsule containing a nucleus, a middle portion containing mitochondria (which provide energy), and a long tail (flagellum). See sexual reproduction.

In most animals, sperm cells (sometimes called 'sperm' for short) are motile, and are propelled by a long flagellum, but in some (such as crabs and lobsters) they are nonmotile. The term is sometimes used for the motile male gametes (antherozoids) of lower plants. The human sperm cell is 0.0002 in/0.005 mm long and can survive inside the female for 2–9 days. Mammalian sperm cells have receptor cells identical to some of those found in the lining of the nose. These may help in navigating towards the egg.

---

spermaceti

glistening waxlike substance, not a true oil, contained in the cells of the huge, almost rectangular 'case' in the head of the sperm whale, amounting to about 2.8 tonnes/3 tons. It rapidly changes in density with variations in temperature. It was formerly used in lubricants and cosmetics, but in 1980 a blend of fatty acids and esters from tallow and coconut oil was developed as a substitute.

---

spermatophore

small capsule containing sperm and other nutrients produced in invertebrates, newts, and cephalopods.

spermatophyte

another name for a seed plant.

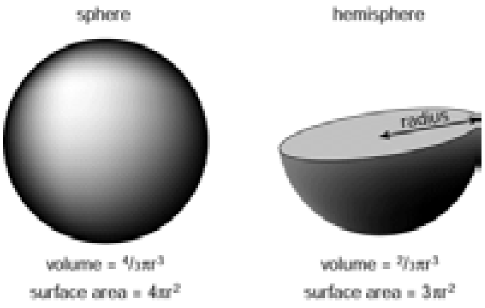
spermicide

any cream, jelly, pessary, or other preparation that kills the sperm cells in semen. Spermicides are used for contraceptive purposes, usually in combination with a condom or diaphragm. Sponges impregnated with spermicide have been developed but are not yet in widespread use. Spermicide used alone is only 75% effective in preventing pregnancy.

sphere

perfectly round object with all points on its surface the same distance from the centre. This distance is the radius of the sphere. For a sphere of radius r, the volume $V = 4/3\pi r^3$ and the surface area $A = 4\pi r^2$.

sphere


sphere
hemisphere
radius
volume = $\frac{4}{3}\pi r^3$
surface area = $4\pi r^2$
volume = $\frac{2}{3}\pi r^3$
surface area = $3\pi r^2$

(Image © Research Machines plc)

A sphere is a perfectly round three-dimensional figure. Its radius is the distance from the centre to the surface. When a sphere is cut along a great circle (a circle on the sphere that has the same diameter as the sphere), two hemispheres are produced.

sphincter

ring of muscle, such as is found at various points in the alimentary canal, that contracts and relaxes to open and close the canal and control the movement of food. The **pyloric sphincter**, at the base of the stomach, controls the release of the gastric contents into the duodenum. After release the sphincter contracts, closing off the stomach. The **external anal sphincter** closes the anus; the **internal anal sphincter** constricts the rectum; the **sphincter vesicae** controls the urethral orifice of the bladder. In the eye the **sphincter pupillae** contracts the pupil in response to bright light.

sphygmomanometer

instrument for measuring blood pressure. Consisting of an inflatable arm cuff joined by a rubber tube to a pressure-recording device (incorporating a column of mercury with a graduated scale), it is used, together with a stethoscope, to measure arterial blood pressure.

Spica

or Alpha Virginis

brightest star in the constellation Virgo and the 16th-brightest star in the night sky. Spica has a true luminosity of over 1,500 times that of the Sun and is 260 light years from the Sun. It is a spectroscopic binary star, the components of which orbit each other every four days.

spice

any aromatic vegetable substance used as a condiment and for flavouring food. Spices are mostly obtained from tropical plants, and include pepper, nutmeg, ginger, and cinnamon. They have little food value but increase the appetite and may help digestion.

---

spicules, solar

in astronomy, short-lived jets of hot gas in the upper chromosphere of the Sun. Spiky in appearance, they move at high velocities along lines of magnetic force to which they owe their shape, and last for a few minutes each. Spicules appear to disperse material into the corona.

---

spider

any arachnid (eight-legged animal) of the order Araneae. There are about 30,000 known species, mostly a few centimetres in size, although a few tropical forms attain great size, for example, some bird-eating spiders attain a body length of 9 cm/3.5 in. Spiders produce silk, and many spin webs to trap their prey. They are found everywhere in the world except Antarctica. Many species are found in woods and dry commons; a few are aquatic. Spiders are predators; they bite their prey, releasing a powerful toxin from poison glands which causes paralysis, together with digestive juices. They then suck out the juices and soft parts.

spider: hunting techniques

Bolas spiders (*Mastophora*) do not use a web to catch their prey. Instead, they swing a sticky globule at the end of a line of silk. At the same time they release a chemical that mimics the pheromone released by some moths to attract mates. When a moth draws within range, it is lassooed.

spider: largest

The world's largest spider is a Goliath bird-eating spider that weighs 122 g/4.3 oz.

spider: silk

Spider silk is up to 200 times finer than the finest human hair and is highly elastic. It can be stretched to over 20% of its length and retains its elasticity at temperatures as low as -40°C.

---

spider monkey

species of monkey found in Central and South America. Spider monkeys have long and very flexible limbs and a long, prehensile tail that is much used in climbing. The thumb is either absent or vestigial (much reduced).

species

There are two species in the genus *Ateles*: the **black spider monkey** (or coaita) *A. paniscus* lives in Brazil and the **long-haired spider monkey** (or marimonda) *A. belzebuth* lives in Guiana. The single species in the genus *Brachyteles* is the **woolly spider monkey** *B. arachnoides*, characterized by its long, woolly hair. It is quite large and varies from grey to brown or even yellow in colour.

classification

Spider monkeys are in the family Cebidae, order Primates.

---

spider plant

African plant belonging to the lily family. Two species (*C. comosum* and *C. elatum*) are popular house plants. They have long, narrow, variegated leaves and produce flowering shoots from which the new plants grow, hanging below the main plant. The flowers are small and white. Spider plants absorb toxins from the air and therefore help to purify the atmosphere around them. (Genus *Chlorophytum*, family Liliaceae.)

---

spikelet

in botany, one of the units of a grass inflorescence. It comprises a slender axis on which one or more flowers are borne.

Each individual flower or floret has a pair of scalelike bracts, the glumes, and is enclosed by a membranous lemma and a thin, narrow palea, which may be extended into a long, slender bristle, or **awn**.

---

spikenard

either of two plants: a Himalayan plant belonging to the valerian family whose underground stems produce a perfume used in Eastern aromatic oils; or a North American plant of the ginseng family, with fragrant roots. (Himalayan *Nardostachys jatamansi*, family Valerianaceae; North American *Aralia racemosa*, family Araliaceae.)

---

spin

in physics, the intrinsic angular momentum of a subatomic particle, nucleus, atom, or molecule, which continues to exist even when the particle comes to rest. A particle in a specific energy state has a particular spin, just as it has a particular electric charge and mass. According to quantum theory, this is restricted to discrete and indivisible values, specified by a spin quantum number. Because of its spin, a charged particle acts as a small magnet and is affected by magnetic fields.

---

spina bifida

congenital defect in which part of the spinal cord and its membranes are exposed, due to incomplete development of the spine (vertebral column). It is a neural tube defect.

Spina bifida, usually present in the lower back, varies in severity. The most seriously affected babies may be paralysed below the waist. There is also a risk of mental retardation and death from hydrocephalus, which is often associated. Surgery is performed to close the spinal lesion shortly after birth, but this does not usually cure the disabilities caused by the condition. Spina bifida can be diagnosed prenatally.

---

spinach

annual plant belonging to the goosefoot family. It is native to Asia and widely cultivated for its leaves, which are eaten as a vegetable. (*Spinacia oleracea*, family Chenopodiaceae.)

---

spinal anaesthetic

in medicine, anaesthetic injected into the spinal cord, as in an epidural, for example.

---

spinal cord

major component of the central nervous system in vertebrates. It consists of bundles of nerves enveloped in three layers of membrane (the meninges) and is bathed in cerebrospinal fluid. The spinal cord is encased and protected by the vertebral column, lying within the vertebral canal formed by the posterior arches of successive vertebrae.

In humans, the spinal cord is about 45 cm/18 in long, extending from the bottom of the skull, where it is continuous with the medulla oblongata, to about waist level. It consists of nerve cell bodies (grey matter) and their myelinated processes or nerve fibres (white matter). In cross-section, the grey matter is arranged in an H-shape around the central canal of the spinal cord, and it is surrounded in turn by the white matter.

Paired spinal nerves arise from the cord at each vertebra. Each is a mixed nerve, consisting of both sensory and motor nerve fibres. The sensory fibres enter the spinal cord at a dorsal root and the motor fibres enter at a ventral root. This arrangement enables the spinal cord to relay impulses coming in and out at the same level, to relay impulses going up and down the cord to other levels, and relay impulses to and from the brain. The first of these involves a **reflex arc**, by which a sensory impulse can create a very rapid, involuntary response to a particular stimulus.

---

spinal tap

or lumbar puncture

insertion of a hollow needle between two lumbar (lower back) vertebrae to withdraw a sample of cerebrospinal fluid (CSF) for testing. Normally clear and colorless, the CSF acts as a fluid buffer around the brain and spinal cord. Changes in its quantity, color, or composition may indicate neurological damage or disease.

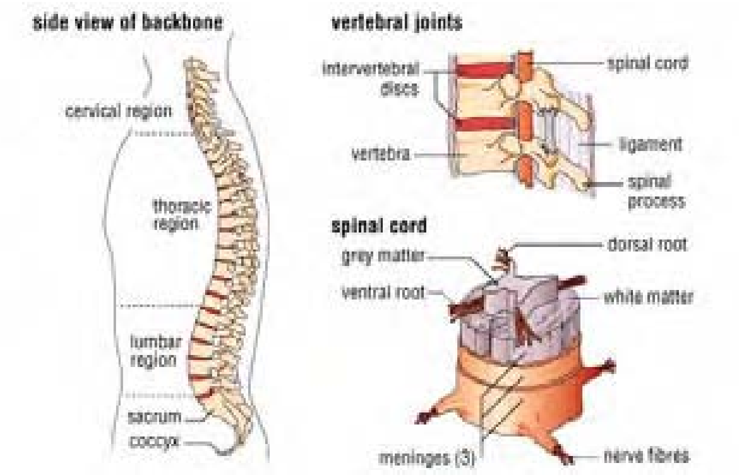
---

spine

backbone of vertebrates. In most mammals, it contains 26 small bones called **vertebrae**, which enclose and protect the **spinal cord** (which links the peripheral nervous system to the brain). The spine articulates with the skull, ribs, and hip bones, and provides attachment for the back muscles.

In humans it is made up of individual vertebrae, separated by intervertebral discs. In the adult there are seven cervical vertebrae in the neck; twelve thoracic in the upper trunk; five lumbar in the lower back; the sacrum (consisting of five rudimentary vertebrae fused together, joined to the hipbones); and the coccyx (four vertebrae, fused into a tailbone). The human spine has four curves (front to rear), which allow for the increased size of the chest and pelvic cavities, and for a degree of spring so as to minimize jolting of the internal organs.

spine



(Image © Research Machines plc)

The human spine extends every night during sleep. During the day, the cartilage discs between the vertebra are squeezed when the body is in a vertical position, standing or sitting, but at night, with pressure released, the discs swell and the spine lengthens by about 8 mm/0.3 in.

---

spinel

any of a group of 'mixed oxide' minerals consisting mainly of the oxides of magnesium and aluminium, $MgAl_2O_4$ and $FeAl_2O_4$. Spinels crystallize in the cubic system, forming octahedral crystals. They are found in high-temperature igneous and metamorphic rocks. The aluminium oxide spinel contains gem varieties, such as the ruby spinels of Sri Lanka and Myanmar (Burma).

---

spinifex

spiny grass chiefly found in Australia, growing on the coastal sand dunes. It is often planted to bind sand along the seashore. The term also refers to porcupine grass, any of a group of spiny-leaved, tussock-forming grasses of inland Australia. (Genus *Spinifex*; porcupine grass genus *Triodia*.)

---

spiny anteater

alternative name for echidna.

---

spiracle

in insects, the opening of a trachea, through which oxygen enters the body and carbon dioxide is expelled. In cartilaginous fishes (sharks and rays), the same name is given to a circular opening that marks the remains of the first gill slit.

In tetrapod vertebrates, the spiracle of early fishes has evolved into the Eustachian tube, which connects the middle ear cavity with the pharynx.

---

spiral

plane curve formed by a point winding round a fixed point from which it distances itself at regular intervals, for example the spiral traced by a flat coil of rope. Various kinds of spirals can be generated mathematically - for example, an equiangular or logarithmic spiral (in which a tangent at any point on the curve always makes the same angle with it) and an involute. Spirals also occur in nature as a normal consequence of accelerating growth, such as the spiral shape of the shells of snails and some other molluscs.

---

spiral galaxy

one of the main classes of galaxy in the Hubble classification comprising up to 30% of known galaxies. Spiral galaxies are characterized by a central bulge surrounded by a flattened disc containing (normally) two spiral arms composed of hot young stars and clouds of dust and gas. In about half of spiral galaxies (barred spirals) the arms originate at the ends of a bar across the central bulge. The bar is not a rigid object but consists of stars in motion about the centre of the galaxy.

---

spirea

any herbaceous plant or shrub of the genus *Spiraea*, family Rosaceae, which includes many cultivated species with ornamental panicles of flowers.

spiritual healing

or psychic healing

transmission of energy from or through a healer, who may practise hand healing or absent healing through prayer or meditation.

In religions worldwide, from shamanism to latter-day charismatic Christianity, healing powers have been attributed to gifted individuals, and sometimes to particular locations (Delphi, Lourdes) or objects (religious relics), and the anecdotal evidence for the reality of spiritual healing is substantial and cross-cultural. Since both healers and beneficiaries can only adduce metaphysical explanations for the effects, medical science remains sceptical, at most allowing that in exceptional cases faith and will may bring about inexplicable cures or remissions, which, however, also occur in cases where no spiritual contribution is claimed.

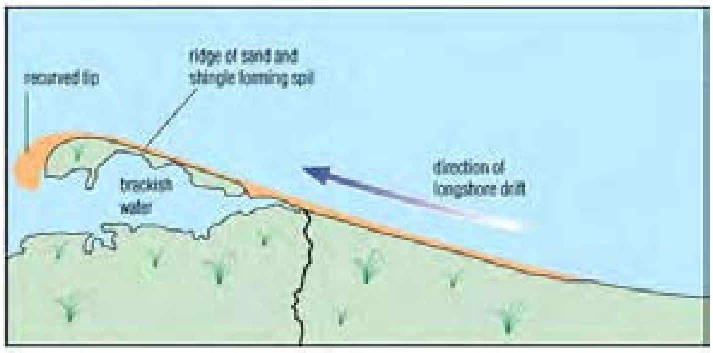
spirochaete

spiral-shaped bacterium. Some spirochaetes are free-living in water, others inhabit the intestines and genital areas of animals. The sexually transmitted disease syphilis is caused by a spirochaete.

spit

ridge of sand or shingle projecting from the land into a body of water. It is formed by a combination of longshore drift, tides, river currents, and/or a bend in the coastline. The decrease in wave energy causes more material to be deposited than is transported down the coast, building up a finger of sand that points in the direction of the longshore drift. Deposition in the brackish water behind a spit may result in the formation of a salt marsh.

spit


recurved tip
ridge of sand and shingle forming spit
brackish water
direction of longshore drift

(Image © Research Machines plc)

Longshore drift carries sand and shingle up coastlines. Deposited material gradually builds up over time at headlands forming a new stretch of land called a spit. A spit that extends across a bay is known as a bar.

spittle

alternative name for saliva and cuckoo spit.

spittlebug

alternative name for froghopper.

spleen

organ in vertebrates, part of the reticuloendothelial system, which helps to process lymphocytes. It also regulates the number of red blood cells in circulation by destroying old cells, and stores iron. It is situated on the left side of the body, behind the stomach.

---

splenectomy

surgical removal of the spleen. It may be necessary following injury to the spleen, or in the course of some blood diseases.

Spock, Benjamin (McLane) (1903-1998)

US paediatrician and writer on child care. His *Common Sense Book of Baby and Child Care* (1946) urged less rigidity in bringing up children than had been advised by previous generations of writers on the subject, but this was misunderstood as advocating permissiveness. He was also active in the peace movement, especially during the Vietnam War.

In his later work he stressed that his common-sense approach had not implied rejecting all discipline, but that his main aim was to give parents the confidence to trust their own judgement rather than rely on books by experts who did not know a particular child.

---

sponge

any saclike simple invertebrate of the phylum Porifera, usually marine. A sponge has a hollow body, its cavity lined by cells bearing flagellae, whose whiplike movements keep water circulating, bringing in a stream of food particles. The body walls are strengthened with protein (as in the bath sponge) or small spikes of silica, or a framework of calcium carbonate.

Fossil sponges only 1 mm/0.04 in in length were found in China and described in 1998. They are estimated to be 580 million years old, the oldest discovered to date.

---

spongiform encephalopathy

in medicine, another term for transmissible spongiform encephalopathy.

---

spontaneous combustion

burning that is not initiated by the direct application of an external source of heat. A number of materials and chemicals, such as hay and sodium chlorate, can react with their surroundings, usually by oxidation, to produce so much internal heat that combustion results.

Special precautions must be taken for the storage and handling of substances that react violently with moisture or air. For example, phosphorus ignites spontaneously in the presence of air and must therefore be stored under water; sodium and potassium are stored under kerosene in order to prevent their being exposed to moisture.

---

spontaneous generation

or abiogenesis

erroneous belief that living organisms can arise spontaneously from nonliving matter. This survived until the mid-19th century, when the French chemist Louis Pasteur demonstrated that a nutrient broth would not generate micro-organisms if it was adequately sterilized. The theory of biogenesis holds that spontaneous generation cannot now occur; it is thought, however, to have played an essential role in the origin of life on this planet 4 billion years ago.

---

spooling

in computing, the process in which information to be printed is stored temporarily in a file, the printing being carried out later. It is used to prevent a relatively slow printer from holding up the system at critical times, and to enable several computers or programs to share one printer.

---

spoonbill

any of several large wading birds of the ibis family Threskiornithidae, order Ciconiiformes, characterized by a long, flat bill, dilated at the tip in the shape of a spoon. Spoonbills are white or pink, and up to 90 cm/3 ft tall. Their feet are adapted for wading, and the birds obtain their food, consisting chiefly of fish, frogs, molluscs, and crustaceans, from shallow water.

---

sporangium

structure in which spores are produced.

---

spore

small reproductive or resting body, usually consisting of just one cell. Unlike a gamete, it does not need to fuse with another cell in order to develop into a new organism. Spores are produced by the lower plants, most fungi, some bacteria, and certain protozoa. They are generally light and easily dispersed by wind movements.

Plant spores are haploid (having a single set of chromosomes in each cell) and are produced by the sporophyte, following meiosis; see alternation of generations.

Bacterial (for example, anthrax) spores pose a threat because they may be resistant to common sterilization procedures, and because they could be treated to create powerful biological weapons.

---

sporophyte

diploid spore-producing generation in the life cycle of a plant that undergoes alternation of generations.

---

spreadsheet

in computing, a program that mimics a sheet of ruled paper, divided into columns down the page, and rows across. The user enters values into cells within the worksheet, then instructs the program to perform some operation on them, such as totalling a column or finding the average of a series of numbers. Calculations are made by using a formula. Highly complex numerical analyses may be built up from these simple steps.

Columns and rows in a spreadsheet are labelled; although different programs use different methods, columns are often labelled with alpha characters, and rows with numbers. When a cell containing a formula is copied and pasted within a spreadsheet, the formula is said to be **relative**, meaning the cell references from which it takes its values are relative to its new position. An **absolute** reference does not change.

Spreadsheets

Go to site

Outlines how to input data into a spreadsheet in easy steps. There is also information on how to make charts from spreadsheet data.

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spring

device, usually a metal coil, that returns to its original shape after being stretched or compressed. Springs are used in some machines (such as clocks) to store energy, which can be released at a controlled rate. In other machines (such as engines) they are used to close valves.

In vehicle-suspension systems, springs are used to cushion passengers from road shocks. These springs are used in conjunction with shock absorbers to limit their amount of travel. In bedding and upholstered furniture springs add comfort.

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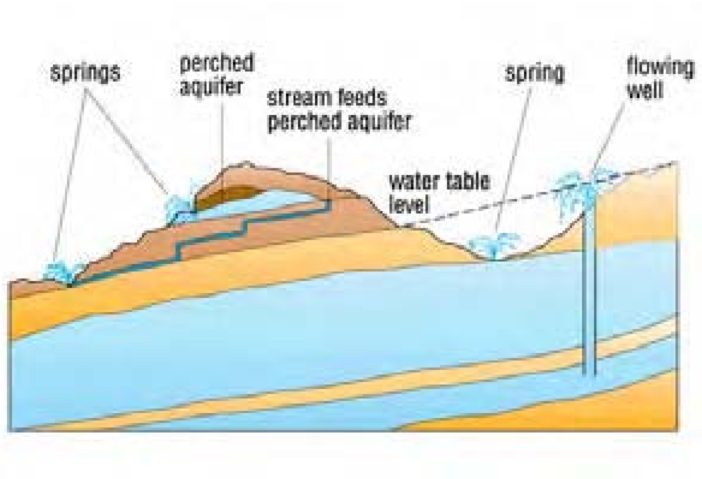
spring

in geology, a natural flow of water from the ground, formed at the point of intersection of the water table and the ground's surface. The source of water is rain that has percolated through the overlying rocks. During its underground passage, the water may have dissolved mineral substances that may then be precipitated at the spring (hence, a mineral spring).

A spring may be continuous or intermittent, and depends on the position of the water table and the topography (surface features).

spring



(Image © Research Machines plc)

Springs occur where water-laden rock layers (aquifers) reach the surface. Water will flow from a well whose head is below the water table.

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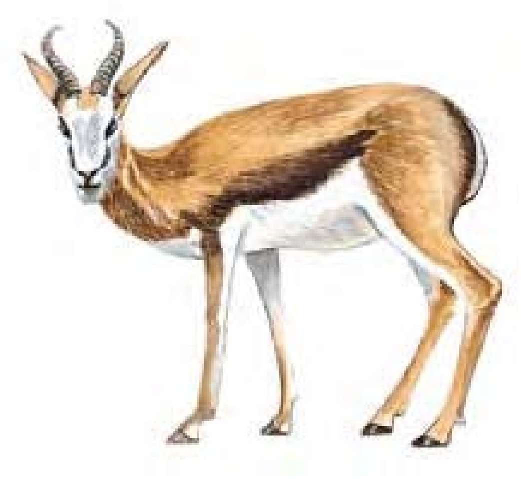
springbok

South African antelope *Antidorcas marsupialis* about 80 cm/30 in at the shoulder, with head and body 1.3 m/4 ft long. It may leap 3 m/10 ft or more in the air when startled or playing, and has a fold of skin along the middle of the back which is raised to a crest in alarm. Springboks once migrated in herds of over a million, but are now found only in small numbers where protected.

springbok



(Image © Research Machines plc)

Male and female springbok look alike, with strong ridged horns. The springbok ranges the treeless grassland or veld of Angola, South Africa, and the Kalahari Desert, Botswana.

Springbok

Go to site

Information on this endangered South African antelope. There is a photo, description of the springbok, and information about its social and mating habits.

---

springtail

small wingless insect. The maximum size is 6 mm/0.2 in in length. Springtails are extremely widespread and can be found in soil, decaying vegetable matter, under the bark of trees, in ant and termite nests, and on the surface of fresh water. There are about 1,500 species of springtail and some species are, unusually for insects, marine.

Springtails have mandibulate mouthparts (adapted for chewing), which are withdrawn into the head when not in use. They do not have compound eyes, but simple eyes may be present. The antennae are usually four-segmented, and the abdomen is six-segmented with, usually, three pairs of appendages, the most important being the forked springing organ attached to the under surface of segment number four. There is, usually, no tracheal (respiratory tube) system and the insects breathe through the cuticle. They usually, therefore, inhabit moist situations.

classification

Springtails are in order Collembola, class Insecta, phylum Arthropoda.

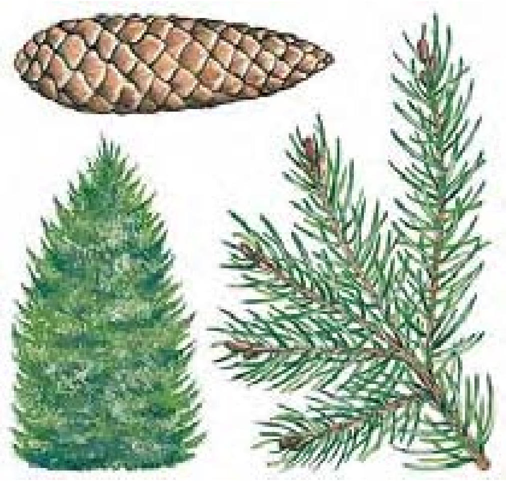
sprite

in computing, a graphics object made up of a pattern of pixels (picture elements) defined by a computer programmer. Some high-level languages and applications programs contain routines that allow a user to define the shape, colours, and other characteristics of individual graphics objects. These objects can then be manipulated and combined to produce animated games or graphic screen displays.

spruce

coniferous tree belonging to the pine family, found over much of the northern hemisphere. Pyramidal in shape, spruces have rigid, prickly needles and drooping, leathery cones. Some are important forestry trees, such as the sitka spruce (*P. sitchensis*), native to western North America, and the Norway spruce (*P. abies*), now planted widely in North America. (Genus *Picea*, family Pinaceae.)

spruce



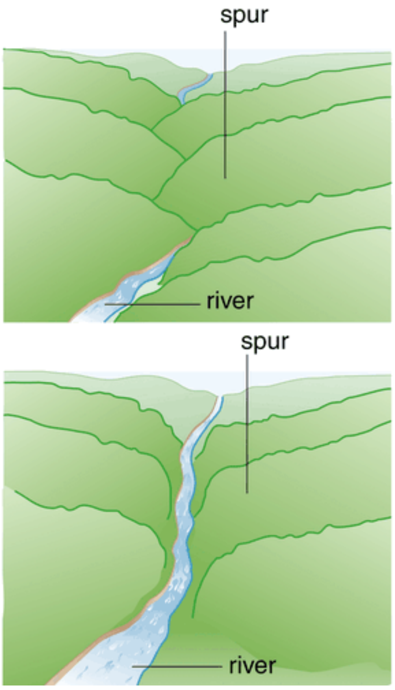
(Image © Research Machines plc)

Spruces are evergreen trees of the pine family. They have hard sharp needles and soft leathery cones hanging from the branches. Perhaps the most familiar is the traditional Christmas tree, the Norway spruce.

spur

ridge of rock jutting out into a valley or plain. In mountainous areas rivers often flow around interlocking spurs because they are not powerful enough to erode through the spurs. Spurs may be eroded away by large and powerful glaciers to form truncated spurs.

spur



(Image © Research Machines plc)

Interlocking spurs (above) and truncated spurs (below). Interlocking spurs are formed by meandering rivers; truncated spurs are interlocking spurs eroded by glaciation.

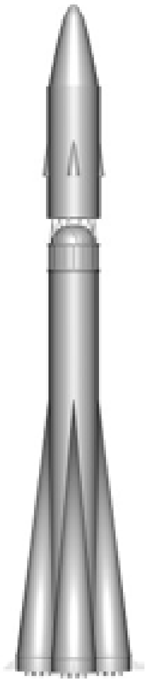
Sputnik

(Russian 'fellow traveller')

series of ten Soviet Earth-orbiting satellites launched from 1957 by R-7 rockets. Sputnik 1 was the first artificial satellite, launched on 4 October 1957. It weighed 84 kg/184 lb, with a 58 cm/23 in diameter, and carried only a simple radio transmitter, which allowed scientists to track the spacecraft as it orbited Earth. It burned up in the atmosphere 92 days later. The Sputnik research team was headed by Sergei Korolev. Sputniks were superseded in the early 1960s by the Cosmos series.

Sputnik 2, launched on 3 November 1957, weighed about 500 kg/1,100 lb and had on board the dog Laika, the first living creature in space. There was no provision for returning the dog to Earth, and it died in space. Later Sputniks were test flights of the Vostok spacecraft.

Sputnik



(Image © Research Machines plc)

The Semiorka R-7 rocket used to launch the Soviet Sputnik satellites.

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sq

abbreviation for **square** (measure).

SQL

abbreviation for structured query language

high-level computer language designed for use with relational databases. Although it can be used by programmers in the same way as other languages, it is often used as a means for programs to communicate with each other. Typically, one program (called the 'client') uses SQL to request data from a database 'server'.

Although originally developed by IBM, SQL came to be widely used on many types of computer.

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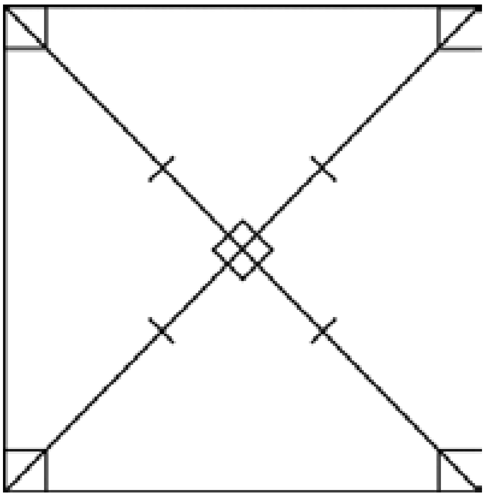
square

in geometry, a quadrilateral (four-sided) plane figure with all sides equal and each angle a right angle. Its diagonals bisect each other at right angles. The area A of a square is the length l of one side multiplied by itself ($A = l \times l$).

Also, any quantity multiplied by itself is termed a square, represented by an exponent of power 2; for example, $4 \times 4 = 4^2 = 16$ and $6.8 \times 6.8 = 6.8^2 = 46.24$.

An algebraic term is squared by doubling its exponent and squaring its coefficient if it has one; for example, $(x^2)^2 = x^4$ and $(6y^3)^2 = 36y^6$. A number that has a whole number as its square root is known as a **perfect square**; for example, 25, 144, and 54,756 are perfect squares (with roots of 5, 12, and 234, respectively).

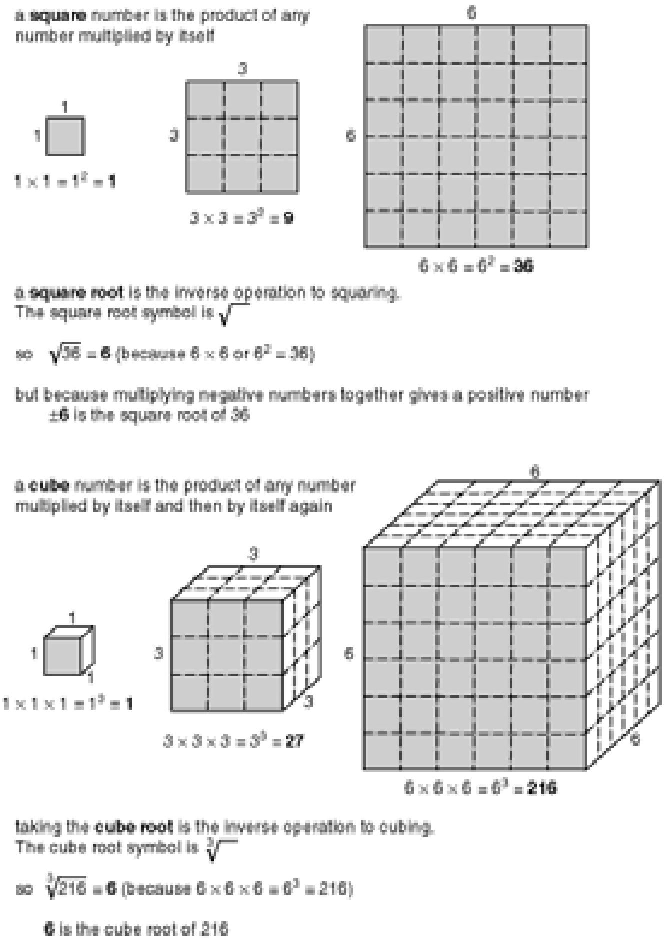
square



(Image © Research Machines plc)

A square has four sides of equal length. Its four angles are all right angles. The diagonals bisect each other at right angles and bisect the corner angles.

square


a **square** number is the product of any number multiplied by itself
1
1
$1 \times 1 = 1^2 = 1$
3
3
$3 \times 3 = 3^2 = 9$
6
6
$6 \times 6 = 6^2 = 36$
a **square root** is the inverse operation to squaring. The square root symbol is $\sqrt{}$
so $\sqrt{36} = 6$ (because 6×6 or $6^2 = 36$)
but because multiplying negative numbers together gives a positive number ±6 is the square root of 36
a **cube** number is the product of any number multiplied by itself and then by itself again
1
1
1
$1 \times 1 \times 1 = 1^3 = 1$
3
3
3
$3 \times 3 \times 3 = 3^3 = 27$
6
6
6
$6 \times 6 \times 6 = 6^3 = 216$
taking the **cube root** is the inverse operation to cubing. The cube root symbol is $\sqrt[3]{}$
so $\sqrt[3]{216} = 6$ (because $6 \times 6 \times 6 = 6^3 = 216$)
6 is the cube root of 216

(Image © Research Machines plc)

Any value multiplied by itself is a square. If that value is multiplied by itself and then by itself again, it is termed a cube. Squares and cubes are represented by the exponent powers 2 and 3 respectively. The reverse operations to squaring and cubing would be finding the square root and finding the cube root.

---

square root

number that when it is squared (multiplied by itself) equals a given number. For example, the square root of 25 (written as √25) is +5 or -5. This is because +5 × +5 = 25, and -5 × -5 = 25. A square root can be written as 1/2. For example, $16^{1/2}$ = +4 or $16^{1/2}$ = -4. This is called an exponent.

Negative numbers (less than 0) do not have square roots that are real numbers. Their roots are represented by complex numbers, in which the square root of -1 is given the symbol i (that is, ± i^2 = -1). All square roots generate two answers and complex square roots occur in **conjugate pairs**, that is, √(a + ib) = c ± id. Thus the square root of -4 is √[(-1) × 4] = √-1 × √4 = ±2i.

---

squill

bulb-forming perennial plant belonging to the lily family, found growing in dry places near the sea in Western Europe. Cultivated species usually bear blue flowers, either singly or in clusters, at the top of the stem. (Genus *Scilla*, family Liliaceae.)

---

squint

or strabismus

common condition in which one eye deviates in any direction. A squint may be convergent (with the bad eye turned inwards), divergent (outwards), or, in rare cases, vertical. A convergent squint is also called **cross-eye**.

There are two types of squint: **paralytic**, arising from disease or damage involving the extraocular muscles or their nerve supply; and **nonparalytic**, which may be inherited or due to some refractive error within the eye. Nonparalytic (or concomitant) squint is the typical condition seen in small children. It is treated by corrective glasses, exercises for the eye muscles, or surgery.

squirrel

rodent of the family Sciuridae. Squirrels are found worldwide except for Australia, Madagascar, and polar regions. Some are tree dwellers; these generally have bushy tails, and some, with membranes between their legs, are called flying squirrels. Others are terrestrial, generally burrowing forms called ground squirrels; these include chipmunks, gophers, marmots, and prairie dogs.

Squirrel Place

Go to site

Comprehensive resources about squirrels, including a history of the species, a selections of videos from the BBC's *Daylight Robbery II*, and a list of 'Frequently Asked Questions'.

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sr

in physics, symbol for steradian, the SI unit of solid angle. For example, a sphere subtends a solid angle of 4π steradians at its centre.

SRAM

acronym for static random-access memory

computer memory device in the form of a silicon chip used to provide immediate-access memory. SRAM is faster but more expensive than DRAM (dynamic random-access memory), and does not require to be refreshed as long as power is being supplied.

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stability

measure of how difficult it is to move an object from a position of balance or equilibrium with respect to gravity.

An object displaced from equilibrium does not remain in its new position if its weight, acting vertically downwards through its centre of mass, no longer passes through the line of action of the contact force (the force exerted by the surface on which the object is resting), acting vertically upwards through the object's new base. If the lines of action of these two opposite but equal forces do not coincide they will form a couple and create a moment (see moment of a force) that will cause the object either to return to its original rest position or to topple over into another position.

An object in **stable equilibrium** returns to its rest position after being displaced slightly. This form of equilibrium is found in objects that are difficult to topple over; these usually possess a relatively wide base and a low centre of mass – for example, a cone resting on its flat base on a horizontal surface. When such an object is tilted slightly its centre of mass is raised and the line of action of its weight no longer coincides with that of the contact force exerted by its new, smaller base area. The moment created will tend to lower the centre of mass and so the cone will fall back to its original position.

An object in **unstable equilibrium** does not remain at rest if displaced, but falls into a new position; it does not return to its original rest position. Objects possessing this form of equilibrium are easily toppled and usually have a relatively small base and a high centre of mass – for example, a cone balancing on its point, or apex, on a horizontal surface. When an object such as this is given the slightest push its centre of mass is lowered and the displacement of the line of action of its weight creates a moment. The moment will tend to lower the centre of mass still further and so the object will fall on to another position.

An object in **neutral equilibrium** stays at rest if it is moved into a new position – neither moving back to its original position nor on any further. This form of equilibrium is found in objects that are able to roll, such as a cone resting on its curved side placed on a horizontal surface. When such an object is rolled its centre of mass remains in the same position, neither rising nor falling, and the line of action of its weight continues to coincide with the contact force; no moment is created and so its equilibrium is maintained.

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stabilizer

one of a pair of fins fitted to the sides of a ship, especially one governed automatically by a gyroscope mechanism, designed to reduce side-to-side rolling of the ship in rough weather.

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stack

in computing, a method of storing data in which the most recent item stored will be the first to be retrieved. The technique is commonly called 'last in, first out'.

Stacks are used to solve problems involving nested structures; for example, to analyse an arithmetical expression containing subexpressions in parentheses, or to work out a route between two points when there are many different paths.

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stack

isolated pillar of rock that has become separated from a headland by coastal erosion. It is usually formed by the collapse of an arch. Further erosion will reduce it to a stump, which is exposed only at low tide.

stack

(Image © Garret Nagle)

Stacks, such as this sea stack off the Dorset coast, are isolated upstanding rocks that are formed by erosion. Wave action pounds away at a rock barrier, such as a headland. First, it attacks weaknesses such as joints and faults, eroding a cave on the headland. The cave is deepened until it passes all the way through the headland to form an arch. If the top of the arch collapses then a stack is formed. Eventually the upstanding stack is eroded to form a stump.

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stag beetle

any of a number of large dark brown beetles, the males of which possess enormous mandibles, or jaws, shaped rather like the antlers of a stag. There are over 900 species within this family.

The males are much bigger than the females and very often the length of their mandibles equals the length of the rest of the body. The mandibles appear to be largely ornamental and cannot be moved by the jaw muscles. Another characteristic feature is the smooth appearance of the chestnut-coloured wing cases, which are devoid of ridges. The larvae inhabit the rotting wood or the roots of trees, such as oak.

classification

The stag beetle is in family Lucanidae of the superfamily Scarabaeoidea, order Coleoptera, class Insecta, phylum Arthropoda.

Stahl, Georg Ernst (1660-1734)

German chemist who developed the theory that objects burn because they contain a combustible substance, phlogiston. Substances rich in phlogiston, such as wood, burn almost completely away. Metals, which are low in phlogiston, burn less well. Chemists spent much of the 18th century evaluating Stahl's theories before these were finally proved false by Antoine Lavoisier.

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stain

coloured compound that will bind to other substances. Stains are used extensively in microbiology to colour micro-organisms and in histochemistry to detect the presence and whereabouts in plant and animal tissue of substances such as fats, cellulose, and proteins.

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stainless steel

widely used alloy, in which chromium is dominant with traces of nickel, that resists rusting. Its chromium content also gives it a high tensile strength. It is used for cutlery and kitchen fittings, and in surgical instruments. Stainless steel was first produced in the UK in 1913 and in Germany in 1914.

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stalactite and stalagmite

cave structures formed by the deposition of calcite dissolved in ground water.
Stalactites grow downwards from the roofs or walls and can be icicle-shaped, straw-shaped, curtain-shaped,

or formed as terraces.
Stalagmites grow upwards from the cave floor and can be conical, fir-cone-shaped, or resemble a stack of saucers. Growing stalactites and stalagmites may meet to form a continuous column from floor to ceiling.

Stalactites are formed when ground water, hanging as a drip, loses a proportion of its carbon dioxide into the air of the cave. This reduces the amount of calcite that can be held in solution, and a small trace of calcite is deposited. Successive drips build up the stalactite over many years. In stalagmite formation the calcite comes out of the solution because of agitation – the shock of a drop of water hitting the floor is sufficient to remove some calcite from the drop. The different shapes result from the splashing of the falling water.

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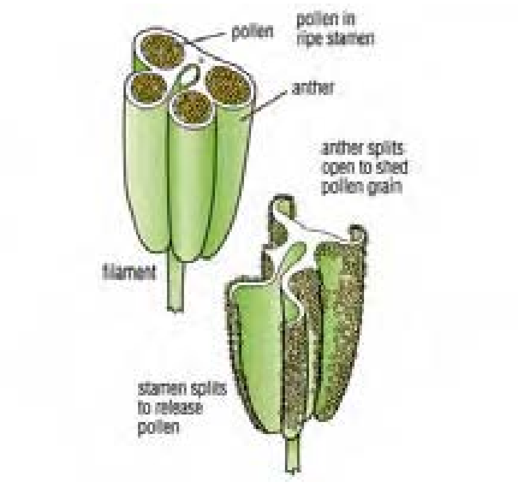
stamen

male reproductive organ of a flower. The stamens are collectively referred to as the androecium. A typical stamen consists of a stalk, or filament, with an anther, the pollen-bearing organ, at its apex, but in some primitive plants, such as *Magnolia*, the stamen may not be markedly differentiated.

The number and position of the stamens are significant in the classification of flowering plants. Generally the more advanced plant families have fewer stamens, but they are often positioned more effectively so that the likelihood of successful pollination is not reduced.

stamen


pollen
pollen in ripe stamen
anther
anther splits open to shed pollen grain
filament
stamen splits to release pollen

(Image © Research Machines plc)

The stamen is the male reproductive organ of a flower. It has a thin stalk called a filament with an anther at the tip. The anther contains pollen sacs, which split to release tiny grains of pollen.

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standard atmosphere

alternative term for atmosphere, a unit of pressure.

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standard deviation

in statistics, a measure (symbol ςor *s*) of the spread of data. The deviation (difference) of each of the data items from the mean is found, and their values squared. The mean value of these squares is then calculated. The standard deviation is the square root of this mean.

If *n* is the number of items of data, *x* is the value of each item, and μ is the mean value, the standard deviation ςmay be given by the formula

$$\sigma = \sqrt{\frac{\sum (x-\mu)^2}{n}}$$

where Σ indicates that the differences between the value of each item of data and the mean should be summed.

To simplify the calculations, the formula may be rearranged to

$$\sigma = \sqrt{\frac{\sum x^2}{n} - \mu^2}$$

As a result, it becomes necessary only to calculate Σx and Σx^2.

For example, if the ages of a set of children were 4, 4.5, 5, 5.5, 6, 7, 9, and 11, Σx would be 52, μ would be $52/n = 52/8 = 6.5$, and Σx^2 would be 378.5 ($= 4^2 + 4.5^2 + 5^2 + 5.5^2 + 6^2 + 7^2 + 9^2 + 11^2$).

Therefore, the standard deviation ςwould be

$$\sqrt{\frac{378.5}{8}-(6.5)^2}=\sqrt{5.0625}=2.25$$

standard form

or scientific notation

method of writing numbers often used by scientists, particularly for very large or very small numbers. The numbers are written with one digit before the decimal point and multiplied by a power of 10. The number of digits given after the decimal point depends on the accuracy required. For example, the speed of light is 2.9979×10^8 m/1.8628×10^5 mi per second.

standard gravity

acceleration due to gravity, generally taken as 9.81274 m/32.38204 ft per second per second. See also *g* scale.

standard illuminant

any of three standard light intensities, A, B, and C, used for illumination when phenomena involving colour are measured. A is the light from a filament at 2,848 K (2,575°C/4,667°F), B is noon sunlight, and C is normal daylight. B and C are defined with respect to A. Standardization is necessary because colours appear different when viewed in different lights.

standard model

in physics, modern theory of elementary particles and their interactions. According to the standard model, elementary particles are classified as leptons (light particles, such as electrons), hadrons (particles, such as neutrons and protons, that are formed from quarks), and gauge bosons. Leptons and hadrons interact by exchanging gauge bosons, each of which is responsible for a different fundamental force: photons mediate the electromagnetic force, which affects all charged particles; gluons mediate the strong nuclear force, which affects quarks; gravitons mediate the force of gravity; and the intermediate vector bosons mediate the weak nuclear force. See also forces, fundamental, quantum electrodynamics, and quantum chromodynamics.

standard temperature and pressure

STP

in chemistry, a standard set of conditions for experimental measurements, to enable comparisons to be made between sets of results. Standard temperature is 0°C/32°F (273 K) and standard pressure 1 atmosphere (101,325 Pa).

standard time

alternate name for zone standard time.

standard volume

in physics, the volume occupied by one kilogram molecule (the molecular mass in kilograms) of any gas at standard temperature and pressure. Its value is approximately 22.414 cubic metres.

standing crop

in ecology, the total number of individuals of a given species alive in a particular area at any moment. It is sometimes measured as the weight (or biomass) of a given species in a sample section.

standing wave

in physics, a wave in which the positions of nodes (positions of zero vibration) and antinodes (positions of maximum vibration) do not move. Standing waves result when two similar waves travel in opposite directions through the same space.

For example, when a sound wave is reflected back along its own path, as when a stretched string is plucked, standing waves are formed. In one wave, called the fundamental vibration, a single antinode remains fixed at the centre, with nodes at the two ends. Other waves will also be set up in the string, with nodes at the ends and a number of antinodes along the string. Water and electromagnetic waves can form standing waves in the same way.

---

staphylococcus

spherical bacterium that occurs in clusters. It is found on the skin and mucous membranes of humans and other animals. It can cause abscesses and systemic infections that may prove fatal.

Staphylococcus aureus is a very common bacterium, present in the nose in 30% of people. Normally it gives no trouble, but, largely due to over-prescribing of antibiotics, strains have arisen that are resistant to the drugs used to treat them, principally methicillin, a semisynthetic form of penicillin. Methicillin-resistant *S. aureus* (MRSA) strains represent a serious hazard to the critically ill or immunosuppressed.

MRSA normally responds to two antibiotics which are considered too toxic for use in any but life-threatening infections (vancomycin and teicoplanin) but it still causes fatalities.

Childhood Infections - Staphylococcus Aureus

Go to site

Useful information about *Staphylococcus aureus*. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection, how it can be treated both at home and professionally, and what to do should the symptoms occur.

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star

luminous globe of gas, mainly hydrogen and helium, which produces its own heat and light by nuclear reactions. Although stars shine for a very long time - many billions of years - they change in appearance at different stages in their lives (they are said to have a 'life cycle'). Stars seen at night belong to our galaxy, the Milky Way. The Sun is the nearest star to Earth; other stars in the Milky Way are large distances away (to get to the nearest would take about 4 years travelling at the speed of light).

The smallest mass possible for a star is about 8% that of the Sun (80 times that of Jupiter), otherwise nuclear reactions do not occur. Objects with less than this critical mass shine only dimly, and are termed **brown dwarfs**.

The largest stars ever seen were discovered in 2004; the analysis of brightness variations in object WR-20a in the constellation of Carina proved that the object was made up from two giant stars orbiting each other. The stars weigh 80 solar masses each, that is 20 solar masses more than the previous record for star size.

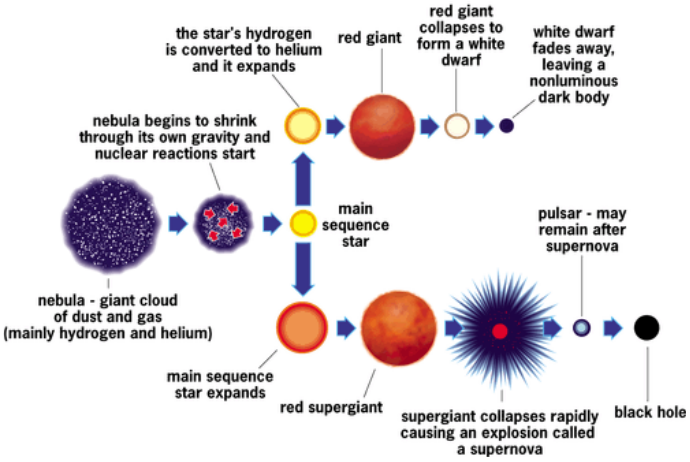
star: brightest

The brightest known star is the Pistol Star, discovered near the centre of the Milky Way in 1997 by the Hubble Space Telescope. It emits as much energy in seconds as the Sun does in one year, making it 10 million times brighter and 100 times larger.

star: Sakurai's object

A new star, named 'Sakurai's object' (after the amateur Japanese astronomer who discovered it in 1996 in the constellation of Sagittarius), has been undergoing an extraordinarily rapid evolution since its discovery. It expanded from being an Earth-sized hot dwarf, with a surface temperature of 50,000°C, to being a bright yellow supergiant about 80 times wider than the Sun and no hotter than 6,000°C. 'Sakurai's object' may be a red giant star that had previously shrunk, the contraction of its core triggering nuclear reactions and subsequent reinflation.

star


the star's hydrogen is converted to helium and it expands
red giant
red giant collapses to form a white dwarf
white dwarf fades away, leaving a nonluminous dark body
nebula begins to shrink through its own gravity and nuclear reactions start
main sequence star
pulsar - may remain after supernova
nebula - giant cloud of dust and gas (mainly hydrogen and helium)
main sequence star expands
red supergiant
supergiant collapses rapidly causing an explosion called a supernova
black hole

(Image © Research Machines plc)

The life cycle of a star. New stars are being formed all the time when nebulae (giant clouds of dust and gas) contract due to the action of gravity. As the star contracts and heats up eventually nuclear reactions begin and the star becomes a main sequence star. If the star is less than 1.2 times the mass of the Sun, it eventually forms a white dwarf that finally fades to a dark body. If it is a massive star, then the main sequence star expands to become a red supergiant that eventually explodes as a supernova. It leaves part of the core as a neutron star (pulsar), or as a black hole if the mass of the collapsing supernova core is three times greater than the Sun.

spectral classification

To remember the spectral classification sequence (star classes on a stellar evolution diagram):

Octopus **B**rains, **A** **F**avourite **G**astronomic **K**itchen **M**enu, **R**equires **N**o **S**auce or **O**ven **B**aked **A**nts, **F**ried **G**ently, **K**ept **M**oist, **R**etain **N**atural **S**ucculence or **O**dd **B**all **A**stronomers **F**ind **G**enerally **K**ooky **M**nemonics **R**eally **N**ifty **S**tuff or **O**n, **B**ackward **A**stronomer, **F**orget **G**eocentricity; **K**epler's **M**otions **R**eveal **N**ature's **S**implicity or **O**h **B**oy, **A**n **F** **G**rade **K**ills **M**e or **O**nly **B**ored **A**stronomers **F**ind **G**ratification **K**nowing **M**nemonics or **O**nly **B**oys **A**dvocating **F**eminism **G**et **K**issed **M**eaningfully

The sequence is **O**, **B**, **A**, **F**, **G**, **K**, **M**, (**R**, **N**, **S**,) ranging from hot, early type stars (**O**) to cool, late type stars (**M**) (the classes **R**, **N**, and **S** are generally no longer used, but appear in most of the mnemonics)

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starburst galaxy

in astronomy, spiral galaxy that appears unusually bright in the infrared part of the spectrum due to a recent burst of star formation, possibly triggered by the gravitational influence of a nearby companion galaxy.

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starch

widely distributed, high-molecular-mass carbohydrate, produced by plants as a food store; main dietary sources are cereals, legumes, and tubers, including potatoes. It consists of varying proportions of two glucose polymers (polysaccharides): straight-chain (amylose) and branched (amylopectin) molecules.

Purified starch is a white powder used to stiffen textiles and paper and as a raw material for making various chemicals. It is used in the food industry as a thickening agent. Chemical treatment of starch gives rise to a range of 'modified starches' with varying properties. Hydrolysis (splitting) of starch by acid or enzymes generates a variety of 'glucose syrups' or 'liquid glucose' for use in the food industry.
Complete hydrolysis of starch with acid generates the monosaccharide glucose only. Incomplete hydrolysis or enzymic hydrolysis yields a mixture of glucose, maltose, and nonhydrolysed fractions called dextrins.

The chemical test for starch consists of adding a drop of iodine solution to the substance. It will turn bright blue if starch is present.

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star cluster

group of related stars, usually held together by gravity. Members of a star cluster are thought to form together from one large cloud of gas in space.
Open clusters such as the Pleiades contain from a dozen to many hundreds of young stars, loosely scattered over several light years. Globular clusters are larger and much more densely packed, containing perhaps 10,000-1,000,000 stars.

The more conspicuous clusters were originally catalogued with the nebulae, and are usually known by their Messier or New General Catalogue (NGC) numbers. A few clusters like the Pleiades, Hyades, and Praesepe are also known by their traditional names.

Stardust

US project to obtain a sample of dust and gas from the head of a comet. Launched in February 1999, the Stardust space probe flew through the head of the comet Wild 2 on 2 January 2004, passing within 240 km/150 mi of the 4-km/2.5-mi nucleus and taking 72 photographs. It is to return to Earth with its samples in January 2006.

Stardust

(Image © NASA)

Workers ready the Stardust spacecraft for its transfer to launch vehicle from the payload hazardous services facility at Kennedy Space Center. Launched on 7 February 1999, the Stardust mission is due to make a fly-by of comet Wild 2 in early 2004 and return samples of interstellar dust to Earth in early 2006.

Welcome to Stardust!

Go to site

Regularly updated NASA Web site provides Stardust mission news and displays the spacecraft's present location. The site has downloadable press kits, educational materials, student activities, and plenty of background information on the mission technology and science goals.

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starfish

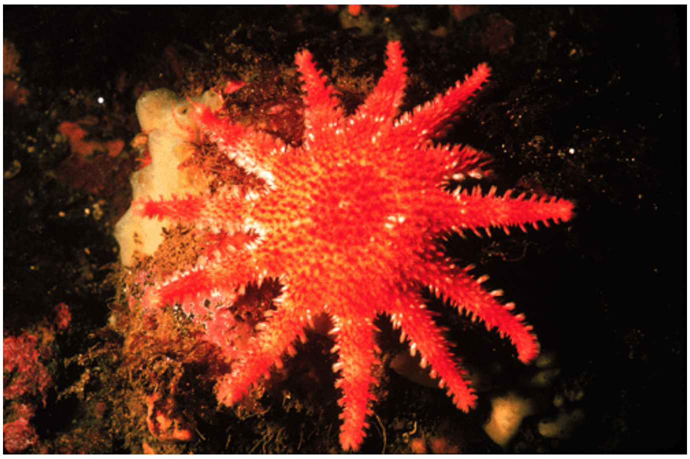
or sea star

any echinoderm of the subclass Asteroidea with arms radiating from a central body. Usually there are five arms, but some species have more. They are covered with spines and small pincerlike organs. There are also a number of small tubular processes on the skin surface that assist in locomotion and respiration. Starfish are predators, and vary in size from 1.2 cm/0.5 in to 90 cm/3 ft.

Some species use their suckered tube feet to pull open the shells of bivalve molluscs, then evert their stomach to surround and digest the animal inside. The poisonous and predatory crown-of-thorns of the Pacific is very destructive to coral and severely damaged Australia's Great Barrier Reef when it multiplied prolifically in the 1960s-70s. Although it had practically disappeared by 1990, in 1996 another outbreak along the Great Barrier Reef was officially declared.

Another destructive species, *Asteria amurensis*, spread round the coast of Tasmania in 1993, and could reach as far as Sydney. It is normally found only in the North Pacific and was probably introduced into Tasmania in the ballast water of a ship travelling from Japan.

starfish



(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

The sun star, a spiny starfish of the order *spinulosa*. The sun star is one of those less common starfish that have more than five arms: it has twelve. One species of starfish which lives in the waters off South America has no fewer than 44 arms. It is not clear whether the extra arms assist in its predatory activities, and they may increase its vulnerability to attack or damage.

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star fruit

fruit of the carambola tree.

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starling

any member of a large widespread Old World family (Sturnidae) of chunky, dark, generally gregarious birds of the order Passeriformes. The European starling *Sturnus vulgaris*, common in northern Eurasia, has been naturalized in North America from the late 19th century. The black, speckled plumage is glossed with green and purple. The feathers on the upper parts are tipped with buff, and the wings are greyish-black, with a reddish-brown fringe. The female is less glossy and lustrous than the male. Its own call is a bright whistle, but it is a mimic of the songs of other birds. It is about 20 cm/8 in long.

Strikingly gregarious in feeding, flight, and roosting, it often becomes a pest in large cities, where it becomes attached to certain buildings as 'dormitories', returning each night from omnivorous foraging in the countryside, feeding principally on worms, snails, and insects. Nests are made almost anywhere, and about five pale blue eggs are laid. If disturbed, starlings have been known to lay eggs in the nests of other birds before starting a new nest with their mate elsewhere.

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stasis

in biology, the cessation of blood flow in the blood vessels or the passage of food in the gastrointestinal tract.

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states of matter

forms (solid, liquid, or gas) in which material can exist. Whether a material is solid, liquid, or gaseous depends on its temperature and pressure. The transition between states takes place at definite temperatures, called the melting point and boiling point.

Kinetic theory describes how the state of a material depends on the movement and arrangement of its atoms or molecules. The atoms or molecules of **gases** move randomly in otherwise empty space, filling any size or shape of container. Gases can be liquefied by cooling as this lowers the speed of the molecules and enables attractive forces between them to bind them together. A **liquid** forms a level surface and assumes the shape of its container; its atoms or molecules do not occupy fixed positions, nor do they have total freedom of movement.
Solids hold their own shape as their atoms or molecules are not free to move about but merely vibrate about fixed positions, such as those in crystal lattices.

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state symbol

symbol used in chemical equations to indicate the physical state of the substances present. The symbols are: (s) for solid, (l) for liquid, (g) for gas, and (aq) for aqueous.

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static electricity

electric charge that is stationary, usually acquired by a body by means of electrostatic induction or friction. Rubbing different materials can produce static electricity, as seen in the sparks produced on combing one's hair or removing a nylon shirt. The frictional force causes electrons to move out of their orbits. The electrons are then transferred to another material. The material that gains electrons becomes negatively charged and the material that loses electrons becomes positively charged. In some processes static electricity is useful, as in paint spraying where the parts to be sprayed are charged with electricity of opposite polarity to that on the paint droplets, and in xerography.

Static Electricity Page

Go to site

Simple Web pages with tutorials and information on static electricity. There are also pages detailing science projects and a good list of electronics and electrostatic resources on the Internet.

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statics

branch of mechanics concerned with the behaviour of bodies at rest and forces in equilibrium, and distinguished from dynamics.

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statistical mechanics

branch of physics in which the properties of large collections of particles are predicted by considering the motions of the constituent particles. It is closely related to thermodynamics.

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statistics

branch of mathematics concerned with the collection and interpretation of data. For example, to determine the mean age of the children in a school, a statistically acceptable answer might be obtained by calculating an average based on the ages of a representative sample, consisting, for example, of a random tenth of the pupils from each class. Probability is the branch of statistics dealing with predictions of events.

mean, median, and mode

The mean, median, and mode are different ways of finding a 'typical' or 'central' value of a set of data. The mean is obtained by adding up all the observed values and dividing by the number of values; it is the number that is commonly used as an average value. The median is the middle value, that is, the value that is exceeded by half the items in the sample. The mode is the value that occurs with greatest frequency, the most common value. The mean is the most useful measure for the purposes of statistical theory. The idea of the median may be extended and a distribution can be divided into four quartiles. The first quartile is the value that is exceeded by three-quarters of the items; the second quartile is the same as the median; the third quartile is the value that is exceeded by one-quarter of the items.

standard deviation and other measures of dispersion

The mean is a very incomplete summary of a group of observations; it is useful to know also how closely the individual members of a group approach the mean, and this is indicated by various measures of dispersion. The **range** is the difference between the maximum and minimum values of the group; it is not very satisfactory as a measure of dispersion. The **mean deviation** is the arithmetic mean of the differences between the mean and the individual values, the differences all being taken as positive. However, the mean deviation also does not convey much useful information about a group of observations. The most useful measure of dispersion is the **variance**, which is the arithmetic mean of the squares of the deviations from the mean. The positive square root of the variance is called the standard deviation, a measure (symbol ςor *s*) of the spread of data. The deviation (difference) of each of the data items from the mean is found, and their values squared. The mean value of these squares is then calculated. The standard deviation is the square root of this mean.

It is usual to standardize the measurements by working in units of the standard deviation measured from the mean of the distributions, enabling statistical theories to be generalized. A standardized distribution has a mean of zero and a standard deviation of unity. Another useful measure of dispersion is the semi-interquartile range, which is one-half of the distance between the first and third quartiles, and can be considered as the average distance of the quartiles from the median. In many typical distributions the semi-interquartile range is about two-thirds of the standard deviation and the mean deviation is about four-fifths of the standard deviation.

applications

One of the most important uses of statistical theory is in testing whether experimental data support hypotheses or not. For example, an agricultural researcher arranges for different groups of cows to be fed different diets and records the milk yields. The milk-yield data are analysed and the means and standard deviations of yields for different groups vary. The researcher can use statistical tests to assess whether the variation is of an amount that should be expected because of the natural variation in cows or whether it is larger than normal and therefore likely to be influenced by the difference in diet.

correlation

Correlation measures the degree to which two quantities are associated, in the sense that a variation in one quantity is accompanied by a predictable variation in the other. For example, if the pressure on a quantity of gas is increased then its volume decreases. If observations of pressure and volume are taken then statistical correlation analysis can be used to determine whether the volume of a gas can be completely predicted from a knowledge of the pressure on it.

Living with Uncertainty

introduction

Whether we call it chance, risk, or luck, uncertainty is part and parcel of most aspects of life. If a risk is persistent or the potential consequences grave - for example, participating in a dangerous sport - we might choose to avoid the risk or to insure against it. If the risk is remote or the consequences trivial - say, the chance of a family outing being rained off - we might opt to live with it. Some risks, such as playing the Lottery or stockmarket, have potentially beneficial outcomes and we often deliberately court these risks. Acting to avoid, manage, or expose ourselves to risks implies that we have some way of evaluating how big or small they are. At a personal level, our assessment of risk is often intuitive and sometimes irrational. It does not need to be, and the decisions taken by businesses and governments must have a more exact and explicit basis. Fundamental to measuring uncertainty are the laws of probability.

basic probability theory

The basics of probability are best understood by taking a simple example, such as rolling a die. There are six possible outcomes. One must occur and two or more cannot occur simultaneously. So there is a 100% chance - in other words, certainty - that you will roll one of the numbers from one to six; this is the same as a probability of 1. If each outcome has an equal chance, the probability of it happening is 1 (certainty) divided by the number of outcomes. In the case of the die, the probability of rolling a six is 1/6. The probability of rolling any number other than six is 1 - 1/6 = 5/6. To find the probability of rolling either a six or, say, a one, you add the probabilities of each outcome: 1/6 + 1/6 = 1/3. To find the probability of two or more outcomes both happening, you multiply the probabilities. For example, the probability of not rolling a six with two dice is 5/6 × 5/6 = 25/36.

games we play

Armed with probability theory, you can assess your chances of winning a game. For example, suppose, for 20 pence a go, you are invited to draw a card from a full pack (without jokers) and you win 60 pence if you draw a picture card or an ace. Is this game worth playing? There are four kings, four queens, four jacks, and four aces in a standard pack, which gives you 16 winning cards out of 52. Your chance of picking a winner is 16/52 or 4/13. This tells you that, if you play long enough, you can expect to win four times out of every 13. For every £2.60 you pay out in stake money, you can, on average, expect to win (4 × 60 pence) = £2.40, giving you an expected loss of 20 pence for every 13 games. Not a good deal! If the prize is big enough, the expectation of losses does not deter people from playing. Since there are 13,983,816 ways of picking six numbers from 49, if you buy one ticket, there is a one in roughly 14 million chance of winning the UK National Lottery (Lotto) jackpot - and a 13,983,815/13,983,816 chance (near certainty) of not winning. There are 260,624 combinations that will win some prize (from £10 upwards), which gives you a 13,723,192/13,983,816 (greater than 98%) chance of losing your £1 stake and winning no prize at all. Yet still, seven out of ten adults play the Lottery regularly!

estimating risks

The previous examples are for mechanical systems where it is straightforward to work out both the outcomes and the probabilities attached to them. Much of life is more complex than this: outcomes and their likelihoods can only be estimated using past experience or data from samples and experiments. The examples below outline some of the techniques that are used.

looking at the past

In the financial world, past data are often used as a basis for estimating future risks. For example, in deciding what premium to charge you for car insurance, an insurance company will look at a mass of statistics showing how many claims have been made against the company in the past, the average size of the claims, and how these figures correlate with the age of the driver involved, the power of the car, where the car is kept, and so on. The past is used to indicate the probability that you, with your set of particular characteristics, will be a claimant during the coming year. The past can help in choosing investments, such as shares. Shares are risky because their price can go down as well as up. You lose some, or even all, of your original investment if the share price falls. On the other hand, you make a profit if the share price rises. The more risky the share - in other words, the more its price swings up and down - the greater the risk of loss but the greater too the potential for profit. One way of measuring this risk/profit potential is to use a measure called 'standard deviation'. Typically, the price of a particular share is recorded for each month during the last three years (36 months in total). All the prices are added together and divided by 36 to find the average price over the period. This is subtracted from each month's price to give the month-by-month swing away from the average. To work out the overall effect, each deviation is squared to convert it into a positive number. The squared deviations are then averaged and the square root is taken to turn the result back into the same units as the share price. The result is the standard deviation. Whatever data you start with, roughly 95% of the measurements (in this case, the 36 share prices) lie within two standard deviations of the average. A risky share has a large standard deviation because its share price consistently swings a long way from its average; a lower risk share has a small standard deviation because its share price tends to stay close to its average (see example). It is highly unlikely that the future will be the same as the past. So assessments based on past data can only be estimates of future risk. EXAMPLE: Comparing the risks associated with two shares On the face of it, shares in two different companies, A and B, look very similar. Over the last three years both share prices have averaged 100 pence and recorded the same low (64 pence) and the same high (149 pence). But A's shares have a standard deviation of 6.2, whereas B's shares have a standard deviation of 15.1. Roughly 95% of the share prices recorded over the last three years lie within two standard deviations of the average. This means that all but 5% of the share prices for Company A lay within the range 100 +/- 12.4 pence, in other words from 87.6 pence to 112.4 pence. All but 5% of Company B's share prices over the three years lay within the range 100 +/- 30.2 pence, or 69.8 pence to 130.2 pence. Assuming that the future will be similar to the past, if you invest in A there is probably little risk of large losses, but not much chance of large gains either. If you invest in B you run the risk of greater losses, but also the chance of higher profits.

taking samples

Sometimes there is no way to gather the precise measurements you need to estimate a future risk or probability. For example, if you are planning hospital blood supplies you might want to know how many people are blood group A, but it would be very costly and time consuming to test everyone in the population. As another example, suppose a manufacturer wants to know how long the batteries he produces will last when used. He could test every one until it is flat – this would give him the answer he seeks, but he would have no batteries left to sell. In such situations it makes sense to base your measurements on a sample drawn from the population of people, batteries, or whatever it is that interests you. But how do you know if the results for your sample are an accurate guide to the true state of affairs? Any sample result is very unlikely to be exactly right, so you work out a range of results, which equals the test result plus or minus a specific margin of error. Choosing a narrow range provides a more precise result, but reduces the probability that the true figure for the whole population lies within the range. Choosing a wider range is less useful, but makes it more likely that the true figure lies within it. A compromise must be struck and often scientists work at the 95% confidence level (which is closely related to the standard deviation techniques looked at previously in the context of shares). This means that, on average, 95 times out of 100 the range will give a good estimate of the true figure; 5% of the time the estimate will be too high or too low. Sample analysis has many applications. For example, drug trials look at how a sample of people react to a new drug. The results are used to estimate the probability of its effectiveness if it goes into public use and also to estimate the risk of side effects. Market research agencies, such as NOP and MORI, are commissioned by governments, companies, lobbyists, and others to question samples of people. The results are used to estimate how likely the population is to behave in a particular way, buy a particular product, or support a particular measure.

conclusion

We are constantly being presented with percentages and probabilities by the media and we tend to react emotionally, ignoring the ones we do not like such as the improbability of our winning the Lottery, or becoming frightened that we are likely to be victims of crime. It is only by looking carefully at how the calculations are made that we can make sound judgements about the risks in our lives and which chances we are willing to take.

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status asthmaticus

in medicine, repeated attacks of asthma with no respite between the spasms. The condition requires urgent treatment in hospital.

Staudinger, Hermann (1881-1965)

German organic chemist who was awarded the Nobel Prize for Chemistry in 1953 for his discoveries in macromolecular chemistry, of which he was the founder. He carried out pioneering research into the structure of albumen and cellulose.

To measure the high molecular weights of polymers he devised a relationship, now known as **Staudinger's law**, between the viscosity of polymer solutions and their molecular weight.

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staurolite

silicate mineral, $(Fe,Mg)_2(Al,Fe)_9Si_4O_{20}(OH)_2$. It forms brown crystals that may be twinned in the form of a cross. It is a useful indicator of medium grade (moderate temperature and pressure) metamorphism in metamorphic rocks formed from clay sediments.

STD

abbreviation for sexually transmitted disease.

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steady-state theory

in astronomy, rival theory to that of the Big Bang, which claims that the universe has no origin but is expanding because new matter is being created continuously throughout the universe. The theory was proposed in 1948 by Austrian-born British cosmologist Hermann Bondi, Austrian-born US astronomer Thomas Gold, and English astronomer, cosmologist, and writer Fred Hoyle, but it was dealt a severe blow in 1965 by the discovery of cosmic background radiation (radiation left over from the Big Bang and the formation of the universe) and is now largely rejected.

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steam

dry, invisible gas formed by vaporizing water. The visible cloud that normally forms in the air when water is vaporized is due to minute suspended water particles. Steam is widely used in chemical and other industrial processes and for the generation of power.

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steam engine

engine that uses the power of steam to produce useful work. The first successful steam engine was built in 1712 by English inventor Thomas Newcomen at Dudley, West Midlands; it was developed further by Scottish instrument maker James Watt from 1769 and by English mining engineer Richard Trevithick, whose high-pressure steam engine of 1802 led to the development of the steam locomotive.

In Newcomen's engine, steam was admitted to a cylinder as a piston moved up, and was then condensed by a spray of water, allowing air pressure to force the piston downwards. James Watt improved Newcomen's engine in 1769 by condensing the steam outside the cylinder (thus saving energy formerly used to reheat the cylinder) and by using steam to move the piston. Watt also introduced the **double-acting engine**, in which steam is alternately sent to each side of the piston forcing it up and down. The **compound engine** (1781) uses the exhaust from one cylinder to drive the piston of another. A later development was the steam turbine, still used today to power ships and generators in power stations. In other contexts, the steam engine was superseded by the internal-combustion engine or the electric motor.

Steam Locomotive

Go to site

Dedicated to the steam engine. It includes technical details about different types of locomotives, and allows you to design your own steam engine.

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stearic acid

$CH_3(CH_2)_{16}COOH$

saturated long-chain fatty acid, soluble in alcohol and ether but not in water. It is found in many fats and oils, and is used to make soap and candles and as a lubricant. The salts of stearic acid are called stearates.

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stearin

mixture of stearic and palmitic acids, used to make soap.

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steel

alloy or mixture of iron and up to 1.7% carbon, sometimes with other elements, such as manganese, phosphorus, sulphur, and silicon. The USA, Russia, Ukraine, and Japan are the main steel producers. Steel has innumerable uses, including ship and car manufacture, skyscraper frames, and machinery of all kinds.

Steels with only small amounts of other metals are called **carbon steels**. These steels are far stronger than pure iron, with properties varying with the composition.
Alloy steels contain greater amounts of other metals. Low-alloy steels have less than 5% of the alloying material; high-alloy steels have more. Low-alloy steels containing up to 5% silicon with relatively little carbon have a high electrical resistance and are used in power transformers and motor or generator cores, for example.
Stainless steel is a high-alloy steel containing at least 11% chromium. Steels with up to 20% tungsten are very hard and are used in high-speed cutting tools. About 50% of the world's steel is now made from scrap.

Steel is produced by increasing the carbon content of wrought iron, or decreasing that of cast iron, produced by a blast furnace. The main industrial process is the **basic-oxygen process**, in which molten pig iron and scrap steel is placed in a container lined with heat-resistant, alkaline (basic) bricks. A pipe or lance is lowered near to the surface of the molten metal and pure oxygen blown through it at high pressure. The surface of the metal is disturbed by the blast and the impurities are oxidized (burned out). The **open-hearth process** is an older steelmaking method in which molten iron and limestone are placed in a shallow bowl or hearth (such as an open-hearth furnace). Burning oil or gas is blown over the surface of the metal, and the impurities are oxidized. High-quality steel is made in an **electric furnace**. A large electric current flows through electrodes in the furnace, melting a charge of scrap steel and iron. The quality of the steel produced can be controlled precisely because the temperature of the furnace can be maintained exactly and there are no combustion by-products to contaminate the steel. Electric furnaces are also used to refine steel, producing the extra-pure steels used, for example, in the petrochemical industry.

The steel produced is cast into ingots, which can be worked when hot by hammering (forging) or pressing between rollers to produce sheet steel. Alternatively, the **continuous-cast process**, in which the molten metal is fed into an open-ended mould cooled by water, produces an unbroken slab of steel.

Stefan-Boltzmann constant

in physics, a constant relating the energy emitted by a black body (a hypothetical body that absorbs or emits all the energy falling on it) to its temperature. Its value is 5.6697×10^{-8} W m^{-2} K^{-4}.

Stefan-Boltzmann law

in physics, a law that relates the energy, E, radiated away from a perfect emitter (a black body), to the temperature, T, of that body. It has the form $E = \sigma T^4$, where E is the energy radiated per unit area per second, T is the temperature, and ςis the **Stefan-Boltzmann constant**. Its value is 5.6697 × 10^{-8} W m^{-2} K^{-4}. The law was derived by the Austrian physicists Josef Stefan and Ludwig Boltzmann.

Stegosaurus

genus of late Jurassic North American dinosaurs of the order Ornithischia. They were ungainly herbivores, with very small heads, a double row of triangular plates along the back, and spikes on the tail.

Steichen, Edward Jean (1879-1973)

Luxembourg-born US photographer, who with Alfred Stieglitz helped to establish photography as an art form. His style evolved during his career from painterly Impressionism to realism.

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steinbok

or steenbok

southern African antelope. It is reddish-brown and about 60 cm/23.5 in high at the shoulder.

classification

The steinbok *Raphicerus campestris* is in family Bovidae, in order Artiodactyla.

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stellar population

in astronomy, classification of stars according to their chemical composition as determined by spectroscopy.

Population I stars have a relatively high abundance of elements heavier than hydrogen and helium, and are confined to the spiral arms and disc of the Galaxy. They are believed to be young stars formed from material that has already been enriched with elements created by nuclear fusion in earlier generations of stars. Examples include open clusters and supergiants.
Population II stars have a low abundance of heavy elements and are found throughout the Galaxy but especially in the central bulge and outer halo. They are among the oldest objects in the Galaxy and include globular clusters. The Sun is a Population II star.

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stem

main supporting axis of a plant that bears the leaves, buds, and reproductive structures; it may be simple or branched. The plant stem usually grows above ground, although some grow underground, including rhizomes, corms, rootstocks, and tubers. Stems contain a continuous vascular system that conducts water and food to and from all parts of the plant.

The point on a stem from which a leaf or leaves arise is called a node, and the space between two successive nodes is the internode. In some plants, the stem is highly modified; for example, it may form a leaf-like cladode or it may be twining (as in many climbing plants), or fleshy and swollen to store water (as in cacti and other succulents). In plants exhibiting secondary growth, the stem may become woody, forming a main trunk, as in trees, or a number of branches from ground level, as in shrubs.

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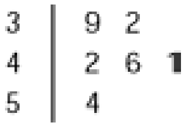
stem and leaf diagram

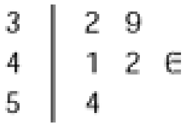
in statistics, a means of representing data using numbers with just two significant figures. The stem is formed by the first digit and the leaf the second. The stem digits are laid out vertically in order, and the leaf digits arranged next to them horizontally. Leaf digits with the same stem number share a row and the leaves are arranged in ascending order from the stem; all leaf digits in a set of data are shown. Numbers should be rounded if necessary. The leaf can represent any chosen unit of measurement for the diagram, such as tens or hundreds, and so on. The unit of measurement being used must always be stated.

For example, a stem and leaf diagram for the numbers 39 42 46 32 54 41 would be:



3	9 2
4	2 6 1
5	4

which is then rearranged to give:


3 | 2 9
4 | 1 2 E
5 | 4

where 3 | 2 9 represents 32 and 39. The unit of measurement used can be shown as '3 | 2 = 32' or 'unit = 1'.

If the same number is repeated in a set of data, the leaf digit must be shown the equivalent number of times against its stem.

When single units are included, the stem digit 0 is used. For example, 8 is shown as 0 | 8, while 18 is 1 | 8.

If the numbers have more than two significant figures, a suitable unit of measurement must be chosen for the diagram and the numbers rounded off if necessary. For example, in a set of numbers ranging between 10 and 900, each leaf unit will represent 10. The number 23 is rounded to 20 as 0 | 2; 370 is 3 | 7; and 838 rounded as 8 | 4.

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stem cell

embryonic cell that can develop into different tissues. Stem cells are used in medical research but their use is ethically controversial as the donor embryo is destroyed. Stem cells differ from other types of cells in that they are unspecialized cells that can reproduce themselves for long periods of time using cell division, but are capable of changing themselves into almost any type of specialist cell given the correct stimulus. Scientists have postulated that stem cell research could lead to cures for a wide range of medical conditions, from heart ailments to Parkinson's disease to growing replacement body parts.

There are three basic kinds of stem cell, which are known as totipotent, pluripotent, and multipotent.
Totipotent stem cells form when a fertilized egg first divides, and can form a complete organism by forming all the necessary tissues, such as bone, muscle, or nerve tissue, and also form the placenta.
Pluripotent stem cells form as part of the blastocyst and can form most kinds of tissue, but are not able to generate the whole organism.
Multipotent cells are generated by an embryo and give rise to only specific kinds of cells.

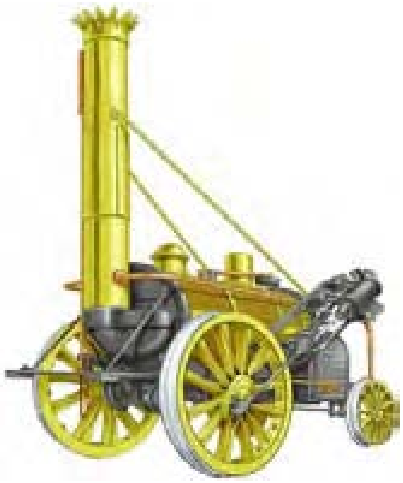
Examples of the types of specialist cell into which stem cells can develop are the cells that operate in the beating of the heart and the cells in the pancreas capable of producing insulin.

Stephenson, George (1781-1848)

English engineer. He built the first successful steam locomotive. He also invented a safety lamp independently of Humphrey Davy in 1815. He was appointed engineer of the Stockton and Darlington Railway, the world's first public railway, in 1821, and of the Liverpool and Manchester Railway in 1826. In 1829 he won a prize with his locomotive *Rocket*.

Experimenting with various gradients, Stephenson found that a slope of 1 in 200, common enough on roads, reduced the haulage power of a locomotive by 50% (on a completely even surface, a tractive force of less than 5 kg/11 lb would move a tonne). Friction was virtually independent of speed. It followed that railway gradients should always be as low as possible, and cuttings, tunnels, and embankments were therefore necessary. He also advocated the use of malleable iron rails instead of cast iron. The gauge for the Stockton and Darlington Railway was set by Stephenson at 1.4 m/4 ft 8 in, which became the standard gauge for railways in most of the world.

Stephenson



(Image © Research Machines plc)

English engineer George Stephenson built the *Rocket* in 1829. It was one of the factors behind the sudden increase in railway construction that helped the spread of the industrial revolution in Britain.

The Rocket Animation

Go to site

Interactive version of one of the first working locomotives, English engineer George Stephenson's *The Rocket*. This BBC site gives a brief background to the project, allows you to understand how the locomotive worked, and shows you a detailed diagram of the engine.

Stephenson, Robert (1803-1859)

English civil engineer. He constructed railway bridges such as the high-level bridge at Newcastle-upon-Tyne, England, and the Menai and Conway tubular bridges in Wales. He was the son of George Stephenson.

The successful *Rocket* steam locomotive was built under his direction in 1829, as were subsequent improvements to it.

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steppe

temperate grasslands of Europe and Asia. The term is sometimes used to refer to other temperate grasslands and semi-arid desert edges.

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stepper motor

electric motor that can be precisely controlled by signals from a computer. The motor turns through a precise angle each time it receives a signal pulse from the computer. By varying the rate at which signal pulses are produced, the motor can be run at different speeds or be turned through an exact angle and then stopped. Switching circuits can be constructed to allow the computer to reverse the direction of the motor.

By combining two or more motors, complex movement control becomes possible. For example, if stepper motors are used to power the wheels of a small vehicle, a computer can manoeuvre the vehicle in any direction.

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steradian

symbol sr

SI unit of measure of solid (three-dimensional) angles, the three-dimensional equivalent of the radian. One steradian is the angle at the centre of a sphere when an area on the surface of the sphere equal to the square of the sphere's radius is joined to the centre.

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stereocilium

sensory hair cell found on the cochlea in the inner ear. When the cochlear fluid vibrates in response to sound the hairs move together pushing on protein molecules on their surface. On each stereocilium the protein molecule triggers the opening of an ion gate that enables the flow of potassium ions through the hair. The ion flow causes an electrical signal to be transmitted to the brain as a nerve impulse, where it is interpreted as sound.

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stereophonic sound

system of sound reproduction using two complementary channels leading to two loudspeakers, which gives a more natural depth to the sound. Stereo recording began with the introduction of two-track magnetic tape in the 1950s. See hi-fi.

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sterilization

killing or removal of living organisms such as bacteria and fungi. A sterile environment is necessary in medicine, food processing, and some scientific experiments. Methods include heat treatment (such as boiling), the use of chemicals (such as disinfectants), irradiation with gamma rays, and filtration. See also asepsis.

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sterilization

in medicine, any surgical operation to terminate the possibility of reproduction. In women, this is normally achieved by sealing or tying off the Fallopian tubes (tubal ligation) so that fertilization can no longer take place. In men, the transmission of sperm is blocked by vasectomy.

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sterling silver

alloy containing 925 parts of silver and 75 parts of copper. The copper hardens the silver, making it more useful.

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sternum

or breastbone

large flat bone, 15-20 cm/5.9-7.8 in long in the adult, at the front of the chest, joined to the ribs. It gives protection to the heart and lungs. During open-heart surgery the sternum must be split to give access to the thorax.

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steroid

any of a group of cyclic, unsaturated alcohols (lipids without fatty acid components), which, like sterols, have a complex molecular structure consisting of four carbon rings. Steroids include the sex hormones, such as testosterone, the corticosteroid hormones produced by the adrenal gland, bile acids, and cholesterol.

The term is commonly used to refer to anabolic steroid. In medicine, synthetic steroids are used to treat a wide range of conditions.

Steroids are also found in plants. The most widespread are the **brassinosteroids**, necessary for normal plant growth.

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sterol

any of a group of solid, cyclic, unsaturated alcohols, with a complex structure that includes four carbon rings; cholesterol is an example. Steroids are derived from sterols.

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stethoscope

instrument used to ascertain the condition of the heart and lungs by listening to their action. It consists of two earpieces connected by flexible tubes to a small plate that is placed against the body. It was invented in 1819 in France by René Théophile Hyacinthe Laënnec.

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stick insect

insect of the order Phasmida, closely resembling a stick or twig. The eggs mimic plant seeds. Many species are wingless. The longest reach a length of 30 cm/1 ft.

Fossilized eggs were identified in 1995, and are thought to be around 44 million years old.

Stick Insect

Go to site

Loads of information on the care of your stick insects - how to house them, what to feed them on, how to handle them, and how to encourage breeding. This illustrated page is part of the Bug Club site and includes links to other bug pets, newsletter, pen pals, and books.

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stickleback

any fish of the family Gasterosteidae, found in marine and fresh waters of the northern hemisphere. It has a long body that can grow to 18 cm/7 in. The spines along a stickleback's back take the place of the first dorsal fin, and can be raised to make the fish difficult to eat for predators. After the eggs have been laid the female takes no part in rearing the young: the male builds a nest for the eggs, which he then guards and rears for the first two weeks.

The common three-spined stickleback *Gasterosteus aculeatus*, up to 10 cm/4 in, is found in freshwater habitats and also in brackish estuaries.

Stieglitz, Alfred (1864-1946)

US photographer. After forming the multimedia Photo-Secession Group with Edward Steichen in New York (1902), he started up the magazine *Camera Work* (1902-17). Through exhibitions at his gallery '291' he helped to establish photography as an art form. In 1924 he married the painter Georgia O'Keeffe, who was the model in many of his photographs. His cloud series, the portraits of O'Keeffe, and his studies of New York City, are his most famous works.

Stieglitz was also instrumental in promoting modern art, both by European and American artists. He was the first exhibitor to show such painters and sculptors as Picasso, Cézanne, Rodin, Matisse, Brancusi, and O'Keeffe.

Masters of Photography: Alfred Stieglitz

Go to site

Part of a large 'artcyclopaedia' containing informative entries on many famous artists, this biographical article contains samples of US photographer Stieglitz's work, links to related articles on other sites, and a list of reference books which can be purchased online.

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stigma

in a flower, the surface at the tip of a carpel that receives the pollen. It often has short outgrowths, flaps, or hairs to trap pollen and may produce a sticky secretion to which the grains adhere.

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stigmata

impressions or marks corresponding to the five wounds Jesus received at his crucifixion, which are said to have appeared spontaneously on St Francis and other saints.

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stimulant

any substance that acts on the brain to increase alertness and activity; for example, amphetamine. When given to children, stimulants may have a paradoxical, calming effect. Stimulants cause liver damage, are habit-forming, have limited therapeutic value, and are now prescribed only to treat narcolepsy and severe obesity.

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stingray

cartilaginous fish that is a species of ray.

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stinkhorn

any of a group of foul-smelling European fungi (see fungus), especially *P. impudicus*; they first appear on the surface as white balls. (Genus *Phallus*, order Phallales.)

The spores of the stinkhorn are dispersed by flies. The flies are attracted by the its corpselike aroma and feed on the spore-containing slime at its tip. This give them diarrhoea almost immediately, so the spores are spread but still likely to end up in suitable habitat.

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stinkwood

any of various trees with unpleasant-smelling wood. The South African tree *O. bullata* has offensive-smelling wood when newly felled, but fine, durable timber used for furniture. Another stinkwood is *G. augusta* from tropical America. (Genera *Ocotea*, family Lauraceae; *Gustavia*.)

---

stipule

outgrowth arising from the base of a leaf or leaf stalk in certain plants. Stipules usually occur in pairs or fused into a single semicircular structure.

---

stock

in botany, any of a group of herbaceous plants commonly grown as garden ornamentals. Many cultivated varieties, including simple-stemmed, queen's, and ten-week stocks, have been derived from the wild stock (*M. incana*); night-scented (or evening) stock (*M. bicornis*) becomes aromatic at night. (Genus *Matthiola*, family Cruciferae.)

STOL

(acronym for **short takeoff and landing**) aircraft fitted with special devices on the wings (such as sucking flaps) that increase aerodynamic lift at low speeds. Small passenger and freight STOL craft are commonly used in difficult terrain; STOLports (airports designed for STOL aircraft) are rare, but a notable example is London City Airport, located in the Docklands area of the city.

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stolon

in botany, a type of runner.

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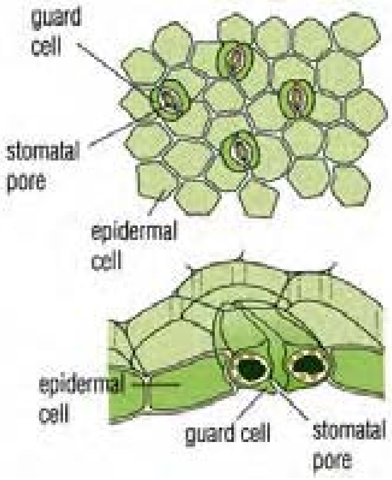
stoma

plural stomata

in botany, a pore (tiny hole) in the epidermis (outer layer of tissue) of a plant. There are lots of these holes, usually in the lower surface of the leaf. A leaf contains several layers of tissue. The outer layer is the epidermis and is only one cell thick. Stomata occur in the lower epidermis. Each stoma is surrounded by a pair of guard cells that are crescent-shaped when the stoma is open but can collapse to an oval shape, thus closing off the opening between them. Stomata allow the exchange of carbon dioxide and oxygen (needed for photosynthesis and respiration) between the internal tissues of the plant and the outside atmosphere. They are also the main route by which water is lost from the plant, and they can be closed to conserve water, the movements being controlled by changes in turgidity of the guard cells.

At night the stomata may allow oxygen to diffuse in and carbon dioxide out because only respiration is taking place. However in many plants the stomata close at night, preventing this gas exchange.

stoma



(Image © Research Machines plc)

The stomata, tiny openings in the epidermis of a plant, are surrounded by pairs of crescent-shaped cells, called guard cells. The guard cells open and close the stoma by changing shape.

---

stomach

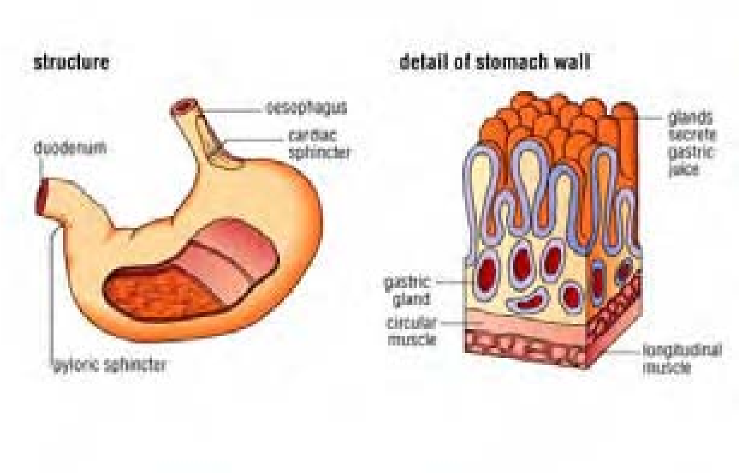
organ that forms the first cavity in the digestive system of animals. In mammals it is a bag of muscle situated just below the diaphragm. Food enters it from the oesophagus, is digested by the acid and enzymes secreted by the stomach lining. The wall of the stomach contracts to mix the food with the digestive juice to help digestion of protein. After a while, partly digested food is then passed into the small intestine (duodenum). Some plant-eating mammals have multi-chambered stomachs that harbour bacteria in one of the chambers to assist in the digestion of cellulose.

The gizzard is part of the stomach in birds.

stomach

The stomach rumbles when empty because of the muscular contractions necessary to move food along. The contractions are controlled by small rhythmic electrical currents generated by cells in the intestine, known as the cells of Cajal.

stomach



(Image © Research Machines plc)

The human stomach can hold about 1.5 l/2.6 pt of liquid. The digestive juices are acidic enough to dissolve metal. To avoid damage, the cells of the stomach lining are replaced quickly – 500,000 cells are replaced every minute, and the whole stomach lining every three days.

---

stone

plural stone; abbreviation st

British unit of mass (chiefly used to express body mass) equal to 14 pounds avoirdupois (6.35 kg).

Stone Age

the developmental stage of humans in prehistory before the use of metals, when tools and weapons were made chiefly of stone, especially flint. The Stone Age is subdivided into the Old or **Palaeolithic**, when flint implements were simply chipped into shape; the Middle or **Mesolithic**; and the New or **Neolithic**, when implements were ground and polished. Palaeolithic people were hunters and gatherers; by the Neolithic period people were taking the first steps in agriculture, the domestication of animals, weaving, and pottery.

Recent research has been largely directed towards the relationship of the Palaeolithic period to geochronology (the measurement of geological time) and to the clarification of an absolute chronology based upon geology. The economic aspects of the Neolithic cultures have attracted as much attention as the typology of the implements and pottery, and the study of chambered tombs.

Stones of England

Go to site

Extensive reference guide with photographs of stone circles, dolmens, burrows, hill forts, and other megalithic sites from around England.

Stones of Ireland

Go to site

Reference guide with impressive photos from a variety of stone circles, dolmens, court and passage tombs, cairns, and stone forts from around Ireland.

Stones of Scotland

Go to site

Reference guide with marvellous photographic material from a variety of megalithic sites in Scotland.

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stonechat

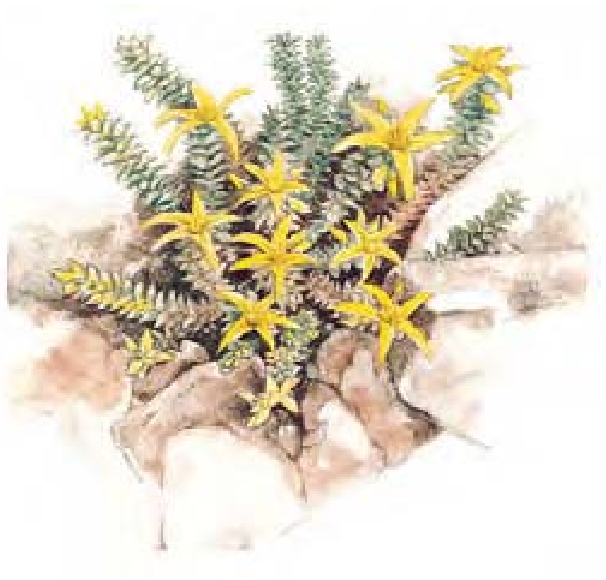
small insectivorous thrush*Saxicola torquata*, family Muscicapidae, order Passeriformes, frequently found in Eurasia and Africa on open land with bushes. The male has a black head and throat, tawny breast, and dark back; the female is browner. It is about 13 cm/5 in long.

---

stonecrop

any of a group of plants belonging to the orpine family, succulent herbs with fleshy leaves and clusters of red, yellow, or white starlike flowers. Stonecrops are characteristic of dry, rocky places and some grow on walls. (Genus *Sedum*, family Crassulaceae.)

stonecrop



(Image © Research Machines plc)

Biting stonecrop *Sedum acre*, a succulent that grows well on chalk and limestone. Called 'biting stonecrop' and 'wall pepper' because of the sharp taste of its leaves, it has a variety of uses in herbal medicine. It is often encouraged to grow on walls.

---

stonefish

any of a family (Synanceiidae) of tropical marine bony fishes with venomous spines and bodies resembling encrusted rocks.

stonefish

Stonefish are the most poisonous of all fish. The needle-like spines along their backs contain sufficient venom to kill within six hours anyone unlucky enough to tread upon them.

---

stonefly

any insect of the order Plecoptera, with a long tail and antennae and two pairs of membranous wings. Stoneflies live near fresh water. There are over 1,300 species.

Stonehenge

(Old English 'hanging stones')

megalithic monument on Salisbury Plain, 3 km/1.9 mi west of Amesbury in Wiltshire, England. The site developed over various periods from a simple henge (earthwork circle and ditch), dating from about 3000 BC, to a complex stone structure, from about 2100 BC, which included a circle of 30 upright stones, their tops linked by lintel stones to form a continuous circle about 30 m/100 ft across.

Within this sarsen **peristyle** was a horseshoe arrangement of five sarsen **trilithons** (two uprights plus a lintel, set as five separate entities), and the so-called 'Altar Stone' - an upright pillar - on the axis of the horseshoe at the open, northeast end, which faces in the direction of the rising sun. A further horseshoe and circle within the sarsen peristyle were constructed from bluestone relocated from previous outer circles.

It has been suggested that Stonehenge was constructed as an observatory.

---

stork

any of the 17 species of the Ciconiidae, a family of long-legged, long-necked wading birds with long, powerful wings, and long conical bills used for spearing prey. Some species grow up to 1.5 m/5 ft tall.

species

Species include the Eurasian **white stork** *Ciconia ciconia*, which is encouraged to build on rooftops as a luck and fertility symbol. It feeds on reptiles, small mammals, and insects. Its plumage is greyish white, its quills and longest feathers on the wing coverts black, and the beak and legs red. It migrates to Africa in winter. The **jabiru** *Jabiru mycteria* of the Americas is up to 1.5 m/5 ft high, and is white plumaged, with a black and red head. In the **black stork** *C. nigra*, the upper surface is black and the lower parts are white. It is widely found in southern and central Europe, Asia, and parts of Africa. The adjutant bird, ibis, heron, and spoonbill are related birds.

stork

Dissatisfied white stork chicks sometimes switch nests. A wandering chick is initially greeted with aggression at its new home, but is soon accepted. The most attractive nests are those where the resident chicks are younger than the new arrival, who will therefore not have to battle for food with older siblings.

storm

extreme weather condition characterized by strong winds, rain, hail, thunder, and lightning.

storm surge

abnormally high tide brought about by a combination of a deep atmospheric depression (very low pressure) over a shallow sea area, high spring tides, and winds blowing from the appropriate direction. It can be intensified by snowmelt and/or river flooding. A storm surge can cause severe flooding of lowland coastal regions and river estuaries.

Bangladesh is particularly prone to surges, because it is sited on a low-lying delta where the Indian Ocean funnels into the Bay of Bengal. In May 1991, 125,000 people were killed there in such a disaster. In February 1953 more than 2,000 people died when a North Sea surge struck the Dutch and English coasts.

STP

abbreviation for standard temperature and pressure.

strabismus

technical term for a squint.

Strabo (c. 63 BC–c.AD 24)

Greek geographer and historian who travelled widely to collect first-hand material for his *Geography*.

strain

in the science of materials, the extent to which a body is distorted when a deforming force (stress) is applied to it. It is a ratio of the extension or compression of that body (its length, area, or volume) to its original dimensions (see Hooke's law). For example, linear strain is the ratio of the change in length of a body to its original length.

strata

singular stratum

layers or beds of sedimentary rock.

stratigraphy

branch of geology that deals with sedimentary rock layers (strata) and their sequence of formation. Its basis was developed by English geologist William Smith. The basic principle of superposition establishes that upper layers or deposits accumulated later in time than the lower ones.

Stratigraphy involves both the investigation of sedimentary structures to determine past environments represented by rocks, and the study of fossils for identifying and dating particular beds of rock. A body of rock strata with a set of unifying characteristics indicative of an environment is called a facies.

Stratigraphic units can be grouped in terms of time or lithology (rock type). Strata that were deposited at the same time belong to a single **chronostratigraphic unit** but need not be the same lithology. Strata of a specific lithology can be grouped into a **lithostratigraphic unit** but are not necessarily the same age.

Stratigraphy in the interpretation of archaeological excavations provides a relative chronology for the levels and the artefacts within rock beds. It is the principal means by which the context of archaeological deposits is evaluated.

---

stratosphere

that part of the atmosphere 10–40 km/6–25 mi from the Earth's surface, where the temperature slowly rises from a low of -55°C/-67°F to around 0°C/32°F. The air is rarefied and at around 25 km/15 mi much ozone is concentrated.

---

strawberry

low-growing perennial plant of the genus *Fragaria*, family Rosaceae, widely cultivated for its red, fleshy fruits, which are rich in vitamin C. Wild strawberry *F. virginiana* has small aromatic fruits and grows over much of the eastern half of North America. Cultivated strawberries are hybrids between North American wild species and European species.

---

streamlining

shaping a body so that it offers the least resistance when travelling through a medium such as air or water. Aircraft, for example, must be carefully streamlined to reduce air resistance, or drag.

In order to reduce the air resistance of an object such as a car, its shape is designed in such a way that it will reduce drag and allow air to flow smoothly over the car. High-speed aircraft must have swept-back wings, supersonic aircraft a sharp nose and narrow body.

---

streetcar

or trolley

transport system for use in cities, where wheeled vehicles run along parallel rails. Streetcars are powered either by electric conductor rails below ground or by conductor arms connected to overhead wires. Greater maneuverability is achieved with the trolleybus, similarly powered by conductor arms overhead but without tracks.

Streetcars originated in British collieries in the 18th century, and the earliest passenger system was in New York City, in 1832. They were designed for urban and interurban service and vast networks ran from city to city, especially in the northeastern USA, where they ran more often to small towns than did the railroads. Streetcars were widespread in the USA and Europe from the late 19th to the mid-20th century, after which they were phased out, especially in the USA and the UK, under pressure from the automobile-transport lobby. During the 1990s both streetcars and trolleybuses were being revived in some areas; they are in use again in several European cities. Both vehicles have the advantage of being nonpolluting to the local environment, since they produce no exhaust gases. However, electricity *is* polluting at the source.

---

strength of acids and bases

in chemistry, the ability of acids and bases to dissociate in solution with water, and hence to produce a low or high pH, respectively.

A strong acid is fully dissociated in aqueous solution, whereas a weak acid is only partly dissociated. Since the dissociation of acids generates hydrogen ions, a solution of a strong acid will have a high concentration of hydrogen ions and therefore a low pH. A strong base will have a high pH, whereas a weaker base will not dissociate completely and will have a pH of nearer 7.

---

streptokinase

enzyme produced by *Streptococcus* bacteria that is capable of digesting fibrin, the protein making up blood clots. It is used to treat pulmonary embolism and heart attacks, reducing mortality.

---

streptomycin

antibiotic drug discovered in 1944, active against a wide range of bacterial infections.

Streptomycin is derived from a soil bacterium *Streptomyces griseus* or synthesized.

---

stress

in psychology, any event or situation that makes heightened demands on a person's mental or emotional resources. Stress can be caused by overwork, anxiety about exams, money, job security, unemployment, bereavement, poor relationships, marriage breakdown, sexual difficulties, poor living or working conditions, and constant exposure to loud noise.

Many changes that are apparently 'for the better', such as being promoted at work, going to a new school, moving to a new house, and getting married, are also a source of stress. Stress can cause, or aggravate, physical illnesses, among them psoriasis, eczema, asthma, and stomach and mouth ulcers. Apart from removing the source of stress, acquiring some control over it and learning to relax when possible are the best responses.

---

stress and strain

in the science of materials, measures of the deforming force applied to a body (stress) and of the resulting change in its shape (strain). For a perfectly elastic material, stress is proportional to strain (Hooke's law).

---

stress fracture

in medicine, bone fracture caused by excessive amounts of exercise.

It is marked by the gradual onset of pain and swelling and a lump may develop over the affected site. Stress fractures cannot be detected by X-rays in the early stages. They are treated by rest, external support, and analgesics to control the pain.

---

stridulatory organs

in insects, organs that produce sound when rubbed together. Crickets rub their wings together, but grasshoppers rub a hind leg against a wing. Stridulation is thought to be used for attracting mates, but may also serve to mark territory.

---

strike

compass direction of a horizontal line on a planar structural surface, such as a fault plane, bedding plane, or the trend of a structural feature, such as the axis of a fold. Strike is 90° from dip.

---

string

in computing, a group of characters manipulated as a single object by the computer. In its simplest form a string may consist of a single letter or word - for example, the single word SMITH might be established as a string for processing by a computer. A string can also consist of a combination of words, spaces, and numbers - for example, 33 HIGH STREET ANYTOWN ALLSHIRE could be established as a single string.

Most high-level languages have a variety of string-handling functions. For example, functions may be provided to read a character from any given position in a string or to count automatically the number of characters in a string.

---

strip mining

or open-pit mining

mining from the surface rather than by tunneling underground. Coal, iron ore, and phosphates are often extracted by strip mining. Often the mineral deposit is covered by soil, which must first be stripped off, usually by large machines such as walking draglines and bucket-wheel excavators. The ore deposit is then broken up by explosives and collected from the surface.

One of the largest excavations in the world has been made by open-pit mining at the Bingham Canyon copper mine in Utah, measuring 2,590 ft/790 m deep and 2.3 mi/3.7 km across.

---

strobilus

in botany, a reproductive structure found in most gymnosperms and some pteridophytes, notably the club mosses. In conifers the strobilus is commonly known as a cone.

---

stroboscope

instrument for studying continuous periodic motion by using light flashing at the same frequency as that of the motion; for example, rotating machinery can be optically 'stopped' by illuminating it with a stroboscope flashing at the exact rate of rotation.

---

stroke

or cerebrovascular accident or apoplexy

interruption of the blood supply to part of the brain due to a sudden bleed in the brain (cerebral haemorrhage) or embolism or thrombosis. Strokes vary in severity from producing almost no symptoms to proving rapidly fatal. In between are those (often recurring) that leave a wide range of impaired function, depending on the size and location of the event.

Strokes involving the right side of the brain, for example, produce weakness of the left side of the body. Some affect speech. Around 80% of strokes are **ischaemic strokes**, caused by a blood clot blocking an artery transporting blood to the brain. Transient ischaemic attacks, or 'mini-strokes', with effects lasting only briefly (less than 24 hours), require investigation to try to forestall the possibility of a subsequent full-blown stroke.

Brain Basics: Preventing Stroke

Go to site

Mini fact sheet and handy reference tool on strokes. It offers a brief description of the diagnostic symptoms, a list of the warning signs of the onset of the attack and suggested ways of preventing a stroke's onset.

---

stromatolite

mound produced in shallow water by mats of algae that trap mud particles. Another mat grows on the trapped mud layer and this traps another layer of mud and so on. The stromatolite grows to heights of a metre or so. They are uncommon today but their fossils are among the earliest evidence for living things - over 2,000 million years old.

---

strong nuclear force

one of the four fundamental forces of nature, the other three being the gravitational force or gravity, the electromagnetic force, and the weak nuclear force. The strong nuclear force was first described by the Japanese physicist Hideki Yukawa in 1935. It is the strongest of all the forces, acts only over very small distances within the nucleus of the atom (10^{-13} cm), and is responsible for binding together quarks to form hadrons, and for binding together protons and neutrons in the atomic nucleus. The particle that is the carrier of the strong nuclear force is the gluon, of which there are eight kinds, each with zero mass and zero charge.

---

strontium

chemical symbol Sr

soft, ductile, pale-yellow, metallic element, atomic number 38, relative atomic mass 87.62. It is one of the alkaline-earth metals, widely distributed in small quantities only as a sulphate or carbonate. Strontium salts burn with a red flame and are used in fireworks and signal flares.

The radioactive isotopes Sr-89 and Sr-90 (half-life 25 years) are some of the most dangerous products of the nuclear industry; they are fission products in nuclear explosions and in the reactors of nuclear power plants. Strontium is chemically similar to calcium and deposits in bones and other tissues, where the radioactivity is damaging. The element was named in 1808 by English chemist Humphry Davy, who isolated it by electrolysis, after Strontian, a mining location in Scotland where it was first found.

---

strophanthus

any of a group of tropical plants belonging to the dogbane family, native to Africa and Asia. Seeds of the handsome climber *S. gratus* yield a poison, strophantin, which is used on arrowheads in hunting, and in medicine as a heart stimulant. (Genus *Strophanthus*, family Apocynaceae.)

---

structured programming

in computing, the process of writing a program in small, independent parts. This makes it easier to control a program's development and to design and test its individual component parts. Structured programs are built up from units called **modules**, which normally correspond to single procedures or functions. Some programming languages, such as Pascal, Ada, and Modula-2, are better suited to structured programming than others.

---

strychnine

$C_{21}H_{22}O_2N_2$

bitter-tasting, poisonous alkaloid. It is a poison that causes violent muscular spasms, and is usually obtained by powdering the seeds of plants of the genus *Strychnos* (for example *S. nux vomica*). Curare is a related drug.

---

stupor

in medicine, state of partial unconsciousness in which the patient can be roused by pain or may respond vaguely to questions. The deeper state of unconsciousness, in which nothing rouses the patient, is coma.

---

sturgeon

large, primitive, bony fish with five rows of bony plates and chin barbels used for exploring the bottom of the water for prey.

Sturgeons take 6–25 years to reach sexual maturity. The population in the Caspian Sea is threatened by pollution and intensive fishing for caviar; there was a 75% decline in the catch 1984–94 and stocks fell from 142 million to 40 million between 1968 and 1998. It has been estimated that sturgeon will vanish from the Caspian Sea by 2007 as a result of poaching and smuggling of fish. Rising pollution levels and the damming of rivers also means that fewer sturgeon are returning to rivers to spawn. Some 90% of the caviar taken from the Caspian Sea is smuggled, and poachers often catch the females before they are mature enough to produce eggs, thus further decimating the stocks. In 1997, in an effort to preserve the species, all sturgeon valued for their caviar were added to the Convention on International Trade in Endangered Species (CITES) Appendix 2 (classed as vulnerable). In June 2001, Russia, Kazakhstan, and Azerbaijan agreed to stop sturgeon fishing in the Caspian Sea until the beginning of 2002 in an attempt to counter overfishing.

---

stutter

in medicine, a disruption to the normal flow of speech. Stuttering usually becomes apparent between the ages of two and five years. It is more common in boys and genetic and environmental factors contribute to its development. Stuttering can be improved considerably by speech therapy. Stuttering rarely develops after puberty and it usually occurs as a result of brain damage.

---

style

in flowers, the part of the carpel bearing the stigma at its tip. In some flowers it is very short or completely lacking, while in others it may be long and slender, positioning the stigma in the most effective place to receive the pollen.

Style, Old and New

forms of dating, see calendar.

---

subatomic particle

any particle smaller than an atom, including elementary particles and particles such as alpha particles, which are composite.

---

subconscious

state of being partially conscious. The mind can perceive impressions or events that may be forgotten at the time but can continue to influence the conscious mind or may enter the conscious mind a long time after the event has taken place.

Psychoanalysis places much importance on the influence of painful and unpleasant experiences that, although forgotten, continue to have a detrimental influence on the mind.

---

subcutaneous tissue

in medicine, loose cellular tissue beneath the skin. Injection into the subcutaneous tissue is a route of administration for some drugs, such as insulin.

---

subduction zone

in plate tectonics, a region where two plates of the Earth's rigid lithosphere collide, and one plate descends below the other into the weaker asthenosphere. Subduction results in the formation of ocean trenches, most of which encircle the Pacific Ocean.

Ocean trenches are usually associated with volcanic island arcs and deep-focus earthquakes (more than 300 km/185 mi below the surface), both the result of disturbances caused by the plate subduction.

---

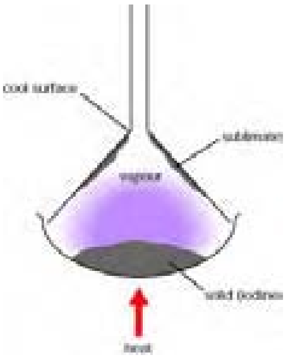
sublimation

conversion of a solid to vapour without passing through the liquid phase. It is one of the changes of state of matter.

Sublimation depends on the fact that the boiling point of the solid substance is lower than its melting point at atmospheric pressure. Thus by increasing pressure, a substance that sublimes can be made to go through a liquid stage before passing into the vapour state.

Some substances that do not sublime at atmospheric pressure can be made to do so at low pressures. This is the principle of freeze-drying, during which ice sublimes at low pressure.

sublimation



(Image © Research Machines plc)

During sublimation, a substance changes from a solid to a gas without first changing to a liquid. Very few chemicals sublimate; those that do include iodine, arsenic, and zinc chloride.

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subliminal message

any message delivered beneath the human conscious threshold of perception. It may be visual (words or images flashed between the frames of a cinema or TV film), or aural (a radio message broadcast constantly at very low volume).

---

submarine

underwater warship. The first underwater boat was constructed in 1620 for James I of England by the Dutch scientist Cornelius van Drebbel (1572-1633). A naval submarine, or submersible torpedo boat, the *Gymnote*, was launched by France in 1888. The conventional submarine of World War I was driven by diesel engine on the surface and by battery-powered electric motors underwater. The diesel engine also drove a generator that produced electricity to charge the batteries.

history

In the 1760s the American David Bushnell (1742-1824) designed a submarine called *Turtle* for attacking British ships, and in 1800 Robert Fulton designed a submarine called *Nautilus* for Napoleon for the same purpose. John P Holland, an Irish emigrant to the USA, designed a submarine in about 1875, which was used by both the US and the British navies at the turn of the century. Submarine warfare was established as a distinct form of naval tactics during World War I and submarines, from the ocean-going vessels to the midget type, played a vital role in both world wars. In particular, German U-boats caused great difficulty to Allied merchant shipping, until the radio codes were broken in 1942.

nuclear submarines

In 1954 the USA launched the first nuclear-powered submarine, the *Nautilus*. The US nuclear submarine *Ohio*, in service from 1981, is 170 m/560 ft long and carries 24 Trident missiles, each with 12 independently targetable nuclear warheads. The nuclear warheads on US submarines have a range that is being extended to 11,000 km/6,750 mi. Four Vanguard-class Trident missile-carrying submarines, which will each wield more firepower than was used in the whole of World War II, were built in the 1990s in the UK. Operating depth is usually up to 300 m/1,000 ft, and nuclear-powered speeds of 30 knots (55 kph/34 mph) are reached. As in all nuclear submarines, propulsion is by steam turbine driving a propeller. The steam is raised using the heat given off by the nuclear reactor (see nuclear energy).

In oceanography, salvage, and pipe-laying, smaller submarines called **submersibles** are used. They are also being developed for tourism.

---

submersible

vessel designed to operate under water, especially a small submarine used by engineers and research scientists as a ferry craft to support diving operations. The most advanced submersibles are the so-called lock-out type, which have two compartments: one for the pilot, the other to carry divers. The diving compartment is pressurized and provides access to the sea.

---

subroutine

in computing, a small section of a program that is executed ('called') from another part of the program. Subroutines provide a method of performing the same task at more than one point in the program, and also of separating the details of a program from its main logic. In some computer languages, subroutines are similar to functions or procedures.

---

subsistence farming

farming when the produce is enough to feed only the farmer and family and there is no surplus to sell.

---

substitution reaction

in chemistry, the replacement of one atom or functional group in an organic molecule by another.

---

substrate

in biochemistry, a compound or mixture of compounds acted on by an enzyme. The term also refers to a substance such as agar that provides the nutrients for the metabolism of micro-organisms. Since the enzyme systems of micro-organisms regulate their metabolism, the essential meaning is the same.

---

subway

or (UK) underground

rail service that runs underground. The first underground line in the world was in London, England. Opened in 1863, it was essentially a roofed-in trench. The London Underground is still the longest subway system, with over 250 mi/400 km of routes. Many major cities throughout the world have extensive systems; those in New York and Moscow each handle millions of passengers a day.

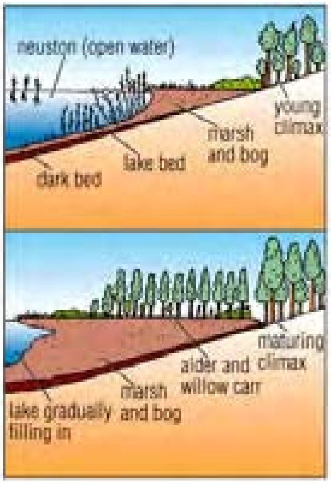
---

succession

in ecology, a series of changes that occur in the structure and composition of the vegetation in a given area from the time it is first colonized by plants (**primary succession**), or after it has been disturbed by fire, flood, or clearing (**secondary succession**).

If allowed to proceed undisturbed, succession leads naturally to a stable climax community (for example, oak and hickory forest or savannah grassland) that is determined by the climate and soil characteristics of the area.

succession



(Image © Research Machines plc)

The succession of plant types along a lake. As the lake gradually fills in, a mature climax community of trees forms inland from the shore. Extending out from the shore, a series of plant communities can be discerned with small, rapidly growing species closest to the shore.

---

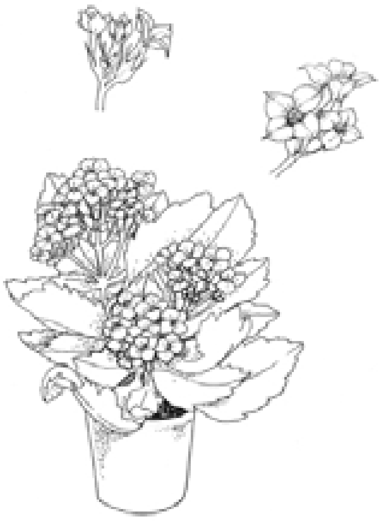
succulent plant

thick, fleshy plant that stores water in its tissues; for example, cacti and stonecrops *Sedum*. Succulents live either in areas where water is very scarce, such as deserts, or in places where it is not easily obtainable because of the high concentrations of salts in the soil, as in salt marshes. Many desert plants are xerophytes.

succulent plant

The flowers of the stapeliads of Africa and southern Asia look very like dung or decaying meat. This is because they rely on carrion-feeding beetles to pollinate them. So convincing are the flowers that they are often covered with maggots that have hatched from eggs mistakenly laid on them.

succulent plant



(Image © Research Machines plc)

Flaming Katy (*Kalanchoe blossfeldiana*), also known as Madagascar's widow's-thrill. Native to Madagascar, the Flaming Katy is one of 124 species of *Kalanchoe*, a popular ornamental houseplant. There are several varieties of *K. blossfeldiana*, which are particularly popular because of their deep pink, red, or orange flowers. Succulent plants, kalanchoes are native to arid and rocky regions.

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sucker fish

another name for remora.

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suckering

in plants, reproduction by new shoots (suckers) arising from an existing root system rather than from seed. Plants that produce suckers include elm, dandelion, and members of the rose family.

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sucrose

or cane sugar or beet sugar; $C_{12}H_{22}O_{11}$

sugar found in the pith of sugar cane and in sugar beet. It is popularly known as sugar.

Sucrose is a disaccharide sugar, each of its molecules being made up of two simple sugar (monosaccharide) units: glucose and fructose.

---

sudden infant death syndrome

SIDS

in medicine, the technical term for cot death.

---

sugar

or sucrose

sweet, soluble, crystalline carbohydrate found in the pith of sugar cane and in sugar beet. It is a **disaccharide** sugar, each of its molecules being made up of two simple-sugar (**monosaccharide**) units: glucose and fructose. Sugar is easily digested and forms a major source of energy in humans, being used in cooking and in the food industry as a sweetener and, in high concentrations, as a preservative. A high consumption is associated with obesity and tooth decay. In the UK, sucrose may not be used in baby foods.

The main sources of sucrose sugar are tropical sugar cane *Saccharum officinarum*, which accounts for two-thirds of production, and temperate sugar beet *Beta vulgaris*. Minor quantities are produced from the sap of maple trees, and from sorghum and date palms. Raw sugar crystals obtained by heating the juice of sugar canes are processed to form brown sugars, such as Muscovado and Demerara, or refined and sifted to produce white sugars, such as granulated, caster, and icing sugar. The syrup that is drained away from the raw sugar is molasses; it may be processed to form golden syrup or treacle, or fermented to form rum. Molasses obtained from sugar beet juice is too bitter for human consumption. The fibrous residue of sugar cane, called bagasse, is used in the manufacture of paper, cattle feed, and fuel; and new types of cane are being bred for low sugar and high fuel production.

Approximately 9 million hectares/22.25 million acres of beet, mostly in Europe, Russia, Ukraine, Georgia, Belarus, and Armenia, and 13 million hectares/32 million acres of cane, grown in tropical and subtropical countries, together produce 100 million tonnes of raw sugar each year. Cane usually yields over 20 tonnes of sugar per hectare/9 tons per acre per year; sugar beet rarely exceeds 7 tonnes per hectare/3 tons per acre per year.

Of the 100 sugar cane-producing countries, India and Brazil are the largest, with 3 million and 2.5 million hectares/7.5 million acres and 6 million acres respectively. In many smaller countries, such as Barbados and Mauritius, sugar production is a vital component of the national economy. However, subsidies given to European beet-sugar producers by the European Union have affected world markets and the export earnings of many sugar-producing countries in the developing world.

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sugar maple

eastern North American maple tree.

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sulphate

SO_4^{2-}

salt or ester derived from sulphuric acid. Most sulphates are water soluble (the chief exceptions are lead, calcium, strontium, and barium sulphates) and require a very high temperature to decompose them.

The commonest sulphates seen in the laboratory are copper(II) sulphate ($CuSO_4$), iron(II) sulphate ($FeSO_4$), and aluminium sulphate ($Al_2(SO_4)_3$). The ion is detected in solution by using barium chloride or barium nitrate to precipitate the insoluble barium sulphate.

sulphide

compound of sulphur and another element in which sulphur is the more electronegative element (see electronegativity). Sulphides occur in many minerals. Some of the more volatile sulphides have extremely unpleasant odours (hydrogen sulphide smells of bad eggs).

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sulphite

SO_3^{2-}

salt or ester derived from sulphurous acid.

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sulphonamide

any of a group of compounds containing the chemical group sulphonamide (SO_2NH_2) or its derivatives, which were, and still are in some cases, used to treat bacterial diseases. Sulphadiazine ($C_{10}H_{10}N_4O_2S$) is an example.

Sulphonamide was the first commercially available antibacterial drug, the forerunner of a range of similar drugs. Toxicity and increasing resistance have limited their use chiefly to the treatment of urinary-tract infection.

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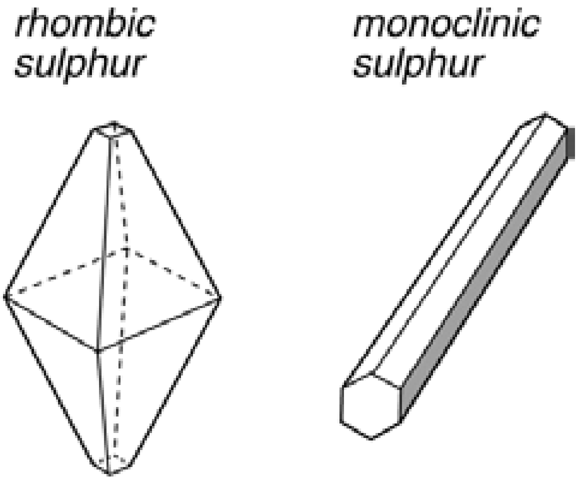
sulphur

chemical symbol S

brittle, pale-yellow, non-metallic element, atomic number 16, relative atomic mass 32.064. It occurs in three allotropic forms: two crystalline (called rhombic and monoclinic, following the arrangements of the atoms within the crystals) and one amorphous. It burns in air with a blue flame and a stifling odour. Insoluble in water but soluble in carbon disulphide, it is a good electrical insulator. Sulphur is widely used in the manufacture of sulphuric acid (used to treat phosphate rock to make fertilizers) and in making paper, matches, gunpowder and fireworks, in vulcanizing rubber, and in medicines and insecticides.

sulphur



(Image © Research Machines plc)

Two common allotropes of sulphur: rhombic and monoclinic crystals. A reactive element, sulphur combines with most other elements and has a wide range of industrial uses. It often occurs around hot springs and in volcanic regions, and there are large deposits in the USA (Texas and Louisiana), Japan, Sicily, and Mexico.

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sulphur dioxide

SO_2

pungent gas produced by burning sulphur or sulphide ores in air or oxygen. It is widely used for making sulphuric acid and for disinfecting food vessels and equipment for bleaching paper, and as a preservative in some food products. It occurs in industrial flue gases and is a major cause of acid rain.

Since the 1990s, most urban areas in Europe and North America have seen a reduction in sulphur dioxide concentrations, due to changes in fuel use.

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sulphuric acid

or oil of vitriol; H_2SO_4

dense, viscous, colourless liquid that is extremely corrosive. It gives out heat when added to water and can cause severe burns. Sulphuric acid is used extensively in the chemical industry, in the refining of petrol, and in the manufacture of fertilizers, detergents, explosives, and dyes. It forms the acid component of car batteries.

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sulphurous acid

H_2SO_3

solution of sulphur dioxide (SO_2) in water. It is a weak acid.

Sumner, James (Batcheller) (1887-1955)

US biochemist. Sumner shared the Nobel Prize for Chemistry in 1946 with John Northrop and Wendell Stanley for his work in 1926 when he succeeded in crystallizing the enzyme urease and demonstrating its protein nature.

He was born in Canton, Massachusetts. He spent his entire career at Cornell 1915-55.

Sun

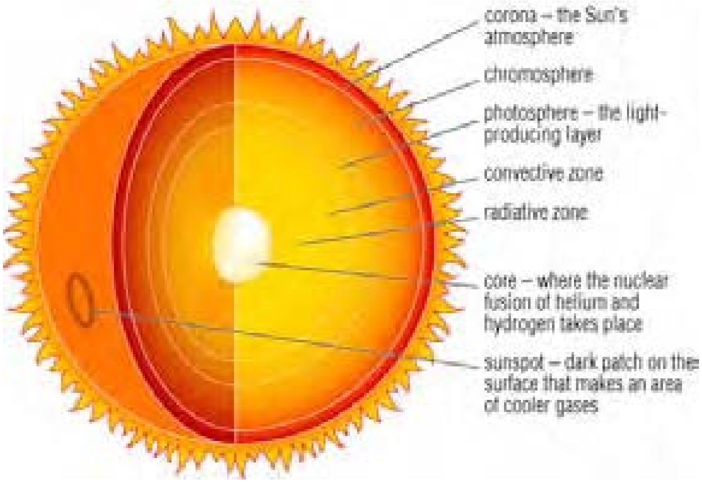
star at the centre of our Solar System. It is about 5 billion years old, with a predicted lifetime of 10 billion years; its diameter is 1.4 million km/865,000 mi; its temperature at the surface (the photosphere) is about 5,800 K/5,530°C/9,986°F, and at the centre 15 million K/about 15 million°C/about 27 million°F. It is composed of about 70% hydrogen and 30% helium, with other elements making up less than 1%. The Sun's energy is generated by nuclear fusion reactions that turn hydrogen into helium, producing large amounts of light and heat that sustain life on Earth.

Space probes to the Sun have included NASA's series of Orbiting Solar Observatory satellites, launched between 1963 and 1975, the Ulysses space probe, launched in 1990, and Genesis, launched in 2001. Since 1995 the Sun has been continuously observed by SOHO, a joint European-US satellite permanently stationed between the Earth and the Sun.

Sun

The further out from the Sun, the hotter it is: the Sun's corona is 1,994,000°C/3,589,000°F hotter than the Sun itself.

Sun


corona – the Sun's atmosphere
chromosphere
photosphere – the light-producing layer
convective zone
radiative zone
core – where the nuclear fusion of helium and hydrogen takes place
sunspot – dark patch on the surface that makes an area of cooler gases

(Image © Research Machines plc)

The structure of the Sun. Nuclear reactions at the core release vast amounts of energy in the form of light and heat that radiate out to the photosphere and corona. Surges of glowing gas rise as prominences from the surface of the Sun and cooler areas, known as sunspots, appear as dark patches on the star's surface.

Sun

Property	Amount
Diameter	1,392,000 km/865,000 mi
Temperature at the surface	approx. 5,800 K/5,530°C/9,986°F

Temperature at the centre	approx. 15 million K/15 million°C/27 million°F
Apparent magnitude	-26.9
Absolute magnitude	4.71
Surface gravity (Earth = 1)	27.9

SDAC

Go to site

Home page of the Solar Data Analysis Center at NASA's Goddard Space Flight Center. The site includes information about, and images of, the Sun, taken from space and also from ground-based observation posts. There are also numerous links to related pages.

Stanford Solar Centre

Go to site

Introduction to the Sun and its effect on the Earth, designed with school children in mind. The site contains information about the Sun's part in global-warming, as well as a quiz, solar art, and various folklore tales about the Sun.

Sun

Go to site

All you ever wanted to know about our closest star, including cross-sections, photographs, a history of exploration, animations of eclipses, and much more. The user can also take a multimedia tour of the Sun or find out what the weather is like on the Sun.

Sun

Go to site

Clear and concise information about the Sun. There are key facts and a summary of what we still have to learn about the Sun. The site features a very good resource list, with links to many other excellent Sun-related sites.

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sunburn

in medicine, skin damage caused by overexposure to sunlight.

Individuals with fair skin are particularly susceptible to the effects of sunlight due to the relative lack of melanin, a pigment that is made in certain cells in the skin. Skin reddening, due to dilation of blood vessels, occurs shortly after exposure to sunlight. This is followed by tanning as melanin production is stimulated. Overexposure to ultraviolet light, especially of medium wavelength (UVB), produces itching and tingling. Swelling of the superficial layer of the skin can be followed by blister formation and peeling. Headache and fever may also occur if sunburn is severe.

Exposure to the ultraviolet light produced by the sun results in thickening of the superficial layer of the skin and premature ageing. The longer wavelengths of ultraviolet light (UVA) are responsible for photosensitivity reactions and long-term damage to the skin. Prolonged exposure to the sun, especially in individuals with fair skin, is a risk factor in the development of skin cancers, including melanomas.

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sundew

any of a group of insectivorous plants found growing in bogs; sticky hairs on the leaves catch and digest insects that land on them. (Genus *Drosera*, family Droseraceae.)

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sundial

instrument measuring time by means of a shadow cast by the Sun. Almost completely superseded by the proliferation of clocks, it survives ornamentally in gardens and public spaces. The dial is marked with the hours at graduated distances, and a style or gnomon (parallel to Earth's axis and pointing north-south) casts the shadow.

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sunfish

any of various small members of the North American family (Centrarchidae) of freshwater bony fishes with compressed, almost circular bodies ranging from 6 in/15 cm to 12 in/30 cm and including bluegills, pumpkinseeds, rock bass, and crappies. The considerably larger basses also belong to this family. Ocean sunfishes of the family Molidae have disk-shaped, abruptly truncated bodies. The 10 ft/3 m species *Mola mola* is found worldwide.

sunflower

tall, thick-stemmed plant with a large, single, yellow-petalled flower, belonging to the daisy family. The common or giant sunflower (*H. annuus*), probably native to Mexico, can grow up to 4.5 m/15 ft high. It is commercially cultivated in central Europe, the USA, Russia, Ukraine, and Australia for the oil-bearing seeds that ripen in the central disc of the flower head; sunflower oil is widely used as a cooking oil and in margarine. (Genus *Helianthus*, family Compositae.)

sunflower

(Image © Corel)

Not just a pretty face, the sunflower provides edible seeds from which cooking oil and margarine are produced.

sunflower

(Image © Research Machines plc)

A field of sunflowers in the province of Córdoba, Andalusia, in Spain.

Growing Sunflowers

Go to site

Comprehensive guide to growing sunflowers, one of the easiest flowers to grow, and one of the most vibrant. The instructions include planting, germination, and soil considerations, and are accompanied by explanatory photographs.

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sungrebe

or finfoot

any one of several species of tropical waterbird in the family Heliornithidae. Sungrebes have an elongated body with a long neck and short legs with lobed toes. The bill is pointed and the plumage drab. They feed on fish, amphibians, invertebrates, seeds, and leaves.

Males are unique in that they carry the young in pouches of skin beneath their wings and are even able to fly with the chicks safely in place. The incubation period for the eggs is only 11 days.

sun protection factor

SPF

in medicine, the multiples of protection provided by sunscreens against burning compared with the unprotected skin.

Sunscreens are used to protect the skin from the harmful effects of excessive exposure to ultraviolet radiation. They should be applied regularly and most do not offer complete protection. Proprietary sunscreens are graded according to the degree of protection provided against medium wavelengths of ultraviolet radiation (UVB). Sunscreens do not prevent the long-term damage due to long wavelengths of ultraviolet radiation (UVA).

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sunshine recorder

device for recording the hours of sunlight during a day. The **Campbell-Stokes sunshine recorder** consists of a glass sphere that focuses the Sun's rays on a graduated paper strip. A track is burned along the strip corresponding to the time that the Sun is shining.

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sunspot

dark patch on the surface of the Sun, actually an area of cooler gas, thought to be caused by strong magnetic fields that block the outward flow of heat to the Sun's surface. Sunspots consist of a dark central **umbra**, about 4,000 K (3,700°C/6,700°F), and a lighter surrounding **penumbra**, about 5,500 K (5,200°C/9,400°F). They last from several days to over a month, ranging in size from 2,000 km/1,250 mi to groups stretching for over 100,000 km/62,000 mi.

Sunspots are more common during active periods in the Sun's magnetic cycle, when they are sometimes accompanied by nearby flares. The number of sunspots visible at a given time varies from none to over 100, in a cycle averaging 11 years. There was a lull in sunspot activity, known as the Maunder minimum, 1645-1715, that coincided with a cold spell in Europe. Various molecules, including water, have been detected in sunspots.

Sunspots

Go to site

Well-written and easily understandable explanation of sunspots. There is a high-resolution image of a group of sunspots and a link for further sunspot pictures. There is information on how to observe sunspots and the Sun's cycle of magnetic activity. For more detailed information, there are links to solar observatories.

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sunstroke

heatstroke caused by excessive exposure to the Sun.

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superactinide

any of a theoretical series of superheavy, radioactive elements, starting with atomic number 113, that extend beyond the transactinide series in the periodic table. They do not occur in nature and none has yet been synthesized.

It is postulated that this series has a group of elements that have half-lives longer than those of the transactinide series.

This group, centred on element 114, is referred to as the 'island of stability', based on the nucleon arrangement. The longer half-lives will, it is hoped, allow enough time for their chemical and physical properties to be studied when they have been synthesized.

---

superbug

popular name given to an infectious bacterium that has developed resistance to most or all known antibiotics. The widespread use of antibiotics, their release into the environment, and the carelessness of patients who do not complete a treatment course have all contributed to the dangerous spread of genes conferring antibiotic resistance to their carriers.

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a superbug that causes problems in many hospitals. Outbreaks of MRSA, which can cause temporary closure of operating rooms and intensive care units, have been met with vancomycin, a 'last resort' antibiotic normally reserved for life-threatening infections. But in the spring of 1997, Japanese doctors reported the most convincing evidence yet of the appearance of vancomycin-resistant strains.

In 1998 US researchers successfully synthesized vancomycin. This should also make it possible to synthesize altered versions of the drug with which to treat vancomycin-resistant bacteria. In 2000 the US Food and Drug Administration approved a new type of antibiotic to fight superbugs resistant to other treatments. The drug Zyvox has proved effective for bacteria which are resistant to vancomycin and methicillin. It works by halting bacteria from multiplying earlier than other antibiotics do by stopping the production of proteins needed for the bacteria's growth.

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supercluster

in astronomy, grouping of several clusters of galaxies to form a structure about 100–300 million light years across. Our own Galaxy and its neighbours in the Local Group lie on the edge of the Local Supercluster, of which the Virgo cluster is the dominant member.

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supercomputer

fastest, most powerful type of computer, with speeds measured in gigaflops (billions of floating-point calculations per second) or, at the high end, in teraflops (trillions of floating-point calculations per second).

To achieve these extraordinary speeds, supercomputers use many processors working together (often in clusters) and techniques such as cooling processors down to nearly absolute zero temperature, so that their components conduct electricity many times faster than normal. Supercomputers are used in weather forecasting, fluid dynamics, and aerodynamics. Manufacturers include Cray Research, Fujitsu, and NEC.

In November 2003, 248 of the world's 500 most powerful supercomputers were located in the USA, 33 in Japan, and 142 in Europe (of which 36 were in Germany and 33 in the UK). In 2004, the IBM-built 'BlueGene/L' became the world's fastest supercomputer, capable of a sustained operational performance of 70.72 teraflops.

TOP 500 Supercomputer Sites

Go to site

Regularly updated list of the top 500 supercomputers around the world. The computer type, manufacturer, country, and performance are given, as well as the broad area of use and a link to the organization using it.

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superconductivity

increase in electrical conductivity at low temperatures. The resistance of some metals and metallic compounds decreases uniformly with decreasing temperature until at a critical temperature (the superconducting point) the resistance suddenly falls to zero. The phenomenon was discovered, at temperatures within a few degrees of absolute zero (0 K/-273.15°C/-459.67°F), by Dutch scientist Heike Kamerlingh Onnes in 1911.

Some metals, such as platinum and copper, do not become superconductive; as the temperature decreases, their resistance decreases to a certain point but then rises again. Superconductivity can be nullified by the application of a large magnetic field. In the superconducting state, an electric current will continue indefinitely once started, provided that the material remains below the superconducting point. In 1986, IBM researchers achieved superconductivity with some ceramics at -243°C/-405°F, opening up the possibility of **'high-temperature' superconductivity**; a year later Paul Chu at the University of Houston, Texas, USA, achieved superconductivity at -179°C/-290°F, a temperature that can be sustained using liquid nitrogen. Researchers are trying to find a material that will be superconducting at room temperature; so far the highest temperature at which superconductivity has been produced is 138 K/-135°C/-211°F.

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supercooling

cooling of a liquid below its freezing point without freezing taking place; or the cooling of a saturated solution without crystallization taking place, to form a supersaturated solution. In both cases supercooling is possible because of the lack of solid particles around which crystals can form. Crystallization rapidly follows the introduction of a small crystal (seed) or agitation of the supercooled solution.

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superego

in Freudian psychology, the element of the human mind concerned with the ideal, responsible for ethics and self-imposed standards of behaviour. It is characterized as a form of conscience, restraining the ego, and responsible for feelings of guilt when the moral code is broken.

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superfluid

fluid that flows without viscosity or friction and has a very high thermal conductivity. Liquid helium at temperatures below 2 K (-271°C/-456°F) is a superfluid: it shows unexpected behaviour. For instance, it flows uphill in apparent defiance of gravity and, if placed in a container, will flow up the sides and escape.

German physicists discovered in 1998 that as few as 60 atoms will exhibit superfluidity.

superfluid

Spin a bowl of superfluid helium and the liquid inside it will remain stationary as the bowl itself spins.

supergiant

largest and most luminous type of star known, with a diameter of up to 1,000 times that of the Sun. Supergiants are likely to become supernovae.

superheterodyne receiver

the most widely used type of radio receiver, in which the incoming signal is mixed with a signal of fixed frequency generated within the receiver circuits. The resulting signal, called the intermediate-frequency (i.f.) signal, has a frequency between that of the incoming signal and the internal signal. The intermediate frequency is near the optimum frequency of the amplifier to which the i.f. signal is passed.

This arrangement ensures greater gain and selectivity. The superheterodyne system is also used in basic television receivers.

superior planet

planet that is farther away from the Sun than the Earth is: that is, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.

supernova

explosive death of a star, which temporarily attains a brightness of 100 million Suns or more, so that it can shine as brilliantly as a small galaxy for a few days or weeks. Very approximately, it is thought that a supernova explodes in a large galaxy about once every 100 years. Many supernovae - astronomers estimate some 50% - remain undetected because of obscuring by interstellar dust.

The name 'supernova' was coined in 1934 by Swiss Astronomer Fritz Zwicky and German-born US astronomer Walter Baade. Zwicky was also responsible for the division into types I and II.
Type I supernovae are thought to occur in binary star systems, in which gas from one star falls on to a white dwarf, causing it to explode.
Type II supernovae occur in stars ten or more times as massive as the Sun, which suffer runaway internal nuclear reactions at the ends of their lives, leading to explosions. These are thought to leave behind neutron stars and black holes. Gas ejected by such an explosion causes an expanding radio source, such as the Crab nebula. Supernovae are thought to be the main source of elements heavier than hydrogen and helium.

supernova remnant

SNR

in astronomy, glowing remains of a star that has been destroyed in a supernova explosion. The brightest and most famous example is the Crab nebula.

superphosphate

phosphate fertilizer made by treating apatite (calcium phosphate mineral) with sulphuric or phosphoric acid. The commercial mixture contains largely monocalcium phosphate. Single-superphosphate obtained from apatite and sulphuric acid contains 16-20% available phosphorus, as P_2O_5; triple-superphosphate, which contains 45-50% phosphorus, is made by treating apatite with phosphoric acid.

supersaturation

state of a solution that has a higher concentration of solute than would normally be obtained in a saturated solution.

Many solutes have a higher solubility at high temperatures. If a hot saturated solution is cooled slowly, sometimes the excess solute does not come out of solution. This is an unstable situation and the introduction of a small solid particle will encourage the release of excess solute.

supersonic speed

speed greater than that at which sound travels, measured in Mach numbers. In dry air at 0°C/32°F, sound travels at about 1,170 kph/727 mph, but its speed decreases with altitude until, at 12,000 m/39,000 ft, it is only 1,060 kph/658 mph.

When an aircraft passes the sound barrier, shock waves are built up that give rise to sonic boom, often heard at ground level. US pilot Captain Charles Yeager was the first to achieve supersonic flight, in a Bell VS-1 rocket plane on 14 October 1947.

Superstring Theory

in physics and astronomy, a theory that attempts to link the four fundamental forces. It postulates that each force emerged separately during the expansion of the very early universe from the Big Bang. It also postulates viewing matter as tiny vibrating strings instead of particles within a universe of more than the currently known four dimensions. Continuing research pursues a model based on a ten-dimensional universe. At the Big Bang, the ten dimensions split into two components, with four dimensions expanded into the current observable universe while the other six dimensions contracted to a point in space.

---

supersymmetry

in physics, a theory that relates the two classes of elementary particle, the fermions and the bosons. According to supersymmetry, each fermion particle has a boson partner particle, and vice versa. It has not been possible to marry up all the known fermions with the known bosons, and so the theory postulates the existence of other, as yet undiscovered fermions, such as the photinos (partners of the photons), gluinos (partners of the gluons), and gravitinos (partners of the gravitons). Using these ideas, it has become possible to develop a theory of gravity – called **supergravity** – that extends Einstein's work and considers the gravitational, nuclear, and electromagnetic forces to be manifestations of an underlying superforce. Supersymmetry has been incorporated into the superstring theory, and appears to be a crucial ingredient in the 'theory of everything' sought by scientists.

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support environment

in computing, a collection of programs (software) used to help people design and write other programs. At its simplest, this includes a text editor (word-processing software) and a compiler for translating programs into executable form; but it can also include interactive debuggers for helping to locate faults, data dictionaries for keeping track of the data used, and rapid prototyping tools for producing quick, experimental mock-ups of programs. Support environments are sometimes referred to as Integrated Development Environments (IDEs). Common examples are Microsoft Visual Studio (for C++, C#, and Java) and Microfocus (for COBOL).

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suprarenal gland

alternative name for the adrenal gland.

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surd

in mathematics, expression containing the root of an irrational number that can never be exactly expressed – for example, $\sqrt{3} = 1.732050808...$.

$\sqrt{3}$ can be expressed in index notation as $3^{1/2}$ or 3 to the power half.

simplifying surds (roots)

Expressions involving surds can be factorized numerically to simplify them. For example, to simplify $\sqrt{20} + \sqrt{5}$:

$\sqrt{20} = \sqrt{(4 \times 5)} = \sqrt{4} \times \sqrt{5} = 2\sqrt{5}$, so

$\sqrt{20} + \sqrt{5} = 2\sqrt{5} + \sqrt{5} = 3\sqrt{5}$

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surface-area-to-volume ratio

in biology, the ratio of an animal's surface area (the area covered by its skin) to its total volume. This is high for small animals, but low for large animals such as elephants.

The ratio is important for endothermic (warm-blooded) animals because the amount of heat lost by the body is proportional to its surface area, whereas the amount generated is proportional to its volume. Very small birds and mammals, such as hummingbirds and shrews, lose a lot of heat and need a high intake of food to maintain their body temperature. Elephants, on the other hand, are in danger of overheating, which is why they have no fur.

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surface tension

property that causes the surface of a liquid to behave as if it were covered with a weak elastic skin; this is why a needle can float on water. It is caused by the exposed surface's tendency to contract to the smallest possible area because of cohesive forces between molecules at the surface. Allied phenomena include the formation of droplets, the concave profile of a meniscus, and the capillary action by which water soaks into a sponge.

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surfactant

contraction of surface-active agent

substance added to a liquid in order to increase its wetting or spreading properties. Detergents are surfactants.

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surge

abnormally high tide; see storm surge.

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surgeon fish

any fish of the tropical marine family Acanthuridae. It has a flat body up to 50 cm/20 in long, is brightly coloured, and has a movable spine on each side of the tail that can be used as a weapon.

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surgery

branch of medicine concerned with the treatment of disease, abnormality, or injury by operation. Traditionally it has been performed by means of cutting instruments, but today a number of technologies are used to treat or remove lesions, including ultrasonic waves and laser surgery.

Surgery is carried out under sterile conditions using an anaesthetic. There are many specialized fields, including cardiac (heart), orthopaedic (bones and joints), ophthalmic (eye), neuro (brain and nerves), thoracic (chest), and renal (kidney) surgery; other specialities include plastic and reconstructive surgery, and transplant surgery.

Historically, surgery for abscesses, amputation, dental problems, trepanning, and childbirth was practised by the ancient civilizations of both the Old World and the New World.

During the Middle Ages, Arabic surgeons passed the techniques of Islamic medicine on to Europe, where, during the Renaissance, anatomy and physiology were pursued.

Great advances in the practice of surgery were made in 19th-century medicine, although, conservatism hindered the adoption of new techniques and ideas; the Hungarian obstetrics assistant Ignaz Semmelweis, who promoted hand-washing in chlorinated lime to prevent cross-infection, was forced to resign for trying to enforce this method of asepsis (clinical hygiene), although mortality on his wards had fallen dramatically.

Anaesthetics were pioneered in the mid-19th century: the use of ether was used for amputations by the Scottish surgeon Robert Liston, and chloroform was introduced in 1847 by Scottish obstetrician James Simpson. Eminent surgeons such as John Snow and James Syme championed the adoption of anaesthetics, and Snow became the first specialist anaesthetist, administering chloroform to Queen Victoria during the birth of Prince Leopold in 1853.

In the second half of the 19th century Joseph Lister's discovery of antiseptics, championed by such surgeons as William Cheyne, became the basis for successful surgical practice. Other notable 19th-century surgeons include Johann Dieffenbach, who pioneered plastic surgery in Berlin, Germany. The discovery of antibiotics and effective methods of blood transfusion in the first half of the 20th century made surgery safer and more effective.

Some early operations, such as thoracoplasty (causing partial collapse of a lung) for tuberculosis, have been replaced by other treatments. Also, the need for exploratory surgery has been reduced by the introduction of noninvasive imaging techniques, such as ultrasound and CAT scans (computed axial tomography scans). The practice of endoscopy (examination of the interior of the body by direct viewing) has enabled the development of minimally invasive keyhole surgery.

surgery

(Image © Research Machines plc)

A patient undergoing coronary artery surgery. The chest has been opened and the heart exposed. A heart-lung machine will take over the vital job of circulating oxygenated blood to the body while the heart is temporarily stopped. During this period, blockages in the coronary arteries will be bypassed using sections of vein taken from the patient's legs.

surgery

(Image © Research Machines plc)

Sir Magdi Yacoub, pioneering surgeon who introduced many innovations in heart and heart-lung transplantation. Born in Cairo in 1935 and trained in Egypt and Britain, Magdi Yacoub has been British Heart Foundation Professor of Cardiothoracic Surgery at the National Heart and Lung Institute, Royal Brompton Hospital, London, since 1986.

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surgical spirit

ethanol to which has been added a small amount of methanol to render it unfit to drink. It is used to sterilize surfaces and to cleanse skin abrasions and sores.

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surrogacy

practice whereby a woman is sought, and usually paid, to bear a child for an infertile couple or a single parent.

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surveying

accurate measuring of the Earth's crust, or of land features or buildings. It is used to establish boundaries, and to evaluate the topography for engineering work. The measurements used are both linear and angular, and geometry and trigonometry are applied in the calculations.

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suslik

small Eurasian ground squirrel*Citellus citellus*.

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suspension

mixture consisting of small solid particles dispersed in a liquid or gas, which will settle on standing. An example is milk of magnesia, which is a suspension of magnesium hydroxide in water.

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suspensory ligament

in the eye, a ring of fibre supporting the lens. The ligaments attach to the ciliary muscles, the circle of muscle mainly responsible for changing the shape of the lens during accommodation. If the ligaments are put under tension, the lens becomes flatter, and therefore able to focus on objects in the far distance.

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sustainable

capable of being continued indefinitely. For example, the sustainable yield of a forest is equivalent to the amount that grows back. Environmentalists made the term a catchword, in advocating the sustainable use of resources.

Animal Info - Information on Rare, Threatened, and Endangered Animals

Go to site

Fascinating, text-only profiles of the world's rarest mammals, some of whose populations, such as that of the northern hairy-nosed wombat, have fallen below three figures. The user can find information on specific animals in the individual species index or browse the species group index.

Center of Excellence for Sustainable Development: Introduction

Go to site

Helpful introduction to the concept of sustainable development. This US site provides common definitions and principles associated with sustainable development, 'success stories' detailing successful projects in the USA, and links to further resources.

Sustainable Architecture: Eco Design and Landscaping

Go to site

This site is an archive of information about sustainable architecture, which includes ecological planning, design, integrated architecture, landscaping for tropical, sub-tropical, or temperate climates, and there is an introduction to sustainable development theory. There are tips on conservation of resources and renewable energy, and information on how to build efficient, livable housing by applying the techniques of sustainable architecture. There is also a list of resources for further research.

Sustainable Development

Go to site

Complex issue tackled from many different points of view. There are sections on trade and key topics such as forests and oceans. The site also reports on global initiatives to encourage sustainability. One of the major advantages of this site, however, is that it makes this issue easy to understand for beginners through its 'Contents and principles' section.

View of a Sustainable World

Go to site

Part of an electronic teacher's guide 'Teaching for a Sustainable World: International Edition', this site also contains useful information for individual students.

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sustained-yield cropping

in ecology, the removal of surplus individuals from a population of organisms so that the population maintains a constant size. This usually requires selective removal of animals of all ages and both sexes to ensure a balanced population structure. Taking too many individuals can result in a population decline, as in overfishing.

Excessive cropping of young females may lead to fewer births in following years, and a fall in population size. Appropriate cropping frequencies can be determined from an analysis of a life table.

Sutherland, Earl Wilbur, Jr (1915-1974)

US physiologist who was awarded a Nobel Prize for Physiology or Medicine in 1971 for his discovery of cyclic AMP, a chemical messenger that plays a role in the action of many hormones.

suture

any thread or wire used in surgery to stitch together the edges of a wound or incision. Also, the stitch itself.

Sv

in physics, symbol for sievert, the SI unit of dose equivalent of ionizing radiation, equal to the dose in grays multiplied by a factor that depends mainly on the type of radiation and its effects.

Svedberg, Theodor (1884-1971)

Swedish chemist. In 1923 he constructed the first ultracentrifuge, a machine that allowed the rapid separation of particles by mass. This can reveal the presence of contaminants in a sample of a new protein, or distinguish between various long-chain polymers. He was awarded the Nobel Prize for Chemistry in 1926 for his investigation of dispersed systems.

swallow

any bird of the family Hirundinidae of small, insect-eating birds in the order Passeriformes, with long, narrow wings, and deeply forked tails. Swallows feed while flying, capturing winged insects in the mouth, which is lined with bristles made viscid (sticky) by a salivary secretion.

swallow: fleas

Most birds have fleas; there are 17 species of flea found only on swallows and martins.

swallow: nestbuilding

A swallow will make up to 1,200 trips to gather mud to build its nest.

swamp

region of low-lying land that is permanently saturated with water and usually overgrown with vegetation; for example, the everglades of Florida, USA. A swamp often occurs where a lake has filled up with sediment and plant material. The flat surface so formed means that run-off is slow, and the water table is always close to the surface. The high humus content of swamp soil means that good agricultural soil can be obtained by draining.

swan

large water bird, with a long slender neck and webbed feet, closely related to ducks and geese. The four species of swan found in the northern hemisphere are white; the three species found in the southern hemisphere are all or partly black. The male (cob) and female (pen) are similar in appearance, and they usually pair for life. They nest on or near water in every continent, except Africa and Antarctica. Swans produce a clutch of 4-6 greenish coloured eggs and their young are known as cygnets. Cygnets are covered with a grey down and only become fully feathered and able to fly after 14-16 weeks.

Swans feed mainly on aquatic plants. They are among the largest and heaviest birds that can fly and because of this require large areas of water to take off. They fly with a slow, graceful wing beat and when migrating, fly in a distinctive V-shaped flock.

In England the swan is a royal bird, as it was once highly valued as food. On the Thames, at the annual 'swan-upping', the cygnets are still marked on the beak as either the property of the crown or of the two privileged City of London companies, the Dyers and Vintners.

The **mute swan** is the most common species. It is native to northern Europe and Asia, but has been introduced and is now widespread in North America. The mute swan has white feathers, black legs and a bright orange flattened bill with a black knob on the upper bill, near the eyes. It may be as long as 150 cm/5 ft in length and weigh as much as 14 kg/30 lb. It hisses loudly when angry.

classification

Swans belong to animal phylum Chordata, class Aves (birds), order Anseriformes, family Anatidae. They belong to the genus *Cygnus*. There are seven species: the mute swan (*Cygnus olor*), the whooper swan (*C. cygnus*), Bewick's swan (*C. bewicki*), the tundra (whistling) swan (*C. columbianus*), the North American trumpeter swan (*C. buccinator*), the black swan of Australia (*C. atratus*), and the South American black-necked swan (*C. melanocoryphus*). The North American trumpeter swan is the largest, with a wingspan of 2.4 m/8 ft.

swan

(Image © Research Machines plc)

A family of mute swans with their young, photographed on a backwater of the River Cam in Cambridge. Swans can expect to produce between four and six cygnets each year.

S-wave

abbreviation of secondary wave

in seismology, a class of seismic wave that passes through the Earth in the form of transverse shear waves. S-waves from an earthquake travel at roughly half the speed of P-waves (about 3 kps/1.9 mps), the speed depending on the density of the rock, and arrive later at monitoring stations (hence secondary waves) though with greater amplitude. They can travel through solid rock but not through the liquid outer core of the Earth. Rocks move perpendicular (at right angles) to the direction of travel of the wave, and as such an S-wave is an example of a transverse wave.

sweat gland

gland within the skin of mammals that produces surface perspiration. In primates, sweat glands are distributed over the whole body, but in most other mammals they are more localized; for example, in cats and dogs they are restricted to the feet and around the face.

sweet cicely

plant belonging to the carrot family, native to southern Europe; the root is eaten as a vegetable, and the aniseed-flavoured leaves are used in salads. (*Myrrhis odorata*, family Umbelliferae.)

sweetener

any chemical that gives sweetness to food. Caloric sweeteners are various forms of sugar; noncaloric, or artificial, sweeteners are used by dieters and diabetics and provide neither energy nor bulk. Questions have been raised about the long-term health effects from several artificial sweeteners.

Sweeteners are used to make highly processed foods attractive, whether sweet or savoury. Most of the noncaloric sweeteners do not have E numbers. Some are banned for baby foods and for young children: thaumatin, aspartame, acesulfame-K, sorbitol, and mannitol. Cyclamate is banned in the UK and the USA; acesulfame-K is banned in the USA.

In 1997, Japanese geneticists engineered a strain of yeast that produces a protein, called monellin, which is 3,000 times as sweet as sugar and 15 times sweeter than aspartame. Monellin occurs naturally in the berries of a West African plant, *Dioscoreophyllum cumminisii* and, as a protein, it contains only 4 kilocalories per gram.

sweet pea

plant belonging to the pea family.

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sweet potato

tropical American plant belonging to the morning-glory family; the white-orange tuberous root is used as a source of starch and alcohol and eaten as a vegetable. (*Ipomoea batatas*, family Convolvulaceae.)

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sweet william

biennial to perennial plant belonging to the pink family, native to southern Europe. It is grown for its fragrant red, white, and pink flowers. (*Dianthus barbatus*, family Caryophyllaceae.)

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swift

fast-flying, short-legged bird of the family Apodidae, order Apodiformes, of which there are about 75 species, found largely in the tropics. They are 9-23 cm/4-11 in long, with brown or grey plumage, long, pointed wings, and usually a forked tail. They are capable of flying at 110 kph/70 mph.

The nests of the **grey-rumped swiftlet** *Collocalia francica* of Borneo consist almost entirely of solidified saliva, and are harvested for bird's-nest soup. The increasing removal of nests for commercial purposes is endangering the birds.

swift

The Chinese delicacy of bird's nest soup is in fact a bowl of coagulated swiftlet saliva. Asian cave swiftlets make their tiny cup-shaped nests from layer upon layer of their quick drying saliva.

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swim bladder

thin-walled, air-filled sac found between the gut and the spine in bony fishes. Air enters the bladder from the gut or from surrounding capillaries (see capillary), and changes of air pressure within the bladder maintain buoyancy whatever the water depth.

In evolutionary terms, the swim bladder of higher fishes is a derivative of the lungs present in all primitive fishes (not just lungfishes).

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swine flu

virulent, highly contagious form of influenza, infecting pigs and communicable to people.

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swine vesicular disease

virus disease (porcine enterovirus) closely resembling foot and mouth disease, and communicable to humans. It may have originated in the infection of pigs by a virus that causes flulike symptoms in people.

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swing wing

common name for variable-geometry wing

aircraft wing that can be moved during flight to provide a suitable configuration for either low-speed or high-speed flight. The British engineer Barnes Wallis developed the idea of the swing wing, first used on the US-built Northrop X-4, and since used in several aircraft, including the US F-111, F-114, and the B-1, the European Tornado, and several Soviet-built aircraft.

These craft have their wings projecting nearly at right angles for takeoff and landing and low-speed flight, and swung back for high-speed flight.

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swordfish

marine bony fish *Xiphias gladius*, the only member of its family (Xiphiidae), characterized by a long swordlike beak protruding from the upper jaw. It may reach 4.5 m/15 ft in length and weigh 450 kg/1,000 lb.

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sycamore

or plane tree

any of several Eurasian trees of the genus *Platanus* of the family Plantanaceae. Species include the oriental plane tree *P. orientalis*, a favorite of the Greeks and Romans; the American sycamore *P. occidentalis* of the eastern USA; and the Arizona sycamore *P. wrightii*.

All species have pendulous burlike fruits and some grow to 100 ft/30 m high.

Sydenham, Thomas (1624-1689)

English physician, the first person to describe measles and to recommend the use of quinine for relieving symptoms of malaria. His original reputation as the 'English Hippocrates' rested upon his belief that careful observation is more useful than speculation. His *Observationes medicae* was published in 1676.

syenite

grey, crystalline, plutonic (intrusive) igneous rock, consisting of feldspar and hornblende; other minerals may also be present, including small amounts of quartz.

symbiosis

any close relationship between two organisms of different species, and one where both partners benefit from the association. A well-known example is the pollination relationship between insects and flowers, where the insects feed on nectar and carry pollen from one flower to another. This is sometimes known as mutualism.

symbolic address

in computing, a symbol used in assembly language programming to represent the binary address of a memory location.

symbolic processor

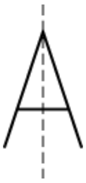
computer purpose-built to run so-called symbol-manipulation programs rather than programs involving a great deal of numerical computation. They exist principally for the artificial intelligence language LISP, although some have also been built to run PROLOG.

symmetry

exact likeness in shape about a given line (axis), point, or plane. A figure has symmetry if one half can be rotated and/or reflected onto the other. (Symmetry preserves length, angle, but not necessarily orientation.) In a wider sense, symmetry exists if a change in the system leaves the essential features of the system unchanged; for example, reversing the sign of electric charges does not change the electrical behaviour of an arrangement of charges.

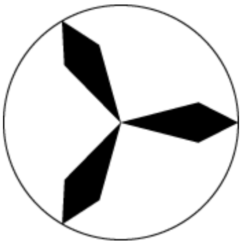
line symmetry

In the diagram, the letter A has one **line of symmetry**, or mirror line, shown by the dotted line. This is the line of reflection:



rotational symmetry

The diagram shows that the shape may be rotated about O into three identical positions. It has rotational symmetry of order three:



Transformation of shapes can also take place by translation, rotation, reflection, and enlargement.

sympathetic nervous system

in medicine, a division of the autonomic nervous system.

symptom

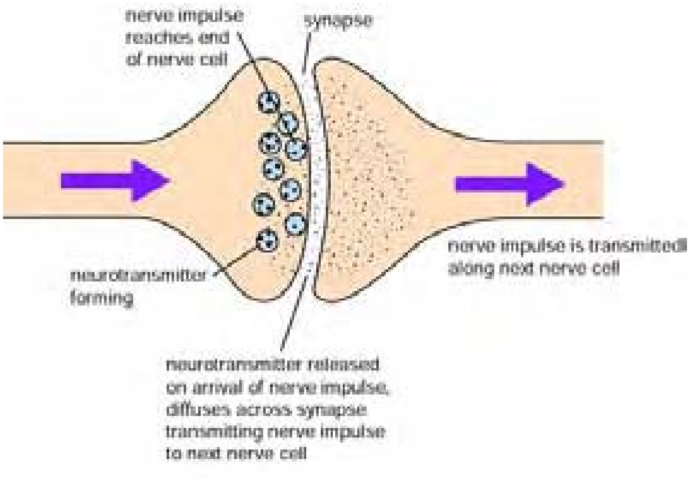
any change or manifestation in the body suggestive of disease as perceived by the sufferer. Symptoms are subjective phenomena. In strict usage, **symptoms** are events or changes reported by the patient; **signs** are noted by the doctor during the patient's examination.

synapse

junction between two nerve cells, or between a nerve cell and a muscle (a neuromuscular junction), across which a nerve impulse is transmitted. The two cells are separated by a narrow gap called the **synaptic cleft**. The gap is bridged by a chemical neurotransmitter, released by the nerve impulse.

The threadlike extension, or axon, of the transmitting nerve cell has a slightly swollen terminal point, the **synaptic knob**. This forms one half of the synaptic junction and houses membrane-bound vesicles, which contain a chemical neurotransmitter. When nerve impulses reach the knob, the vesicles release the transmitter and this flows across the gap and binds itself to special receptors on the receiving cell's membrane. If the receiving cell is a nerve cell, the other half of the synaptic junction will be one or more extensions called dendrites; these will be stimulated by the neurotransmitter to set up an impulse, which will then be conducted along the length of the nerve cell and on to its own axons. If the receiving cell is a muscle cell, it will be stimulated by the neurotransmitter to contract.

synapse


nerve impulse reaches end of nerve cell
synapse
neurotransmitter forming
nerve impulse is transmitted along next nerve cell
neurotransmitter released on arrival of nerve impulse, diffuses across synapse transmitting nerve impulse to next nerve cell

(Image © Research Machines plc)

How the nerve impulse is transmitted across the synapse. When the impulse reaches the end of the nerve cell, neurotransmitter is released. This diffuses across the synapse to the next nerve cell, which then continues to transmit the impulse.

Synapsida

group of mammal-like reptiles living 315-195 million years ago, whose fossil record is largely complete, and who were for a while the dominant land animals, before being replaced by the dinosaurs. The true mammals are their descendants.

synchronous orbit

another term for geostationary orbit.

synchronous rotation

in astronomy, another name for captured rotation.

synchrotron

particle accelerator in which particles move, at increasing speed, around a hollow ring. The particles are guided around the ring by electromagnets, and accelerated by electric fields at points around the ring. Synchrotrons come in a wide range of sizes, the smallest being about 1 m/3.3 ft across while the largest, the Large Hadron Collider, is 27 km/17 mi in circumference. The Tevatron synchrotron at Fermilab is some 6 km/4 mi in circumference and accelerates protons and antiprotons to 1 TeV.

The European Synchrotron Radiation Facility (ESRF) opened in Grenoble, France, in September 1994, funded by £400 million from 12 European countries.

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syncline

geological term for a fold in the rocks of the Earth's crust in which the layers or beds dip inwards, thus forming a trough-like structure with a sag in the middle. The opposite structure, with the beds arching upwards, is an anticline.

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syncope

medical term for any temporary loss of consciousness, as in fainting.

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syndrome

in medicine, a set of signs and symptoms that always occur together, thus characterizing a particular condition or disorder.

---

synergy

in medicine, the 'cooperative' action of two or more drugs, muscles, or organs; applied especially to drugs whose combined action is more powerful than their simple effects added together.

Synge, Richard Laurence Millington (1914-1994)

British biochemist who improved paper chromatography (a means of separating mixtures) to the point where individual amino acids could be identified. He shared the Nobel Prize for Chemistry in 1952 with his colleague Archer Martin for the development in 1944 of the technique known as partition chromatography.

Martin and Synge worked together at Cambridge and at the Wool Industries Research Association in Leeds, Yorkshire. Their chromatographic method became an immediate success, widely adopted. It was soon demonstrated that not only the type but the concentration of each amino acid can be determined.

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synodic period

time taken for a planet or moon to return to the same position in its orbit as seen from the Earth; that is, from one opposition to the next. It differs from the sidereal period because the Earth is moving in orbit around the Sun.

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synovial fluid

viscous colourless fluid that bathes movable joints between the bones of vertebrates. It nourishes and lubricates the cartilage at the end of each bone.

Synovial fluid is secreted by a membrane, the synovium, that links movably jointed bones. The same kind of fluid is found in bursae, the membranous sacs that buffer some joints, such as in the shoulder and hip region.

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synovitis

inflammation of the membranous lining of a joint, or of a tendon sheath, caused by injury or infection.

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synthesis

in chemistry, the formation of a substance or compound from more elementary compounds. The synthesis of a drug can involve several stages from the initial material to the final product; the complexity of these stages is a major factor in the cost of production.

synthetic

any material made from chemicals. Since the 1900s, more and more of the materials used in everyday life are synthetics, including plastics (polythene, polystyrene), synthetic fibres (nylon, acrylics, polyesters), synthetic resins, and synthetic rubber. Most naturally occurring organic substances can now be made synthetically, especially pharmaceuticals.

synthetic fibre

fibre made by chemical processes, unknown in nature. There are two kinds. One, a regenerated synthetic fibre, is made from natural materials that have been chemically processed in some way; rayon, for example, is made by processing the cellulose in wood pulp. The other type is the true synthetic fibre, made entirely from chemicals. Nylon was the original true synthetic fibre, made from chemicals obtained from petroleum (crude oil).

Fibres are drawn out into long threads or filaments, usually by so-called spinning methods, melting or dissolving the parent material and then forcing it through the holes of a perforated plate, or spinneret.

Textiles Online

Go to site

Flash-based site dedicated to providing textile information. This colourful page has seven sections: 'Activity centre', 'Recycling', 'Future', 'Environment', 'Sustainability', 'Library', and 'Design'. Clicking on any of the sections brings up a page with detailed information about a specific area of textiles.

syphilis

sexually transmitted disease caused by the spiral-shaped bacterium (spirochete) *Treponema pallidum*. Untreated, it runs its course in three stages over many years, often starting with a painless hard sore, or chancre, developing within a month on the area of infection (usually the genitals). The second stage, months later, is a rash with arthritis, hepatitis, and/or meningitis. The third stage, years later, leads eventually to paralysis, blindness, insanity, and death. The Wassermann test is a diagnostic blood test for syphilis.

With widespread availability of antibiotics, syphilis is now increasingly treatable in the industrialized world, at least to the extent that the final stage of the disease is rare. The risk remains that the disease may go undiagnosed or that it may be transmitted by a pregnant woman to her fetus.

syphilis

Undergarments with a mercury coating were sometimes worn as a precautionary measure to protect the wearer against syphilis in 17th-century Italy.

Childhood Infections - Syphilis

Go to site

Useful information about syphilis. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection, how it can be treated both at home and professionally, and what to do should the symptoms occur.

syringa

common, but not technically accurate, name for the mock orange. The genus *Syringa* includes lilacs, and is not related to the mock orange.

syrinx

voice-producing organ of a bird. It is situated where the trachea divides in two and consists of vibrating membranes, a reverberating capsule, and numerous controlling muscles.

Système International d'Unités

official French name for SI units.

systemic

in medicine, relating to or affecting the body as a whole. A systemic disease is one where the effects are present throughout the body, as opposed to local disease, such as conjunctivitis, which is confined to one part.

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systems analysis

in computing, the investigation of a business activity or clerical procedure, with a view to deciding if and how it can be computerized. The analyst discusses the existing procedures with the people involved, observes the flow of data through the business, and draws up an outline specification of the required computer system. The next step is systems design. A recent system is Unified Modeling Language (UML), which is specifically designed for the analysis and design of object-oriented programming systems.

Systems analysis and design methodologies currently in use include Yourdon, SSADM (Structured Systems Analysis and Design Methodology), and Soft Systems Methodology.

Systems Analysis Interesting Web Sites List

Go to site

Systems analysis at the University of Missouri, St Louis. This collection of readings in systems analysis and software design was assembled to assist students but the notes are well presented and generally accessible and so of use to anyone with an interest in the field.

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systems design

in computing, the detailed design of an applications package. The designer breaks the system down into component programs, and designs the required input forms, screen layouts, and printouts. Systems design forms a link between systems analysis and programming.

Systems are a series of blocks fitted together in a logical sequence. All systems have an input where information is put into a system, a process where the information is altered, and an output which communicates with the outside world. There are many different types of systems, including computer systems, mechanical systems, and electronic systems.

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systems program

in computing, a program that performs a task related to the operation and performance of the computer system itself. For example, a systems program might control the operation of the display screen, or control and organize backing storage. In contrast, an applications program is designed to carry out tasks for the benefit of the computer user.

System X

in communications, a modular, computer-controlled, digital switching system used in telephone exchanges.

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systole

in biology, the contraction of the heart. It alternates with diastole, the resting phase of the heart beat.

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systolic pressure

in medicine, the measurement due to the pressure of blood against the arterial wall during systole (the contraction of the heart). It is the highest blood pressure during the cardiac cycle.

The average systolic blood pressure in young adults is 120 mmHg. It increases with age as the arteries get thicker and harder and it may rise to more than 200 mmHg in people with untreated hypertension (high blood pressure).

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syzygy

in astronomy, alignment of three celestial bodies, usually the Sun, Earth, and Moon or the Sun, Earth, and another planet. A syzygy involving the Sun, Earth, and Moon usually occurs during solar and lunar eclipses.

The term also refers to the Moon or another planet when it is in conjunction or opposition.

Szent-Györgyi, Albert von Nagyrapolt (1893-1986)

Hungarian-born US biochemist who was awarded the Nobel Prize for Physiology or Medicine in 1937 for his investigation of biological oxidation processes and of the action of ascorbic acid (vitamin C).

In 1928 Szent-Györgyi isolated a substance from the adrenal glands that he named hexuronic acid; he also found it in oranges and paprika, and in 1932 proved it to be vitamin C.

Szent-Györgyi also studied the uptake of oxygen by muscle tissue. In 1940 he isolated two kinds of muscle protein, actin and myosin, and named the combined compound actinomyosin. When adenosine triphosphate (ATP) is added to it, a change takes place in the relationship of the two components which results in the contraction of the muscle. When a muscle contracts, myosin and actin move in relation to one another powered by energy released by hydrolysis of ATP and elevated levels of calcium in the muscle cells.

In the 1960s Szent-Györgyi began studying the thymus gland, and isolated several compounds from the thymus that seem to be involved in the control of growth.

T

in physics, symbol for tesla, the SI unit of magnetic flux density, equal to a flux density of one weber of flux per square metre.

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tablet

in medicine, preparation containing drugs and inert substances that is compressed to form a disc with flat or convex surfaces. Tablets enable accurate doses of drugs to be given and they are a convenient form of medication for the patient to take.

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tachograph

combined speedometer and clock that records a vehicle's speed and the length of time the vehicle is moving or stationary. It is used to monitor a lorry driver's working hours.

Tagliacozzi, Gaspare (1546-1599)

Italian surgeon who pioneered plastic surgery. He was the first to repair noses lost in duels or through syphilis. He also repaired ears. His method involved taking flaps of skin from the arm and grafting them into place.

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taiga

or boreal forest

Russian name for the forest zone south of the tundra, found across the northern hemisphere. Here, dense forests of conifers (spruces and hemlocks), birches, and poplars occupy glaciated regions punctuated with cold lakes, streams, bogs, and marshes. Winters are prolonged and very cold, but the summer is warm enough to promote dense growth.

The varied fauna and flora are in delicate balance because the conditions of life are so precarious. This ecology is threatened by mining, forestry, and pipeline construction.

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taipan

species of small-headed cobra *Oxyuranus scutellatus*, found in northeastern Australia and New Guinea. It is about 3 m/10 ft long, and has a brown back and yellow belly. Its venom is fatal within minutes.

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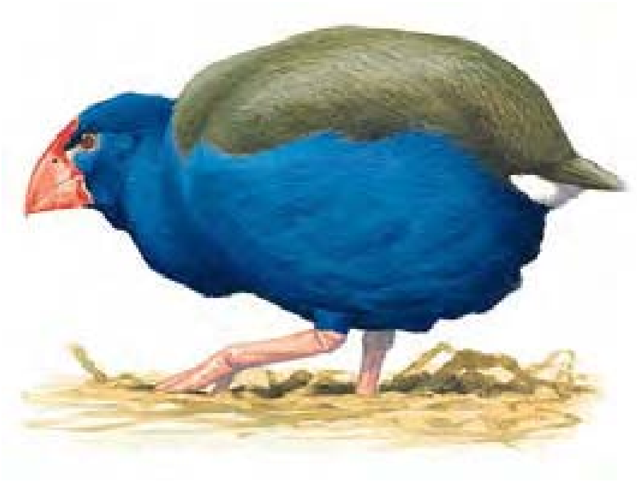
takahe

flightless bird *Porphyrio mantelli* of the rail family, order Gruiformes, native to New Zealand. It is about 60 cm/2 ft tall and weighs just over 2 kg/4.4 lb, with blue and green plumage and a red bill. The takahe was thought to have become extinct at the end of the 19th century, but in 1948 small numbers were rediscovered in the tussock grass of a mountain valley on South Island.

takahe



(Image © Research Machines plc)

The takahe, native to New Zealand, was once thought to be extinct, but now its habitat is protected and numbers are gradually increasing. In 1995 there were approximately 180 birds.

Talbot, William Henry Fox (1800-1877)

English pioneer of photography. He invented the paper-based calotype process, patented in 1841, which was the first negative/positive method. Talbot made photograms several years before Louis Daguerre's invention was announced.

Fox Talbot Museum

Go to site

Site of the museum dedicated to the memory of the multi-talented pioneer of photography. A biography of Talbot is accompanied by photos. There is information of exhibitions and the museum's photo collection.

talc

$Mg_3Si_4O_{10}(OH)_2$

mineral, hydrous magnesium silicate. It occurs in tabular crystals, but the massive impure form, known as **steatite** or **soapstone**, is more common. It is formed by the alteration of magnesium compounds and is usually found in metamorphic rocks. Talc is very soft, ranked 1 on the Mohs scale of hardness. It is used in powdered form in cosmetics, lubricants, and as an additive in paper manufacture.

French chalk and potstone are varieties of talc. Soapstone has a greasy feel to it, and is used for carvings such as Inuit sculptures.

Talgai skull

cranium of a pre-adult male, dating from 10,000-20,000 years ago, found at Talgai station, southern Queensland, Australia. It was one of the earliest human archaeological finds in Australia, having been made in 1886. Its significance was not realized, however, until the work of Edgeworth David and others after 1914. The skull is large with heavy eyebrow ridges and cheekbones.

talus

pile of rubble and sediment that forms an ascending slope at the foot of a mountain range or cliff.

The rock fragments that form a talus are usually slide rock or pieces broken off by frost action. As fragments are loosened they clatter downward in a series of free falls, bounces, and slides. With time, the rock waste builds in a heap or sheet of rubble that may eventually bury even the upper cliffs, and the growth of the talus then stops. Usually, however, erosional forces decompose the rock waste so that a talus stays restricted to lower slopes.

tamandua

tree-living toothless anteater *Tamandua tetradactyla* found in tropical forests and tree savannah from southern Mexico to Brazil. About 56 cm/1.8 ft long with a prehensile tail of equal length, it uses its strong foreclaws to break into nests of tree ants and termites, which it licks up with its narrow tongue.

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tamarack

coniferous tree native to boggy soils in North America, where it is used for timber. It is a type of larch. (*Larix laricina*, family Pinaceae.)

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tamarind

evergreen tropical tree native to the Old World, with pinnate leaves (leaflets either side of the stem) and reddish-yellow flowers, followed by pods. The pulp surrounding the seeds is used in medicine and as a flavouring. (*Tamarindus indica*, family Leguminosae.)

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tamarisk

any of a group of small trees or shrubs that flourish in warm, salty, desert regions of Europe and Asia where no other vegetation is found. The common tamarisk *T. gallica*, which grows in European coastal areas, has small, scalelike leaves on feathery branches and produces spikes of small pink flowers. (Genus *Tamarix*, family Tamaricaceae.)

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tanager

New World passerine bird, of the family Emberizidae, which also includes blackbirds, orioles, and grackles. Tanagers that breed in North America all belong to the genus *Piranga*. There are about 230 species in forests of Central and South America; all males are brilliantly colored.

Species include the **paradise tanager** *Tangara chilensis*. Its plumage has a metallic luster; the head is sea-green in color, the breast is violet, and there is a flame-colored patch on the lower part of the back. It feeds on fruit and insects. The **scarlet tanager** *Piranga olivacea* is about 7 in/18 cm long and has brilliant scarlet plumage in the male with black wings and tail. In autumn its plumage changes to a dull green, like that of the female.

Tanegashima Space Centre

Japanese rocket-launching site on a small island off southern Kyushu.

Tanegashima is now run by the Japan Aerospace Exploration Agency (JAXA) following a merger in October 2003 of four space organizations. One of them, the National Space Development Agency (NASDA), ran Tanegashima up to that time, being responsible for the practical applications of Japan's space programme (research fell under a separate organization based at Kagoshima Space Centre). NASDA, founded in 1969, turned over to JAXA its headquarters in Tokyo; a tracking and testing station, the Tsukuba Space Centre, in eastern central Honshu; and an Earth-observation centre near Tsukuba.

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tangent

line that touches a circle at only one point. A tangent is at right angles to the radius at the point of contact. From any point outside a circle, the lines of two tangents drawn to the circle will be of equal length.

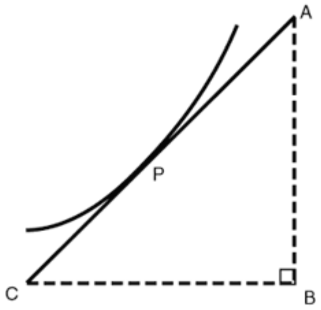
See also tangent (trigonometry) and tangent (graph).

---

tangent

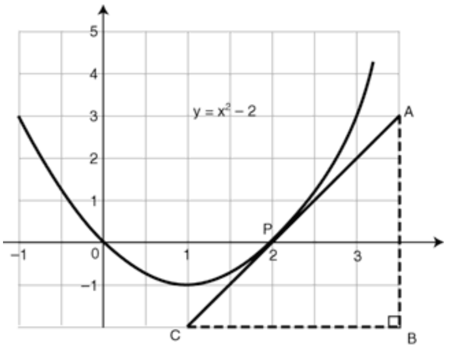
in graphs, a straight line that touches a curve and gives the gradient of the curve at the point of contact. At a maximum, minimum, or point of inflection, the tangent to a curve has zero gradient.

To find the gradient of the tangent of the curve at point P, extend the tangent AC and construct the right-angled triangle ABC:



The gradient of the tangent at the point P is AB/BC. This is only an approximation. To make the answer as accurate as possible, the length of the tangent AC should be large.

For example, to find the gradient of the curve $y = x^2 - 2x$ at the point P(2,0):



P = AB/BC = 5/2.5 = 2

See also tangent (trigonometry) and tangent (circle).

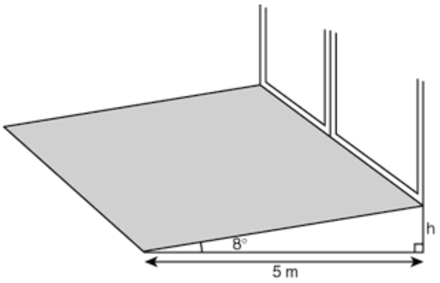
---

tangent

tan

in trigonometry, a function of an acute angle in a right-angled triangle, defined as the ratio of the length of the side opposite the angle to the length of the side adjacent to it; a way of expressing the gradient of a line. This function can be used to find either sides or angles in a right-angled triangle.

For example, to work out the height (h) of a 5-m ramp set at an angle of 8°:



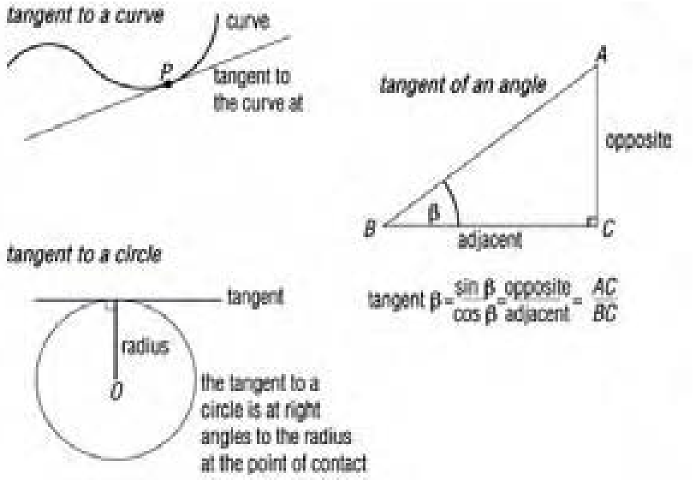
tan 8° = opposite/adjacent = $h/5$

$h = 5 \times \tan 8° = 0.70$ m (to the nearest cm)

The height of the ramp is 70 cm.

See also sine, cosine, tangent (graph), and tangent (circle).

tangent


tangent to a curve
curve
P
tangent to the curve at
tangent of an angle
A
opposite
β
B
adjacent
C
tangent β = $\frac{\sin\beta}{\cos\beta} = \frac{\text{opposite}}{\text{adjacent}} = \frac{AC}{BC}$
tangent to a circle
tangent
radius
O
the tangent to a circle is at right angles to the radius at the point of contact

(Image © Research Machines plc)

The tangent of an angle is a mathematical function used in the study of right-angled triangles. If the tangent of an angle β is known, then the length of the opposite side can be found given the length of the adjacent side, or vice versa.

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tangerine

small type of orange.

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tangram

puzzle made by cutting up a square into seven pieces.

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tannic acid

or tannin; $C_{14}H_{10}O_9$

yellow astringent substance, composed of several phenol rings, occurring in the bark, wood, roots, fruits, and galls (growths) of certain trees, such as the oak. It precipitates gelatin to give an insoluble compound used in the manufacture of leather from hides (tanning).

---

tanning

treating animal skins to preserve them and make them into leather. In vegetable tanning, the prepared skins are soaked in tannic acid. Chrome tanning, which is much quicker, uses solutions of chromium salts.

---

tansy

perennial herb belonging to the daisy family, native to Europe. The yellow flower heads grow in clusters on stalks up to 120 cm/4 ft tall, and the aromatic leaves are used in cookery. (*Tanacetum vulgare*, family Compositae.)

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tantalum

symbol Ta

hard, ductile, lustrous, grey-white, metallic element, atomic number 73, relative atomic mass 180.948. It occurs with niobium in tantalite and other minerals. It can be drawn into wire with a very high melting point and great tenacity, useful for lamp filaments subject to vibration. It is also used in alloys, for corrosion-resistant laboratory apparatus and chemical equipment, as a catalyst in manufacturing synthetic rubber, in tools and instruments, and in rectifiers and capacitors.

Tantalum was discovered and named in 1802 by Swedish chemist Anders Ekeberg (1767-1813) after the mythological Greek character Tantalus. It is mined as tantalite ore and most of the world's supply comes from Australia, with significant deposits in Brazil, Canada, and Nigeria. Tantalum is used in mobile phone capacitors, and as a consequence demand for the element has risen dramatically.

---

tape recording, magnetic

method of recording electric signals on a layer of iron oxide, or other magnetic material, coating a thin plastic tape. The electrical signals from the microphone are fed to the electromagnetic recording head, which magnetizes the tape in accordance with the frequency and amplitude of the original signal. The impulses may be audio (for sound recording), video (for television), or data (for computer). For playback, the tape is passed over the same, or another, head to convert magnetic into electrical signals, which are then amplified for reproduction. Tapes are easily demagnetized (erased) for reuse, and come in cassette, cartridge, or reel form.

Taperinha

archaeological site on the Amazon River, east of Santarem, Brazil. Its discovery in 1991 provided evidence that an ancient New World civilization, predating Mexican and Andean cultures, existed 6,000-8,000 years ago.

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tape streamer

in computing, a backing storage device consisting of a continuous loop of magnetic tape. Tape streamers are largely used to store dumps (rapid back-up copies) of important data files (see data security).

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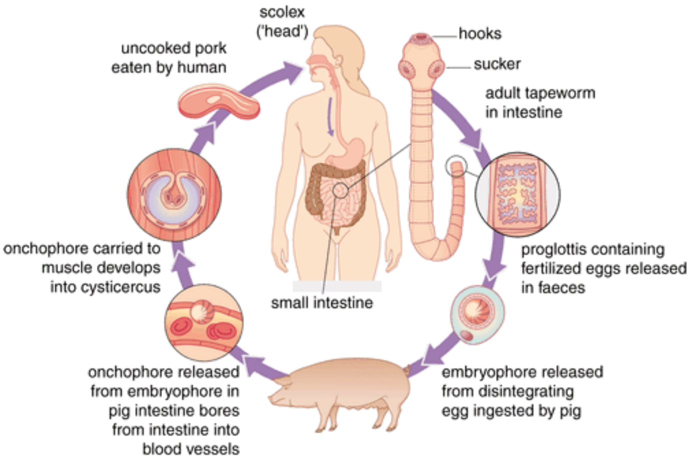
tapeworm

any of various parasitic flatworms of the class Cestoda. They lack digestive and sense organs, can reach 15 m/50 ft in length, and attach themselves to the host's intestines by means of hooks and suckers. Tapeworms are made up of hundreds of individual segments, each of which develops into a functional hermaphroditic reproductive unit capable of producing numerous eggs. The larvae of tapeworms usually reach humans in imperfectly cooked meat or fish, causing anaemia and intestinal disorders.

tapeworm


scolex ('head')
hooks
sucker
uncooked pork eaten by human
adult tapeworm in intestine
onchophore carried to muscle develops into cysticercus
small intestine
proglottis containing fertilized eggs released in faeces
onchophore released from embryophore in pig intestine bores from intestine into blood vessels
embryophore released from disintegrating egg ingested by pig

(Image © Research Machines plc)

The life cycle of the pork tapeworm *Taenia solium*. If a person eats pork from an infected pig that has not been properly cooked, the cysticercus attaches to the intestine and develops into an adult tapeworm. The tapeworm is a hermaphrodite and fertilizes itself, releasing proglottis, each of which may contain as many as 40,000 embryos encased in separate capsules. If the embryos are eaten by a pig, they bore from the pig's intestine into the bloodstream which carries them to the muscles, where they may be eaten by a human and the cycle continues.

---

tapir

any of the odd-toed hoofed mammals (perissodactyls) of the single genus *Tapirus*, now constituting the family Tapiridae. There are four species living in the American and Malaysian tropics. They reach 1 m/3 ft at the shoulder and weigh up to 350 kg/770 lb. Their survival is in danger because of destruction of the forests.

Tapirs have thick, hairy, black skin, short tails, and short trunks. They are vegetarian, harmless, and shy. They are related to the rhinoceros, and slightly more distantly to the horse.

The Malaysian tapir *T. indicus* is black with a large white patch on the back and hindquarters. The three South American species are dark to reddish brown; the **Brazilian tapir** *T. terrestris* is the most widespread. **Baird's tapir** *T. bairdii* is rare and found only in Central America.

The **mountain tapir** *T. pinchaque* is the rarest tapir (fewer than 2,500 remaining), and is found only in the northern Andes. It weighs 150-200 kg/330-440 lb and is about 80 cm/32 in tall. It is mainly solitary except when breeding. The gestation period is 13 months and the single young remains with the mother for 18 months. Mountain tapirs are strong swimmers.

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taproot

in botany, a single, robust, main root that is derived from the embryonic root, or radicle, and grows vertically downwards, often to considerable depth. Taproots are often modified for food storage and are common in biennial plants such as the carrot *Daucus carota*, where they act as perennating organs.

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tar

dark brown or black viscous liquid obtained by the destructive distillation of coal, shale, and wood. Tars consist of a mixture of hydrocarbons, acids, and bases. Creosote and paraffin oil are produced from wood tar. See also coal tar.

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tarantula

wolf spider *Lycosa tarantula* (family Lycosidae) with a 2.5 cm/1 in body. It spins no web, relying on its speed in hunting to catch its prey. The name 'tarantula' is also used for any of the numerous large, hairy spiders of the family Theraphosidae, with large poison fangs, native to the southwestern USA and tropical America.

The theraphosid *Aphonopelma* has a body length of 5 cm/2 in and a leg span of 12.5 cm/5 in. They are no more poisonous than other spiders of similar size. They burrow in the ground and catch their prey by pouncing on it and not by means of a web.

In the Middle Ages, the wolf spider's bite was thought to cause hysterical ailments or **tarantism** for which dancing was the cure, hence the name 'tarantula' and its popular association with the dance 'tarantella'.

American Tarantula Society

Go to site

Information on tarantulas, other spiders, and scorpions from the world's largest arachnid society. There are articles on buying, feeding, looking after, and breeding tarantulas. Tarantula owners exchange experiences and there is a listing of other arachnid sites.

tare

common name for any of the plants known as vetches.

taro

or eddo

plant belonging to the arum family, native to tropical Asia; the tubers (underground stems) are edible and are the source of Polynesian poi (a fermented food). (*Colocasia esculenta*, family Araceae.)

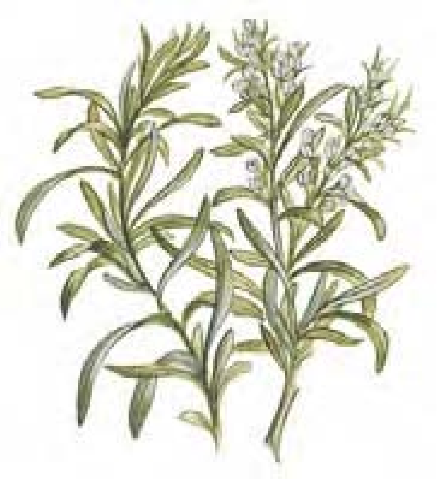
tarpon

large silver-sided fish *Tarpon atlanticus* of the family Megalopidae. It reaches 2 m/6 ft and may weigh 135 kg/300 lb. It lives in warm western Atlantic waters.

tarragon

perennial bushy herb belonging to the daisy family, native to the Old World. It grows up to 1.5 m/5 ft tall and has narrow leaves and small green-white flower heads arranged in groups. Tarragon contains an aromatic oil; its leaves are used to flavour salads, pickles, and tartar sauce. It is closely related to wormwood. (*Artemisia dracunculus*, family Compositae.)

tarragon



(Image © Research Machines plc)

Tarragon is a bushy perennial with narrow green leaves and small green-white flowers in July and August. It is one of the subtlest of herbs, going well with foods of delicate flavour.

tarsier

any of three species of the prosimian primates, genus *Tarsius*, of the East Indies and the Philippines. These survivors of early primates are about the size of a rat with thick, light-brown fur, very large eyes, and long feet and hands. They are nocturnal, arboreal, and eat insects and lizards.

tartaric acid

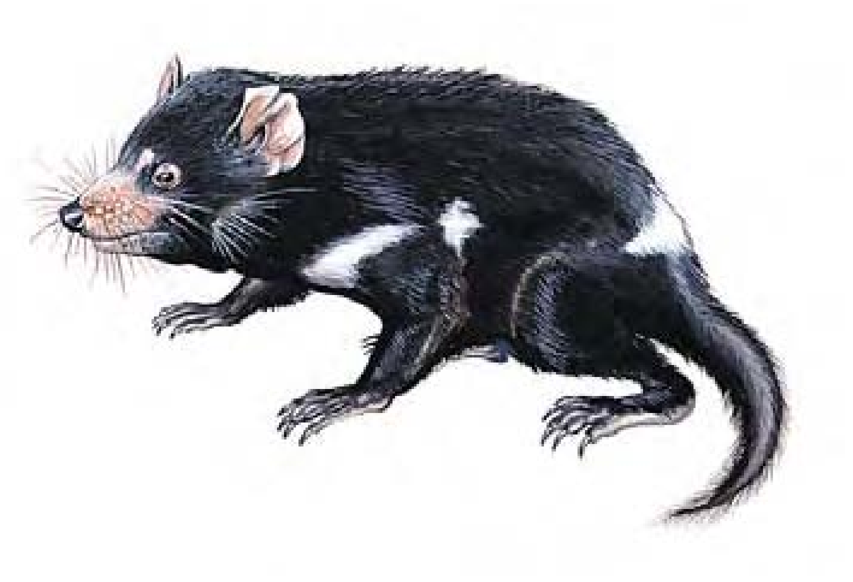
$HOOC(CHOH)_2COOH$

organic acid present in vegetable tissues and fruit juices in the form of salts of potassium, calcium, and magnesium. It is used in carbonated drinks and baking powders.

Tasmanian devil

carnivorous marsupial *Sarcophilus harrisii*, in the same family (Dasyuridae) as native 'cats'. It is about 65 cm/2.1 ft long with a 25 cm/10 in bushy tail. It has a large head, strong teeth, and is blackish with white patches on the chest and hind parts. It is nocturnal, carnivorous, and can be ferocious when cornered. It has recently become extinct in Australia and survives only in remote parts of Tasmania.

Tasmanian devil



(Image © Research Machines plc)

The Tasmanian devil, despite its name, is not particularly aggressive – it is more likely to scavenge for dead animals than to attack living ones. Nevertheless, it has powerful jaws, capable of crushing large bones.

Tasmanian wolf

or Tasmanian tiger or thylacine

carnivorous marsupial *Thylacinus cynocephalus*, in the family Dasyuridae. It is doglike in appearance with a long tail, characteristic dark stripes on back and hindquarters, and measures nearly 2 m/6 ft from nose to tail tip. It was hunted to probable extinction in the 1930s, the last known Tasmanian wolf dying in Hobart Zoo, Tasmania, in 1936, but there are still occasional unconfirmed reports of sightings, both on the Australian mainland and in the Tasmanian mountains, its last known habitat.

A team of scientists at the Australian Museum, Sydney, has extracted DNA from a preserved Tasmanian wolf pup as the first stage in an attempt to recreate the extinct marsupial. The leader of the project and head of evolutionary biology at the Australian Museum, Dr Don Colgan, gave the project, at its outset in 2000, only an 8-10% chance of success. It would be the first cloning of an animal from dead DNA.

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taste

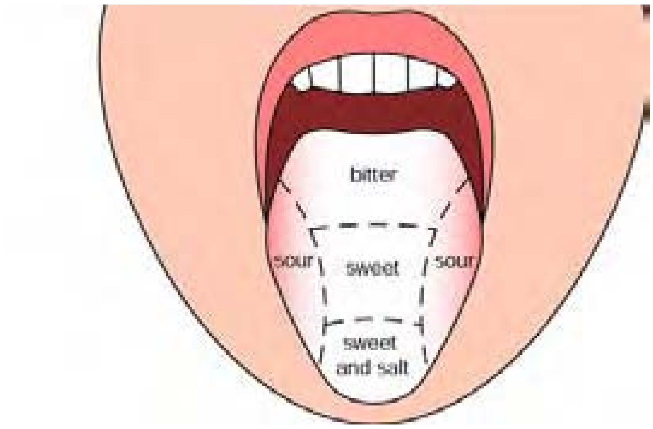
sense that detects some of the chemical constituents of food. The human tongue can distinguish five basic tastes: sweet, sour, bitter, salty, and 'umami' (a taste sensation triggered by the amino acid glutamate). However, what we refer to as taste is really a composite sense made up of both taste and smell.

Umami is now called L-glutamate and a specific molecule receptor for it has been identified in taste buds.

In terms of evolution, the receptors for the five basic tastes can each be associated with a specific survival function. Sweet, salty, and 'umami' serve the recognition of food rich in carbohydrates, minerals, and protein. Sour and bitter tastes presumably evolved as warning signs against acids and natural poisons.

Receptor molecules for taste sensation remained elusive until 2000, when systematic search of the human genome enabled researchers to identify the genes and then investigate the proteins in detail. Like many other signalling events, taste sensation was found to involve a specific G protein (called gustducin), thus taste receptors belong to the large family of G-protein coupled receptors.

taste



(Image © Research Machines plc)

The regions of the tongue that detect different categories of taste.

Tatum, Edward Lawrie (1909-1975)

US microbiologist who was awarded the Nobel Prize for Physiology or Medicine in 1958 for the discovery that genes regulate precise chemical effects. He shared the prize with his co-workers George Beadle and Joshua Lederberg.

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tau

elementary particle with the same electric charge as the electron but a mass nearly double that of a proton. It has a lifetime of around 3×10^{-13} seconds and belongs to the lepton family of particles – those which interact via the electromagnetic, weak nuclear, and gravitational forces, but not the strong nuclear force.

Taube, Henry (1915-2005)

US chemist who established the basis of inorganic chemistry through his study of the loss or gain of electrons by atoms during chemical reactions. He was awarded the Nobel Prize for Chemistry in 1983 for his work on electron transference between molecules in chemical reactions.

Tau Ceti

one of the nearest stars visible to the naked eye, 11.9 light years from Earth in the constellation Cetus. It has a diameter slightly less than that of the Sun, and an actual luminosity of about 45% of the Sun's. Its similarity to the Sun is sufficient to suggest that Tau Ceti may possess a planetary system, and it has been found that it is surrounded by a cloud of debris more than ten times as massive as that surrounding the Sun.

Taurus

conspicuous zodiacal constellation in the northern hemisphere near Orion, represented as a bull. The Sun passes through Taurus from mid-May to late June. In astrology, the dates for Taurus are between about 20 April and 20 May (see precession).

The V-shaped Hyades open star cluster is in the bull's head, with Aldebaran as the red eye. The Pleiades open cluster is in the shoulder. Taurus also contains the Crab nebula, the remnants of the supernova of AD 1054, which is a strong radio and X-ray source and the location of one of the first pulsars to be discovered.

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tautomerism

form of isomerism in which two interconvertible isomers are in equilibrium. It is often specifically applied to an equilibrium between the keto ($—CH_2\text{-}C{=}O$) and enol ($\text{-}CH{=}C—OH$) forms of carbonyl compounds.

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taxis

plural taxes; or tactic movement

in botany and microbiology, the movement of a single cell, such as a bacterium, protozoan, single-celled alga, or gamete, in response to an external stimulus. A movement directed towards the stimulus is described as positive taxis, and away from it as negative taxis. The alga *Chlamydomonas*, for example, demonstrates positive **phototaxis** by swimming towards a light source to increase the rate of photosynthesis.

Chemotaxis is a response to a chemical stimulus, as seen in many bacteria that move towards higher concentrations of nutrients.

taxol

in medicine, an anticancer drug originally extracted from the bark of the Pacific yew *Taxus brevifolia* but synthesized in 1994. Its principal use is in the treatment of breast and ovarian cancer.

taxonomy

another name for the classification of living organisms.

Tay-Sachs disease

inherited disorder, due to a defective gene, causing an enzyme deficiency that leads to blindness, retardation, and death in infancy. It is most common in people of Eastern European Jewish descent.

TB

abbreviation for the infectious disease tuberculosis.

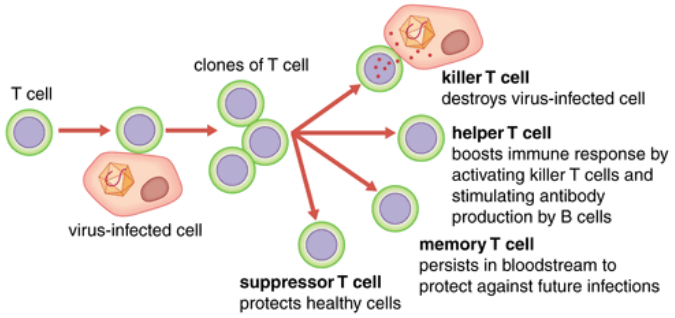
T cell

or T lymphocyte

immune cell (see immunity and lymphocyte) that plays several roles in the body's defences. T cells are so called because they mature in the thymus.

There are three main types of T cells: T helper cells (Th cells), which allow other immune cells to go into action; T suppressor cells (Ts cells), which stop specific immune reactions from occurring; and T cytotoxic cells (Tc cells), which kill cells that are cancerous or infected with viruses. Like B cells, to which they are related, T cells have surface receptors that make them specific for particular antigens.

T cell


T cell
clones of T cell
virus-infected cell
killer T cell
destroys virus-infected cell
helper T cell
boosts immune response by activating killer T cells and stimulating antibody production by B cells
memory T cell
persists in bloodstream to protect against future infections
suppressor T cell
protects healthy cells

(Image © Research Machines plc)

T cells, a type of lymphocyte (white blood cell), have an important role in the body's immune system. When a T cell encounters an invading virus it begins to divide, forming four different types of T cell, each with a different function. Killer T cells destroy cells that have become infected with the virus by lysis. Helper T cells activate more killer T cells and also stimulate B cells to begin antibody production (unlike B cells, T cells do not produce antibodies to destroy invading pathogens). Suppressor T cells protect healthy cells from viral attack and memory T cells persist in the bloodstream to guard against re-infection.

tea

evergreen shrub or small tree whose fermented, dried leaves are soaked in hot water to make a refreshing drink, also called tea. Known in China as early as 2737 BC, tea was first brought to Europe AD 1610 and rapidly became a popular drink. In 1823 the shrub was found growing wild in northern India, and plantations were later established in Assam and Sri Lanka; producers today include Africa, South America, Georgia, Azerbaijan, Indonesia, and Iran. (*Camellia sinensis*, family Theaceae.)

the tea plant

In the wild the tea plant can grow as tall as 12 m/40 ft, but in cultivation it is kept down to a bush 1.5 m/4 ft high. The young shoots and leaves are picked every five days.

processing

Once plucked, the young leaves are spread out on shelves in withering lofts and allowed to wither (dry and shrivel up) in a current of air for 4–18 hours.
Black teas (from Sri Lanka and India) are macerated (soaked and softened) in rolling machines to release the essential oils, allowed to ferment, and then dried and graded. The fermentation gives them a blackish-brown colour.
Green teas (from China, Taiwan, and Japan) are steamed or heated and then rolled, dried, and finally graded. They are green or partly green in colour.

Some teas are scented with plant oils: Earl Grey, for example, is flavoured with oil of bergamot.

grading

Grading is carried out according to the size of leaf. For example, some Sri Lankan (Ceylon) tea grades are orange pekoe, flowery pekoe, broken orange pekoe, broken pekoe, and fannings. The latter grades are mostly the black teas sold in tea bags. Black teas make up 75% of the world's trade in tea.

tea customs

Methods of drinking tea vary in different countries: in Japan special teahouses and an elaborate tea ceremony have evolved, and in Tibet, hard slabs of compressed tea are used as money before being finally brewed.

recent research

Black tea contains flavonols, antioxidant chemicals that remove harmful oxidizing agents from the body. In 1999 US researchers concluded that tea drinking can provide some protection against heart attacks, with tea drinkers experiencing a 44% reduction in heart attack risk compared with non-tea drinkers.

tea

(Image © Corel)

Tea plantation near Hangzhou, the capital of Zhejiang province, China. This area is well known for the production of high-quality green tea. Tea cultivation in China is labour-intensive as most processes are carried out by hand.

tea plantations, Zimbabwe

(Image © Corel)

Tea plantations in the Honde Valley of Zimbabwe, southern Africa. The Honde is a fertile, intensively cultivated valley, producing tea and tropical fruit, especially in the north, near the eastern buttress of Mount Inyangani.

Welcome to Teatime.com

Go to site

Useful resource for tea lovers with nutrition information, flavours, a glossary of tea terms, and a wealth of features on tea-related issues, such as tea and health, tea and caffeine, the origins of tea tradition, and tea vendor lists. Visitors can also take part in chats, learn about tea books, and read tea quotes.

teak

tropical Asian timber tree with yellowish wood used in furniture and shipbuilding. (*Tectona grandis*, family Verbenaceae.)

teal

any of various small, short-necked dabbling ducks of the genus *Anas*, order Anseriformes, but particularly *A. crecca*. The male is dusky grey; its tail feathers ashy grey; the crown of its head deep cinnamon or chestnut; its eye is surrounded by a black band, glossed with green or purple, which unites on the nape; its wing markings are black and white; and its bill is black. The female is mottled brown. The total length is about 35cm/14 in.

The **blue-winged teal** *A. discors* is a brillantly coloured bird 35-42 cm/14-17 in long, with bright blue wing coverts. It is a native of North America, and migrates in winter to South America.

tear gas

any of various volatile gases that produce irritation and watering of the eyes, used by police against crowds and used in chemical warfare. The gas is delivered in pressurized, liquid-filled canisters or grenades, thrown by hand or launched from a specially adapted rifle. Gases (such as Mace) cause violent coughing and blinding tears, which pass when the victim breathes fresh air, but there are no lasting effects.

tears

salty fluid exuded by lacrimal glands in the eyes. The fluid contains proteins that are antibacterial, and also absorbs oils and mucus. Apart from cleaning and disinfecting the surface of the eye, the fluid supplies nutrients to the cornea, which does not have a blood supply.

If insufficient fluid is produced, as sometimes happens in older people, the painful condition of 'dry-eye' results and the eye may be damaged.

teasel

upright prickly biennial herb, native to Europe and Asia. It grows up to 1.5 m/5 ft tall, has prickly stems and leaves, and a large prickly head of purple flowers. The dry, spiny seed heads were once used industrially to tease or fluff up the surface fibres of cloth. (*Dipsacus fullonum*, family Dipsacaceae.)

Teazles

Go to site

In-depth information about teazles, or teasels. There is an informative description of the plant itself, and there are even detailed notes on a number of its uses: for curing jaundice and fleecing wool. It also includes information on the different types of teazles.

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technetium

chemical symbol Tc

(Greek technetos 'artificial')

silver-grey, radioactive, metallic element, atomic number 43, relative atomic mass 98.906. It occurs in nature only in extremely minute amounts, produced as a fission product from uranium in pitchblende and other uranium ores. Its longest-lived isotope, Tc-99, has a half-life of 216,000 years. It is a superconductor and is used as a hardener in steel alloys and as a medical tracer.

It was synthesized in 1937 (named in 1947) by Italian physicists Carlo Perrier and Emilio Segrè, who bombarded molybdenum with deuterons, looking to fill a gap in the periodic table of the elements (at that time it was considered not to occur in nature). It was later isolated in larger amounts from the fission product debris of uranium fuel in nuclear reactors.

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technology

the use of tools, power, and materials, generally for the purposes of production. Almost every human process for getting food and shelter depends on complex technological systems, which have been developed over a 3-million-year period. Significant milestones include the advent of the steam engine in 1712, the introduction of electricity and the internal combustion engine in the mid-1870s, and recent developments in communications, electronics, and the nuclear and space industries. The **advanced technology** (highly automated and specialized) on which modern industrialized society depends is frequently contrasted with the **low technology** (labour-intensive and unspecialized) that characterizes some developing countries. **Intermediate technology** is an attempt to adapt scientifically advanced inventions to less developed areas by using local materials and methods of manufacture.
Appropriate technology refers to simple and small-scale tools and machinery of use to developing countries.

power

In human prehistory, the only power available was muscle power, augmented by primitive tools, such as the wedge or lever.

The domestication of animals about 8500 BC and invention of the wheel about 2000 BC paved the way for the water mill (1st century BC) and later the windmill, which was in use in Asia by 400 AD. Not until 1712 did an alternative source of power appear in the form of the first working steam engine, constructed by English inventor Thomas Newcomen; subsequent modifications improved its design. English chemist and physicist Michael Faraday's demonstration of the dynamo in 1831 revealed the potential of electromagnetic induction and electrical generation, and in 1876 the German scientist Nikolaus Otto introduced the four-stroke cycle used in the modern internal combustion engine. The 1940s saw the explosion of the first atomic bomb and the subsequent development of the nuclear power industry. Latterly concern over the use of non-renewable power sources and the pollution caused by the burning of fossil fuels has caused technologists to turn increasingly to exploring renewable sources of energy, in particular solar energy, wind energy, and wave power.

materials

The earliest materials used by humans were wood, bone, horn, shell, and stone. Metals were rare and/or difficult to obtain, although forms of iron were in use from 1000 BC. The improvements made to the blast furnace in the 15th century enabled cast iron to be extracted, but this process remained expensive until English ironmaker Abraham Darby substituted coke for charcoal in 1709, thus ensuring a plentiful supply of cheap iron at the start of the Industrial Revolution. Rubber, glass, leather, paper, bricks, and porcelain underwent similar processes of trial and error before becoming readily available. From the mid-1800s, entirely new materials, synthetics, appeared. First dyes, then plastic and the more versatile celluloid, and later drugs were synthesized, a process continuing into the 1980s with the growth of genetic engineering, which enabled the production of synthetic insulin and growth hormones.

production

The utilization of power sources and materials for production frequently lagged behind their initial discovery. The lathe, known in antiquity in the form of a pole powered by a foot treadle, was developed further in the 18th century when it was used to produce objects of great precision, ranging from astronomical instruments to mass-produced screws. The realization that gears, cranks, cams, and wheels could operate in harmony to perform complex motion made mechanization possible. Early attempts at automation include Scottish engineer James Watt's introduction of the governor into the steam engine in 1769 to regulate the machine's steam supply automatically, and French textile maker Joseph Marie Jacquard's demonstration in 1804 of how looms could be controlled automatically by punched cards. The first moving assembly line appeared in 1870 in meat-packing factories in Chicago, USA, transferring to the motor industry in 1913. With the perfection of the programmable electronic computer in the 1960s, the way lay open for fully automatic plants. The 1960s-90s saw extensive developments in the electronic and microelectronic industries (initially in the West, later joined by Japan and the Pacific region) and in the field of communications.

Doors of Perception

Go to site

Site full of commentaries and papers from the five 'Doors of Perception' conferences. These were held to examine the effects of the rapid growth of technology and how we can best use this to improve everyone's quality of life. It is quite a highbrow and hi-tech site, but there are a lot of interesting ideas here.

Electronic School Online

Go to site

US-based online magazine targeted at comprehensive school children. It contains news and features relating to how technology is used by schools and children.

Forgotten Inventors

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *The American Experience*, this page tells the stories of the mostly ignored inventors of useful products we often take for granted. Read about British merchant Peter Durand, inventor of the tin can for storing food, an invention that was soon greatly aided by Ezra Warner's invention of the can opener. Learn what inspired Levi Strauss to invent blue jeans. You can also find information about the inventors of the Frisbee, feather duster, oil burner, and the blood bank.

Technology Summary

Go to site

Daily online magazine specializing in features associated with technology. It includes access to previous issues.

Technology Timeline

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *The American Experience*, this page follows the course of technological progress and invention in the USA from the time of Benjamin Franklin's experiments in the 1750s to the creation of the Hubble Telescope in the 1990s. The information is divided into decades along a time line. Along the way, you can learn about such inventions as the cotton gin, steamboat, revolver, false teeth, passenger elevator, burglar alarm, barbed wire, skyscraper, dishwasher, zipper, frozen food, electric guitar, atomic bomb, optic fibre, video game, bar code, space shuttle, personal computer, and artificial heart.

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tectonics

in geology, the study of the movements of rocks on the Earth's surface. On a small scale tectonics involves the formation of folds and faults, but on a large scale plate tectonics deals with the movement of the Earth's surface as a whole.

Introduction to Plate Tectonics

Go to site

Detailed guide to the background and major characteristics of plate tectonic theory. This site includes sections on 'fossil distribution', 'lithology', 'paleomagnetism', 'oceanography', and 'What causes plates to move?'.

Science Odyssey: You Try It: Plate Tectonics

Go to site

Well-presented site to 'the theory that Earth's outer layer is made up of plates'. This site, labelled 'Mountain Maker, Earth Shaker' has science-related interactive activities that use the Shockwave plug-in.

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teething

the erupting of the teeth. In children, it can accompanied by irritability, loss of sleep, salivation, and failure to feed. Similar, but less severe, symptoms may occur in adults when the wisdom teeth erupt.

Teflon

trade name for polytetrafluoroethene (PTFE), a tough, waxlike, heat-resistant plastic used for coating nonstick cookware and in gaskets and bearings.

In 2001 Canadian scientists discovered that Teflon degraded when heated to form trifluoroacetic acid (TFA), a pollutant that persists in the environment for many years.

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tektite

(from Greek tektos 'molten')

small, rounded glassy stone, found in certain regions of the Earth, such as Australasia. Tektites are probably the scattered drops of molten rock thrown out by the impact of a large meteorite.

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telecommunications

communications over a distance, generally by electronic means. Long-distance voice communication was pioneered in 1876 by Scottish scientist Alexander Graham Bell when he invented the telephone. The telegraph, radio, and television followed. Today it is possible to communicate internationally by telephone cable or by satellite or microwave link, with over 100,000 simultaneous conversations and several television channels being carried by the latest satellites.

history

The first mechanical telecommunications systems were semaphore and the heliograph (using flashes of sunlight), invented in the mid-19th century, but the forerunner of the present telecommunications age was the electric telegraph. The earliest practicable telegraph instrument was invented by William Cooke and Charles Wheatstone in Britain in 1837 and used by railway companies. In the USA, Samuel Morse invented a signalling code, Morse code, which is still used, and a recording telegraph, first used commercially between England and France in 1851.

Following German physicist Heinrich Hertz's discovery of electromagnetic waves, Italian inventor Guglielmo Marconi pioneered a 'wireless' telegraph, ancestor of the radio. He established wireless communication between England and France in 1899 and across the Atlantic in 1901.

The modern telegraph uses teleprinters to send coded messages along telecommunications lines. Telegraphs are keyboard-operated machines that transmit a five-unit Baudot code (see baud). The receiving teleprinter automatically prints the received message. The modern version of the telegraph is e-mail in which text messages are sent electronically from computer to computer via network connections such as the Internet.

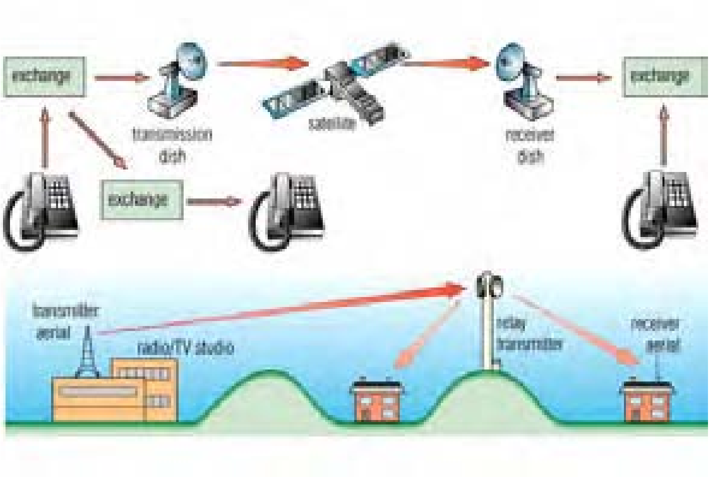
communications satellites

The chief method of relaying long-distance calls on land is microwave radio transmission. The drawback to long-distance voice communication via microwave radio transmission is that the transmissions follow a straight line from tower to tower, so that over the sea the system becomes impracticable. A solution was put forward in 1945 by the science fiction writer Arthur C Clarke, when he proposed a system of communications satellites in an orbit 35,900 km/22,300 mi above the Equator, where they would circle the Earth in exactly 24 hours, and thus appear fixed in the sky. Such a system is now in operation internationally, by Intelsat. The satellites are called geostationary satellites (syncoms). The first to be successfully launched, by Delta rocket from Cape Canaveral, was *Syncom 2* in July 1963. Many such satellites are now in use, concentrated over heavy traffic areas such as the Atlantic, Indian, and Pacific oceans. Telegraphy, telephony, and television transmissions are carried simultaneously by high-frequency radio waves. They are beamed to the satellites from large dish antennae or Earth stations, which connect with international networks.

Integrated Services Digital Network (ISDN) makes videophones and high-quality fax possible; the world's first large-scale centre of ISDN began operating in Japan in 1988. ISDN is a system that transmits voice and image data on a single transmission line by changing them into digital signals.

Fibre-optic cables consisting of fine glass fibres present an alternative to the usual copper cables for telephone lines. The telecommunications signals are transmitted along the fibres in digital form as pulses of laser light.

telecommunications



(Image © Research Machines plc)

The international telecommunications system relies on microwave and satellite links for long-distance international calls. Cable links are increasingly made of optical fibres. The capacity of these links is enormous. The TDRS-C (tracking and data-relay satellite communications) satellite, the world's largest and most complex satellite, can transmit in a single second the contents of a 20-volume encyclopedia, with each volume containing 1,200 pages of 2,000 words. A bundle of optical fibres, no thicker than a finger, can carry 10,000 phone calls - more than a copper wire as thick as an arm.

Telecommunications: key dates

1794	Claude Chappe in France builds a long-distance signalling system using semaphore.
1839	Charles Wheatstone and William Cooke devise an electric telegraph in England.
1843	Samuel Morse transmits the first message along a telegraph line in the USA, using his Morse code of signals - short (dots) and long (dashes).
1858	The first transatlantic telegraph cable is laid.
1876	Alexander Graham Bell invents the telephone.
1877	Thomas Edison invents the carbon transmitter for the telephone.
1878	The first telephone exchange is opened at New Haven, Connecticut.
1884	The first long-distance telephone line is installed, between Boston and New York.
1891	A telephone cable is laid between England and France.
1892	The first automatic telephone exchange is opened, at La Porte, Indiana.
1894	Guglielmo Marconi pioneers wireless telegraphy in Italy, later moving to England.
1900	Reginald Fessenden in the USA first broadcasts voice by radio.
1901	Marconi transmits the first radio signals across the Atlantic.
1904	John Ambrose Fleming invents the thermionic valve.
1907	Charles Krumm introduces the forerunner of the teleprinter.
1920	Stations in Detroit and Pittsburgh begin regular radio broadcasts.
1922	The BBC begins its first radio transmissions, for the London station 2LO.
1932	The Telex is introduced in the UK.
1956	The first transatlantic telephone cable is laid.
1962	Telstar pioneers transatlantic satellite communications, transmitting live TV pictures.
1966	Charles Kao in England advances the idea of using optical fibres for telecommunications transmissions.
1969	Live TV pictures are sent from astronauts on the Moon back to Earth.
1975	Prestel, the world's first viewdata system, using the telephone lines to link a computer data bank with the TV screen, is introduced in the UK.
1977	The first optical fibre cable is installed in California.
1984	First commercial cellphone service starts in Chicago, USA.
1988	International Services Digital Network (ISDN), an international system for sending signals in digital format along optical fibres and coaxial cable, is launched in Japan.
1989	The first transoceanic optical fibre cable, capable of carrying 40,000 simultaneous telephone conversations, is laid between Europe and the USA.
1991	ISDN is introduced in the UK.
1992	Videophones, made possible by advances in image compression and the development of ISDN, are introduced in the UK.
1993	Electronic version of the *Guardian* newspaper, for those with impaired vision, is launched in the UK. The newspaper is transmitted to the user's home and printed out in braille or spoken by a speech synthesizer.
1995	The USA's main carrier of long-distance telecommunications, AT&T, processes 160 million calls daily, an increase of 50% since 1990.
1996	Researchers in Tokyo and California use lasers to communicate with an orbiting satellite, the first time lasers have been used to provide two-way communications with space.
1996	Work begins on laying the world's longest fibreoptic cable, which will follow a 17,000-mi/27,300-km route around the globe from Europe, through the Suez Canal, across the Indian Ocean, and around the Pacific.
1996	Computer scientists in Japan and the USA transmit information along optical fibre at a rate of one trillion bits. At this rate, 300 years' worth of a daily newspaper can be transmitted in one second.
1997	There are 300 active artificial satellites in orbit around Earth, the majority of which are used for communications purposes.
1998	US vice-president Al Gore announces plans for Internet2, a high-speed data communications network that will serve the main US research universities, and bypass the congestion on the Internet.
2003	3G mobile phones become available offering a greater range of mobile multimedia.
2005	With the increasing take-up of broadband internet, communicating over the web using Voice Over Internet Protocol (VoIP) becomes significant.

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telegraphy

transmission of messages along wires by means of electrical signals. The first modern form of telecommunication, it now uses computer terminals and printers for the transmission and receipt of messages. Telex is an international telegraphy network.

Overland cables were developed in the 1830s, but early attempts at underwater telegraphy were largely unsuccessful until the discovery of the insulating gum gutta-percha in 1845 enabled a cable to be successfully laid across the English Channel in 1851.
Duplex telegraph was invented in the 1870s, enabling messages to be sent in both directions simultaneously. Early telegraphs were mainly owned by the UK: 72% of all submarine cables were British-

owned in 1900.

Teleostei

dominant superorder within the class Osteichthyes (bony fish), consisting of the 'modern' fish, such as the herring, salmon, catfish, eels, and anglerfish. This is the largest group of living vertebrates with more than 20,000 species known.

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telepathy

'the communication of impressions of any kind from one mind to another, independently of the recognized channels of sense', as defined by the English essayist F W H Myers (1843-1901), cofounder in 1882 of the Psychical Research Society, who coined the term. It is a form of extrasensory perception.

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telephone

instrument for communicating by voice along wires, developed by Scottish-US inventor Alexander Graham Bell in 1876, consisting of an earpiece that receives electrical signals and a mouthpiece that sends electrical signals. The transmitter (mouthpiece) consists of a carbon microphone, with a diaphragm that is vibrated by sound waves when a person speaks into it. The diaphragm vibrations compress grains of carbon to a greater or lesser extent, altering their resistance to an electric current passing through them. This sets up variable electrical signals, which travel along the telephone lines to the receiver of the person being called. The earpiece contains an electromagnet attached to a diaphragm. As the incoming electrical signal varies, the strength of the electromagnet also varies, resulting in a variable movement of an armature of the electromagnet. These movements cause the diaphragm to vibrate, producing the pattern of sound waves that originally entered the mouthpiece.

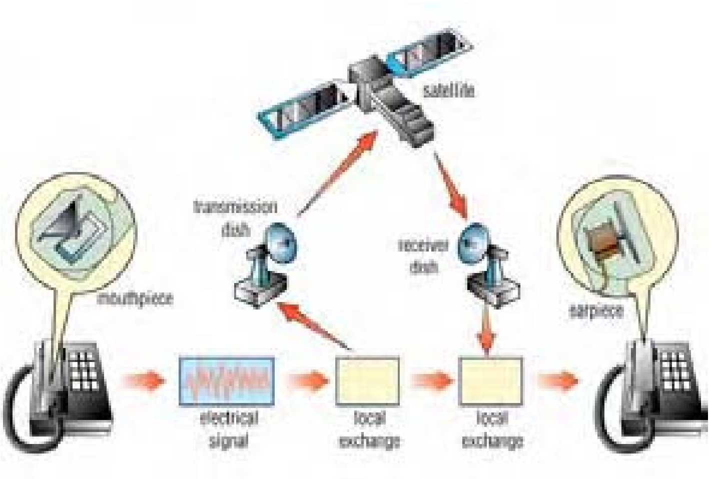
The standard instrument has a handset, which houses the transmitter (mouthpiece), and receiver (earpiece), resting on a base, which has a dial or push-button mechanism for dialling a telephone number. Cordless telephones combine a push-button mechanism, a mouthpiece, and an earpiece in one unit, and are connected to the base unit not by wires but by radio. They can be used at distances of up to 100 m/330 ft from the base unit.

In the 1990s, digital networks provided wireless mobility with the mobile phone, and enabled the adaptation of personal computers for telephone use with the Internet phone.

telephone

More than half of the world's population have never made a telephone call. Three quarters of the world's telephones are in eight industrialized countries.

telephone



(Image © Research Machines plc)

In the telephone, sound vibrations are converted to an electric signal and back again. The mouthpiece contains a carbon microphone that produces an electrical signal which varies in step with the spoken sounds. The signal is routed to the receiver via local or national exchanges. The earpiece contains an electromagnetic loudspeaker which reproduces the sounds by vibrating a diaphragm.

International direct dialling codes from the UK

When dialling overseas from the UK, prefix the country codes below with the international network access code: 00; then dial the area code, followed by the number that you wish to call.

Country/territory	Code
Afghanistan	93

Albania	355
Algeria	213
Andorra	376
Angola	244
Anguilla	1 264
Antarctica (Scott Base)	672
Antigua and Barbuda	1 268
Argentina	54
Armenia	374
Aruba	297
Ascension Island	247
Australia	61
Austria	43
Azerbaijan	994
Bahamas	1 242
Bahrain	973
Bangladesh	880
Barbados	1 246
Belarus	375
Belgium	32
Belize	501
Benin	229
Bermuda	1 441
Bhutan	975
Bolivia	591
Bosnia-Herzegovina	387
Botswana	267
Brazil	55
Brunei	673
Bulgaria	359
Burkina Faso	226
Burundi	257
Cambodia	855
Cameroon	237
Canada	1
Cape Verde	238
Cayman Islands	1 345
Central African Republic	236
Chad	235
Chile	56
China	86
Colombia	57
Comoros	269
Congo, Democratic Republic of	243
Congo, Republic of the	242
Cook Islands	682
Costa Rica	506
Côte d'Ivoire	225
Croatia	385
Cuba	53
Cyprus	357
Czech Republic	420
Denmark	45
Djibouti	253
Dominica	1 767
Dominican Republic	1 809
Ecuador	593
Egypt	20
El Salvador	503
Equatorial Guinea	240
Eritrea	291
Estonia	372
Ethiopia	251
Falkland Islands	500
Faroe Islands	298

Fiji Islands	679
Finland	358
France	33
French Antilles	596
French Guiana	594
French Polynesia	689
Gabon	241
Gambia	220
Georgia	995
Germany	49
Ghana	233
Gibraltar	350
Greece	30
Greenland	299
Grenada	1 473
Guadeloupe	590
Guam	671
Guatemala	502
Guinea	224
Guinea-Bissau	245
Guyana	592
Haiti	509
Honduras	504
Hong Kong	852
Hungary	36
Iceland	354
India	91
Indonesia	62
Iran	98
Iraq	964
Ireland, Republic of	353
Israel	972
Italy	39
Jamaica	1 876
Japan	81
Jordan	962
Kazakhstan	7
Kenya	254
Kiribati	686
Korea, North	850
Korea, South	82
Kuwait	965
Kyrgyzstan	996
Laos	856
Latvia	371
Lebanon	961
Lesotho	266
Liberia	231
Libya	218
Liechtenstein	423
Lithuania	370
Luxembourg	352
Macau	853
Macedonia, Former Yugoslav Republic of	389
Madagascar	261
Malawi	265
Malaysia	60
Maldives	960
Mali	223
Malta	356
Marshall Islands	692
Martinique	596
Mauritania	222
Mauritius	230
Mayotte	269

Mexico	52
Micronesia	691
Moldova	373
Monaco	377
Mongolia	976
Montserrat	1 664
Morocco	212
Mozambique	258
Myanmar	95
Namibia	264
Nauru	674
Nepal	977
Netherlands	31
Netherlands Antilles	559
New Caledonia	687
New Zealand	64
Nicaragua	505
Niger	227
Nigeria	234
Niue	683
Norfolk Island	672
Northern Mariana Islands	1 670
Norway	47
Oman	968
Pakistan	92
Palestine	970
Palau	680
Panama	507
Papua New Guinea	675
Paraguay	595
Peru	51
Philippines	63
Poland	48
Portugal	351
Puerto Rico	1 787
Qatar	974
Réunion	262
Romania	40
Russia	7
Rwanda	250
St Helena	290
St Kitts and Nevis	1 869
St Lucia	1 758
St Pierre and Miguelon	508
St Vincent and the Grenadines	1 809
Samoa	685
Samoa, American	1 684
San Marino	378
São Tomé and Príncipe	239
Saudi Arabia	966
Senegal	221
Serbia and Montenegro	381
Seychelles	248
Sierra Leone	232
Singapore	65
Slovak Republic	421
Slovenia	386
Solomon Islands	677
Somalia	252
South Africa	27
Spain	34
Sri Lanka	94
Sudan	249
Suriname	597
Swaziland	268

Sweden	46
Switzerland	41
Syria	963
Taiwan	886
Tajikistan	992
Tanzania	255
Thailand	66
Togo	228
Tokelau	690
Tonga	676
Trinidad and Tobago	1 868
Tunisia	216
Turkey	90
Turkmenistan	993
Turks and Caicos Islands	1 649
Tuvalu	688
Uganda	256
UK	44
Ukraine	380
United Arab Emirates	971
Uruguay	598
USA	1
Uzbekistan	998
Vanuatu	678
Vatican City	39
Venezuela	58
Vietnam	84
Virgin Islands, British	1 809 49
Virgin Islands, US	1 340
Wallis and Futuna	681
Yemen	967
Zambia	260
Zimbabwe	263

telephone tapping

or telephone bugging

listening in on a telephone conversation, without the knowledge of the participants; in the UK and the USA this is a criminal offence if done without a warrant or the consent of the person concerned.

teleprinter

or teletypewriter

transmitting and receiving device used in telecommunications to handle coded messages. Teleprinters are automatic typewriters keyed telegraphically to convert typed words into electrical signals (using a five-unit Baudot code, see baud) at the transmitting end, and signals into typed words at the receiving end. They are now largely obsolete, their functions having been taken over by networked computers.

telescope

optical instrument that magnifies images of faint and distant objects; any device for collecting and focusing light and other forms of electromagnetic radiation. A telescope with a large aperture, or opening, can distinguish finer detail and fainter objects than one with a small aperture. The **refracting telescope** uses lenses, and the **reflecting telescope** uses mirrors. A third type, the **catadioptric telescope**, is a combination of lenses and mirrors. See also radio telescope.

refractor

In a refractor, light is collected by a lens called the **object glass** or **objective**, which focuses light down a tube, forming an image magnified by an **eyepiece**. Invention of the refractor is attributed to a Dutch optician, Hans Lippershey, in 1608. Hearing of the invention in 1609, Galileo quickly constructed one for himself and went on to produce a succession of such instruments which he used from 1610 onwards for astronomical observations. The largest refracting telescope in the world, at Yerkes Observatory, Willimas Bay, Wisconsin, has an aperture of 102 cm/40 in.

reflector

In a reflector, light is collected and focused by a concave mirror. The first reflector was built about 1670 by Isaac Newton. Large mirrors are cheaper to make and easier to mount than large lenses, so all the largest telescopes are reflectors. The largest reflector with a single mirror, 6 m/236 in, is at Zelenchukskaya, Russia. Telescopes with larger apertures composed of numerous smaller segments have been built, such as the Keck Telescopes on Mauna Kea, Hawaii. A **multiple-mirror telescope** was installed on Mount Hopkins, Arizona, USA, in 1979. It originally consisted of six mirrors of 1.8 m/72 in aperture, which performed like a single 4.5-m/176-in mirror. The six mirrors were replaced in 1996 by a single 6.5-m/21.3-ft mirror.
Schmidt telescopes are used for taking wide-field photographs of the sky. They have a main mirror plus a thin lens at the front of the tube to increase the field of view.

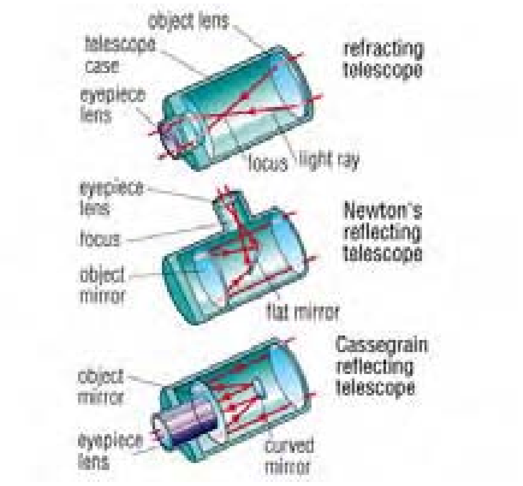
In 1995 NASA completed a 3-m/9.8-ft **liquid-mirror telescope** at its Orbital Debris Observatory in New Mexico. The liquid-mirror telescope is a reflecting telescope constructed with a rotating mercury mirror.

telescopes in space

Large telescopes can now be placed in orbit above the distorting effects of the Earth's atmosphere. Telescopes in space have been used to study infrared, ultraviolet, and X-ray radiation that does not penetrate the atmosphere but carries much information about the births, lives, and deaths of stars and galaxies. The 2.4-m/94-in Hubble Space Telescope, launched in 1990, can see the sky more clearly than can any telescope on Earth. The European Space Agencyseverals Herschel Space Observatory is scheduled for launch in July 2007. Stationed in the Earthseverals shadow, 1.5 million km/930,000 miles away, it will observe infrared (heat) radiation. Some time from 2013 onward, NASAseverals James Webb Space Telescope will be positioned in the same region of space, where instruments can be kept close to absolute zero in order to observe the faint heat radiation from space.

One design for X-ray telescopes for satellites is based on the structure of a lobster's eye, which has thousands of square tubes reflecting light onto the retina. The Lobster-ISS mission is due to be flown on the International Space Station (ISS) in 2008–09, and features a telescope of lobster-eye design.

telescope



(Image © Research Machines plc)

Three kinds of telescope. The refracting telescope uses a large objective lens to gather light and form an image which the smaller eyepiece lens magnifies. A reflecting telescope uses a mirror to gather light. The Schmidt telescope uses a corrective lens to achieve a wide field of view. It is one of the most widely used tools of astronomy.

Telescope Buying Guide

Go to site

Extensive and plain-English guide to buying a telescope. For anybody interested in astronomy and contemplating buying a telescope or setting up an observatory, this is an indispensable source of non-commercial advice.

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television

TV

reproduction of visual images at a distance using radio waves. For transmission, a television camera converts the pattern of light it takes in into a pattern of electrical charges. This is scanned line by line by a beam of electrons from an electron gun, resulting in variable electrical signals that represent the picture. These signals are combined with a radio carrier wave and broadcast as electromagnetic waves. The receiving 'aerial' (antenna) or satellite dish picks up the wave and feeds it to the receiver (TV set). This separates out the vision signals, which pass to the display device. This is usually a cathode-ray tube) in which a beam of electrons is made to scan across the screen line by line, mirroring the action of the electron gun in the TV camera. The result is a recreation of the pattern of light that entered the camera.

How Digital Television Works

introduction

Digital television is changing the face of home entertainment. Satellite television services in Europe and the USA were the first to start the big switch from analogue to digital transmission, because these broadcasters only have a limited number of viewers to convert, and the cost of conversion can be subsidized by the viewing fees. Now terrestrial or ground-based services are also converting. The UK has led the world with a mass-market DTTV (digital terrestrial television) service, but most viewers are being tempted by the offer of the heavily subsidized - even free - receivers on offer in return for paying to view the wider choice of programmes that digital television can offer. An analogue television station needs up to 8 MHz of frequency space. Two terrestrial transmitters cannot use the same frequency within several hundred kilometres of each other because even weak signals from one will interfere with strong signals from the other. Therefore, each country can only have a few analogue television channels. A satellite can transmit more channels, and its transmitters cover a wide geographical area. So the satellite usually delivers a handful of channels in different languages to several adjacent countries.

from analogue to digital

Converting a transmission system from analogue to digital multiplies the number of programme channels it can deliver, by up to ten. The bitstream can be used to carry a few programmes with better-than-analogue picture quality, or many programmes with compromised clarity. Digital television needs far less transmission power than analogue television. As a result, the digital signals can slot between the analogue frequencies, in the so-called 'taboo' channels that cannot be used for analogue broadcasting because of interference risks. Because the digital terrestrial frequencies are similar to existing analogue frequencies, existing aerials can sometimes receive new digital broadcasts. Once digital television becomes ubiquitous, broadcasters can shut down their analogue transmitters. This will release more frequencies for either digital broadcasting or mobile radio. Governments want this to happen as soon as possible because they can earn money by selling off, often by auction, the released airwaves.

television sets

Viewers can use a set-top box that converts the digital signals into analogue television, which an existing television can display. New television sets incorporate the digital circuitry. Many have a wide-format screen, with a 16:9 aspect ratio to do justice to movies and widescreen sports broadcasts. Conventional television sets, with 4:3 screens, may show a slight letterboxing effect, with black borders at the top and bottom of the picture.

pay viewing

National broadcasters can 'simulcast' existing 4:3 analogue programmes in digital widescreen, 'free to air'. Extra programmes can be encrypted and made available only if the viewer pays a fee, either by subscription or by special event payment. Pay viewing is controlled by a smart card, a credit card with a microchip that slots into the receiver to authorize decoding. Making good television programmes is expensive, and digital technology creates space for more programme channels. Broadcasters can only fill their channels if they charge viewers to watch. Graded monthly subscriptions buy different selections of entertainment, sport, and movies. Recent movies, sports specials, and concerts are sold on a pay-per-view basis. The money earned is used to buy more and better programmes, which leaves free-to-air broadcasters less able to compete.

digital television systems

The digital television system for Europe was developed in the 1990s by an independent voluntary industry group, the Digital Video Broadcasting (DVB) Project. The DVB Project's standards were then simply rubber-stamped by Europe's governments and official bodies. Services are now rolling out across Europe, and the same technology is being adopted in many other countries round the world - with the notable exception of the USA. The impetus for DVB came from the commercial failure of the high-definition television system developed in the 1980s as an official European research project, Eureka 95. High Definition Multiplexed Analogue Components (HD-MAC) was a hybrid system; the transmitted pictures were analogue but they travelled with digitally coded 'helper' signals that a suitable television set could use to make the images much wider and clearer than for conventional television. Although HD-MAC worked, the high-definition receivers were prohibitively expensive. There are three main DVB standards for cable, satellite, and terrestrial broadcasting. All are based on MPEG-2 coding, the digital compression standard set by the Motion Picture Experts Group of the International Electrotechnical Commission (IEC) and the International Standards Organization (ISO). The main differences are in the way the compressed signal is packaged for transmission. Terrestrial digital television uses a system similar to that developed for digital radio. Instead of transmitting one wide channel, the broadcaster transmits several thousand narrow sub-channels, packed tightly together. The digital code is split into a similar number of streams, so each channel carries fewer bits of code each second, and the bits in each channel are widely spaced apart in time. Unwanted reflections arrive in the gaps and the receiver rejects them. The European DVB and North American digital terrestrial systems are not compatible. One difference is that the American signal is not split between numerous sub-channels; also, the American system was designed to bridge the gap between televisions and computers, with emphasis on high-definition viewing, whereas the European system is aimed primarily at squeezing more programme channels into the available frequency space. The North American terrestrial system is taking off slowly and some US broadcasters have said they would prefer to use the European DVB technology. Satellite services round the world are converting from analogue to digital transmission. Cable services are converting to digital delivery. Although most services (terrestrial, satellite, and cable) use similar core technology (such as MPEG-2 digital coding), the agreed standards leave room for individual broadcasters to use their own proprietary systems to control pay viewing. This is blocking the design of a single receiver that works with rival services.

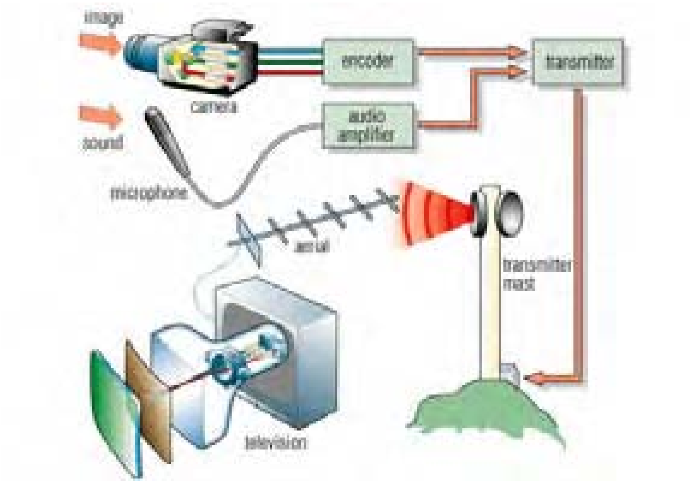
picture quality and interaction

On a technical level, digital television means that viewers no longer have to tolerate pictures that are snowy or blemished with ghost images caused by spurious reflections of the transmitted signal. If the signal is good enough to decode, the pictures are 'perfect'. But if the received signal is corrupted, for example by interference, the receiver simply stops working; the pictures on screen freeze and break up into a mosaic pattern. However, even 'perfect' pictures need not necessarily be very good. If the broadcaster tries to squeeze too many programme channels into the available frequency space, the bit rate for each channel is reduced and the pictures blur and smear. Digital television provides the opportunity for interaction, with the broadcaster providing different but related programmes on different channels, for example different views of the same football game with different commentaries, or a driver's-eye view of the track from a choice of racing cars. If the receiver is connected to a phone line it provides the opportunity for viewers to cast votes in a talent contest or buy goods on offer from the screen. This is already happening, but no one is quite sure how much interaction viewers want.

televisions and computers

The next major development in television will come from the computer world. An add-on unit, or even a unit built into a television set, can record video on a magnetic hard disk like that used in a personal computer. This lets the viewer watch a programme as it is being recorded, but pause playback if, for instance, the telephone rings. While playback is paused, the programme continues to record and viewing can be started again at any time, with the programme now running a few minutes behind its live transmission. The same devices can be set to record all programmes of a selected type, for example soaps, football, operas, and so on, while the viewer is out. A menu of available viewing then appears on screen. Scheduling becomes irrelevant to the viewer; broadcasters no longer have peak viewing times. And viewers can easily skip through commercials, too.

television



(Image © Research Machines plc)

Simplified block diagram of a complete colour television system – transmitting and receiving. The camera separates the picture into three colours – red, blue, green – by using filters and different camera tubes for each colour. The audio signal is produced separately from the video signal. Both signals are transmitted from the same aerial using a special coupling device called a diplexer. There are four sections in the receiver: the aerial, the tuners, the decoders, and the display. As in the transmitter, the audio and video signals are processed separately. The signals are amplified at various points.

Digital television in the UK: key dates

1991	The European Launching Group (ELG), an independent voluntary industry group, is established to oversee development of a digital television system for Europe.
1993	The ELG becomes Digital Video Broadcasting (DVB).
1996	The BBC begins a limited trial service of Digital Terrestrial Television (DTT).
1997	DVB is making digital television a reality, using a system that delivers programmes of standard (analogue phase alternate line (PAL) system) quality. Its technology and standards are adopted by Europe's governments and official bodies, and services begin to roll out across Europe. The same technology is being adopted in many other countries round the world – with the exception of the USA where digital TV is seen as a way of delivering a few channels of high definition (HD) pictures to viewers willing to buy new HD receivers. In the UK the new pay broadcaster ONdigital (the trading name for British Broadcasting plc owned by Granada and Carlton) is granted a DTT licence.
September 1998	The BBC launch BBC Choice a week before the necessary receiving equipment is available in the shops.
October 1998	Rupert Murdoch's British Sky Broadcasting Group (BSkyB) launches its Sky Digital satellite service with a unique offer: anyone who agrees to connect the receiver to a telephone line pays a reduced price for the set-top receiver box, or digibox, and dish aerial. The service allows BSkyB's sister company, British Interactive Broadcasting, to offer its online shopping service, Open, through an ordinary television set.
November 1998	Launch of FilmFour, a new DTT film subscription channel. ONdigital launches its 30-channel DTT service. Viewers who sign up for ONdigital's pay channels pay a reduced price for the set-top box, which connects the aerial to an ordinary television set.
December 1998	Channel ITV2, a new DTT service for England and Wales, is launched.
February 1999	The cable company Telewest Communications plc launches its DTT service in the Midlands, promising rapid expansion.
April 1999	S2, Scotland's second ITV channel, is launched on DTT.
May 1999	BSkyB announces that from June it will give away set-top boxes for free to anyone who signs up for a subscription; the cost to BSkyB is an estimated £400 million. ONdigital quickly matches the offer. Just like the cellphone companies, which have long given away free phones, digital broadcasters must now make their money from customer use.
June 1999	BBC Knowledge is launched (available through ONdigital Channel 13, via a set-top box; Sky Digital Channel 573, via a set-top box and satellite dish; and Digital Cable). Northern Ireland's second ITV channel, TV-YOU, is launched on DTT.

July 1999	The music channel MTV becomes available through ONdigital.
August 1999	Sky Digital launches British Eurosport. The government-appointed Davies Panel recommends a digital supplement of £24 on top of the licence fee for those buying digital services, in order to support BBC digital television. 60% of viewers say this would put them off buying the technology. The supplement is rejected by parliament in February 2000.
September 1999	UK culture secretary Chris Smith announces that the government expects to switch off the existing analogue service between 2006 and 2010, but only if at least 95% of viewers have digital television sets or set-top boxes, and if providers can reach 99.4% of the population. At this time 70% of households have analogue sets and 1.5 million households have digital television. A survey conducted for the BBC by media consultancy ECON concludes that only just over 55% of households are interested in pay television, interest being lowest among older age and lower income groups. Using Sky's interactive digital TV channel, Open, Abbey National is the first UK financial service to launch its services on DTT.
February 2000	Chris Smith announces that a white paper overhauling the regulations governing broadcasting and telecommunications services will be published in the autumn, in order to pave the way for a switch to digital television.
March 2000	Around 3 million households have signed up to digital television in the last 18 months, but an independent television commission says that the switch to digital television in six years is unrealistic.
April 2000	NTL, the UK's biggest cable company, begins its digital services in Scotland, Northern Ireland, and Wales, including pay per view and full Internet access. HSBC becomes the first bank to make its digital banking service (launched autumn 1999) fully interactive on digital television screens (using Open).
May 2000	According to researchers at Oxford University's environmental change unit, digital television will increase domestic power consumption in UK homes by 7% by 2010 and so add significantly to global warming. This is because set-top boxes have to be on full power all the time in order to receive.
March 2002	ITV Digital collapses with debts of £1.2 billion.
October 2002	Freeview is launched, a BBC- and BSkyB-backed free-to-air service offering 30 television and radio channels for a one-off payment of about £99. Its channels include BBC3, BBC4, and CBeebies.
June 2003	A report finds that Freeview is attracting viewers previously disinterested in pay-TV services, particularly those aged over 55, who make up 40% of its customers.
May 2006	Sky launches its high definition television (HDTV) service.

Television: key dates

1878	English engineer William Crookes invents the Crookes tube, which produces cathode rays.
1884	German inventor Paul Nipkow builds a mechanical scanning device, the Nipkow disc, a rotating disc with a spiral pattern of holes in it.
1897	German inventor Karl Ferdinand Braun modifies the Crookes tube to produce the ancestor of the TV receiver picture tube. In his evacuated tube, a beam of cathode rays (electrons), guided by electromagnetic fields, forms a picture on a fluorescent screen.
1906	Russian engineer Boris Rosing begins to experiment with the Nipkow disc and cathode-ray tube, eventually succeeding in transmitting some crude TV pictures.
1919	US inventor Charles Francis Jenkins patents a television system using prismatic rings.
1923	Russian-born US engineer Vladimir Zworykin invents the first electronic camera tube, the iconoscope.
1926	Scottish inventor John Logie Baird demonstrates a workable TV system, using mechanical scanning by Nipkow disc.
1928	Baird demonstrates colour TV.
1929	The British Broadcasting Corporation (BBC) begins broadcasting experimental TV programmes, using Baird's system.
1931	US physicist Allen Balcom Du Mont perfects the first practical, low-cost cathode-ray tube.
1936	The BBC begins regular broadcasting from Alexandra Palace, London, using a high-definition all-electronic system developed by EMI. This marks the end of the BBC's usage of Baird's system.
1938	Allen Balcom Du Mont manufactures the first all-electronic receiver to be marketed in the USA. It uses a huge 35 cm/14 in cathode ray tube.
1939	The National Broadcasting Company (NBC) begins the first regular television broadcasting service in the USA.
1940	Experimental colour TV transmission begins in the USA, as the Columbia Broadcasting System (CBS) in New York City makes colour broadcasts using a semi-mechanical method called the 'field sequential system'.
Late 1940s	Cable television, also known as community antenna television (CATV) begins in the USA.
1953	Successful colour TV transmissions begin in the USA, using the NTSC (National Television Systems Committee) system. This system is used today throughout the American continents and Japan.
1956	The first videotape recorder is produced in California by the Ampex Corporation.
1950s	Two systems for transmitting colour television are introduced in Europe. Germany brings in the phase-alternate line (PAL) system, which is later adopted in the UK and most of Western Europe, Africa, Asia, and Australia. Meanwhile France introduces *Sequentiel coleur à mémoir* (SECAM), a system that becomes the standard there and in Eastern Europe and the Middle East.
1962	TV signals are transmitted across the Atlantic via the Telstar satellite.
1970	The first video disc system is announced by Decca in Britain and AEG-Telefunken in Germany, but it is not perfected until the 1980s, when laser scanning is used for playback.
1973	The BBC and Independent Television in the UK introduce the world's first teletext systems, Ceefax and Oracle, respectively.
1975	Sony introduces a videocassette tape-recorder system, Betamax, for domestic viewers, six years after their professional U-Matic system. The UK Post Office (now British Telecom) announces the Prestel viewdata system.
1979	Matsushita in Japan develops a pocket-sized, flat-screen TV set, using a liquid-crystal display.
1986	Data broadcasting using digital techniques is developed; an enhancement of teletext is produced.
1989	The Japanese begin broadcasting high definition television; satellite television is introduced in the UK.
1990	The BBC introduces a digital stereo sound system (NICAM); MAC, a European system allowing greater picture definition, more data, and sound tracks, is introduced.

1992	All-digital high definition television is demonstrated in the USA.
1993	A worldwide standard for digital television is agreed at a meeting of manufacturers and broadcasters in Sydney, Australia. The Japanese electronics company NEC announces the development of a flat thin screen that produces full-colour high-resolution pictures, without a cathode-ray tube. Television in the form of wraparound 'Sport' television glasses goes on sale in the USA, enabling the wearer to watch television while walking.
1995	The US House of Representatives votes in favour of including a chip in all TV sets that will allow parents to censor and block out certain categories of programmes that they consider unsuitable for their children's viewing.
1998	A report by the British Government select committee on culture, media, and sport recommends that the government set 2010 as the latest date for closing down the analogue network. All non-digital television receivers from that date will need a set-top box or adaptor, but many may not be worth upgrading.
1999	Multi-channel digital television broadcasting, launched in late 1998, becomes widely available to the public in the UK. The chief service providers are Sky, providing a digital service via satellite, and ONdigital, supplying digital television through existing terrestrial aerials. Both services require a set-top box. UK broadcasting services offer new digital channels alongside digital versions of existing analogue channels. The first digital video recorders, which record television shows to digital storage, were launched.
2000	Television and online computer technologies begin to converge as digital TV service providers begin marketing limited Internet (Web browsing and e-mail) services via television. Digital TV providers and cable companies also begin selling 'movies-on-demand' services. In the UK, the government expects digital TV to supersede analogue TV by 2006.
2006	High definition television is launched in the UK.

Big Dream, Small Screen

Go to site

Companion to the US Public Broadcasting Service (PBS) television programme *The American Experience*, this page tells the story of Philo Farnsworth, David Sarnoff, and the invention of the television. You will also find an interesting section on TV milestones that features numerous photographs, a list of quotes about television, a biography of David Sarnoff, and a list of sources for further reading.

Farnsworth Chronicles

Go to site

Account of the little known story of Philo T Farnsworth, the 'forgotten genius who invented electronic video'. First published in 1977, the material displayed in this page was gathered during the 1970s from exhaustive interviews conducted with Farnsworth's widow and eldest son, which were then set against the existing historical records. The site also comprises bonus features on the time before television, Farnsworth's single, and intriguing appearance on TV and more.

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telex

contraction of teleprinter exchange

international telecommunications network that handles telegraph messages in the form of coded signals. It uses teleprinters for transmitting and receiving, and makes use of land lines (cables) and radio and satellite links to make connections between subscribers.

Teller, Edward (1908-2003)

Hungarian-born US physicist known as the father of the hydrogen bomb (H-bomb). He worked on the Manhattan Project developing the fission bomb – the first atomic bomb 1942–46, and on the fusion, or hydrogen, bomb 1946–52. Vigorous in his promotion of nuclear weapons and in his opposition to communism, he was, in the 1980s, one of the leading advocates of the Star Wars programme (the Strategic Defense Initiative).

He was a key witness against his colleague J Robert Oppenheimer at the security hearings in 1954. Teller was widely believed to be the model for the leading character in Stanley Kubrick's film *Dr Strangelove* (1964). It was also Teller who convinced US president Ronald Reagan of the feasibility of the Star Wars project for putting fission-bomb-powered X-ray lasers into orbit for the purpose of shooting down enemy ballistic missiles. Millions of dollars were spent before the project was discontiued. Teller also suggested the use of nuclear explosions to prevent asteroids hitting the Earth. He opposed all test-ban treaties.

Edward Teller Profile

Go to site

Description of the life and work of the 'father of the hydrogen bomb', physicist Edward Teller. The Web site contains not only a profile and biographical information, but also holds a lengthy interview with Teller from 1990 accompanied by a large number of photographs, video sequences, and audio clips.

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tellurium

chemical symbol Te

(Latin Tellus 'Earth')

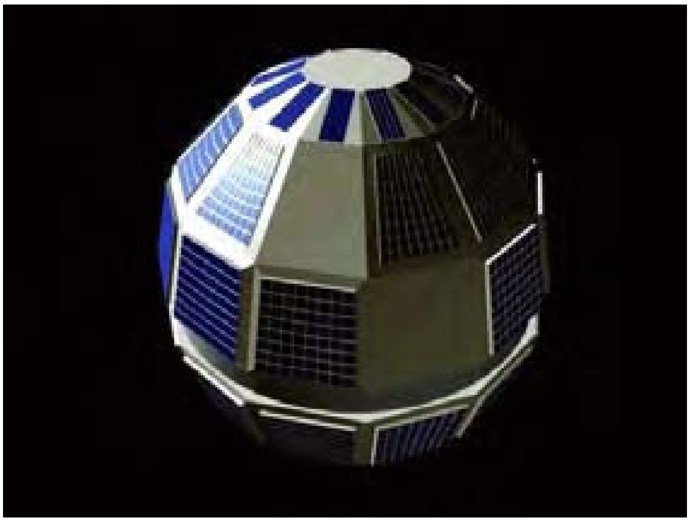
silver-white, semi-metallic (metalloid) element, atomic number 52, relative atomic mass 127.60. Chemically it is similar to sulphur and selenium, and it is considered one of the sulphur group. It occurs naturally in telluride minerals, and is used in colouring glass blue-brown, in the electrolytic refining of zinc, in electronics, and as a catalyst in refining petroleum.

It was discovered in 1782 by the Austrian mineralogist Franz Müller (1740-1825), and named in 1798 by the German chemist Martin Klaproth.

Telstar

US communications satellite, launched on 10 July 1962, which relayed the first live television transmissions between the USA and Europe. Telstar orbited the Earth every 2.63 hours, and unlike later geostationary satellites was only usable when in line-of-sight of two tracking stations.

Telstar



(Image © Research Machines plc)

The early satellite Telstar, made by AT&T Bell Labs and launched by NASA. Telstar ceased transmission after it was affected by radiation from a nuclear test on Earth.

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temperature

measure of how hot an object is. It is temperature difference that determines whether heat transfer will take place between two objects and in which direction it will flow, that is from warmer object to cooler object. The temperature of an object is a measure of the average kinetic energy possessed by the atoms or molecules of which it is composed. The SI unit of temperature is the kelvin (symbol K) used with the Kelvin scale. Other measures of temperature in common use are the Celsius scale and the Fahrenheit scale. The Kelvin scale starts at absolute zero (0 K = -273°C). The Celsius scale starts at the freezing point of water (0°C = 273 K). 1 K is the same temperature interval as 1°C.

The normal temperature of the human body is about 36.9°C/98.4°F. Variation by more than a degree or so indicates ill health, a rise signifying excessive activity (usually due to infection), and a decrease signifying deficient heat production (usually due to lessened vitality).

temperature

To understand temperature on the Celsius scale for those used to Fahrenheit temperatures:

30 is hot; 20 is nice; 10 is cold; 0 is ice

Explanation of Temperature Related Theories

Go to site

Detailed explanatory site on the laws and theories of temperature. It explains what temperature actually is, what a thermometer is, and the development of both, complete with illustrations and links to pioneers in the field. There is a temperature conversion facility and explanations of associated topics such as kinetic theory and thermal radiation.

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temperature regulation

ability of an organism to control its internal body temperature. Animals that rely on their environment for their body temperature (and therefore have a variable temperature) are known as **ectotherms** or 'cold-blooded' animals (for example, lizards). Animals with a constant body temperature irrespective of their environment are known as **endotherms** or 'warm-blooded' animals (for example, birds and mammals). Their temperature is regulated by the hypothalamus in the brain.

Ectotherms have behavioural means of temperature control; they can warm themselves up by basking in the sun, or shivering, and can cool themselves down by sheltering from the sun under a rock or by bathing in water. In cold weather their metabolism slows and they become less active.

Endotherms too can regulate temperature by behavioural means (for example, seeking sun or shade), but also make use of physical and metabolic processes of regulation. The skin plays an important role - heat can be lost by sweating, whereby the water secreted evaporates from the skin and causes cooling. Heat can also be lost through capillaries near the surface of the skin, which flush with blood and lose heat by radiation. In the same way, heat can be retained by diverting blood from the surface capillaries, which gives the skin a paler colour in the cold. Heat can also be retained by hairs which become erect and trap an insulating layer of air next to the skin (producing 'goose bumps'). In some animals, there is a more specialized insulating layer such as fur, feathers, or blubber. Endotherms can also gain heat metabolically through shivering, whereby involuntary muscle contractions release heat, and by an increased metabolism in the liver.

tempering

heat treatment for improving the properties of metals, often used for steel alloys. The metal is heated to a certain temperature and then quenched (cooled suddenly) in a water or oil bath to fix its state.

The temperature of steel during this process can be measured by changes in the colour of the metal as it gets hotter: it is light yellow at around 230°C/446°F, changes to dark yellow, red-brown, then purple, and finally becomes blue at around 295°C/563°F.

tench

European freshwater bony fish *Tinca tinca*, a member of the carp family, now established in North America. It is about 45 cm/18 in long, weighs 2 kg/4.5 lb, and is coloured olive-green above and grey beneath. The scales are small and there is a barbel at each side of the mouth.

tendon

or sinew

in vertebrates, a cord of very strong, fibrous connective tissue that joins muscle to bone. Tendons are largely composed of bundles of fibres made of the protein collagen, and because of their inelasticity are very efficient at transforming muscle power into movement.

tendril

in botany, a slender, threadlike structure that supports a climbing plant by coiling around suitable supports, such as the stems and branches of other plants. It may be a modified stem, leaf, leaflet, flower, leaf stalk, or stipule (a small appendage on either side of the leaf stalk), and may be simple or branched. The tendrils of Virginia creeper *Parthenocissus quinquefolia* are modified flower heads with suckerlike pads at the end that stick to walls, while those of the grapevine *Vitis* grow away from the light and thus enter dark crevices where they expand to anchor the plant firmly.

tension

in physics, the stress (force) set up in a stretched material. In a stretched string or wire it exerts a pull that is equal in magnitude but opposite in direction to the stress being applied at the string ends. Tension is measured in newtons.

teratogen

any substance or agent that can induce deformities in the fetus if absorbed by the mother during pregnancy. Teratogens include some drugs (notably alcohol and thalidomide), other chemicals, certain disease organisms, and radioactivity.

terbium

chemical symbol Tb

soft, silver-grey, metallic element of the lanthanide series, atomic number 65, relative atomic mass 158.925. It occurs in gadolinite and other ores, with yttrium and ytterbium, and is used in lasers, semiconductors, and television tubes. It was named in 1843 by Swedish chemist Carl Mosander (1797-1858) after the town of Ytterby, Sweden, where it was first found.

Tereshkova, Valentina Vladimirovna (1937-)

Soviet cosmonaut, the first woman to fly in space. She was the solo pilot of a three-day flight 16-19 June 1963 in *Vostok 6*, orbiting the Earth 48 times. Her flight on the last of the *Vostok* series was her only experience in space.

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terminal

in computing, a device consisting of a keyboard and display screen (VDU) to enable the operator to communicate with the computer. The terminal may be physically attached to the computer or linked to it by a telephone line (remote terminal). A dumb terminal has no processor of its own, whereas an intelligent terminal has its own processor and takes some of the processing load away from the main computer.

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terminal moraine

linear, slightly curved ridge of rocky debris deposited at the front end, or snout, of a glacier. It represents the furthest point of advance of a glacier, being formed when deposited material (till), which was pushed ahead of the snout as it advanced, became left behind as the glacier retreated.

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terminal velocity

or terminal speed

the maximum velocity that can be reached by a given object moving through a fluid (gas or liquid) under the action of an applied force. As the speed of the object increases so does the total magnitude of the forces resisting its motion. Terminal velocity is reached when the resistive forces exactly balance the applied force that has caused the object to accelerate; because there is now no resultant force, there can be no further acceleration.

For example, an object falling through air experiences air resistance. It will reach a terminal velocity and cease to accelerate under the influence of gravity when the air resistance equals the force of gravity (the object's weight).

Parachutes are designed to increase air resistance so that the acceleration of a falling person or package ceases more rapidly, thereby limiting terminal velocity to a safe level.

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terminal voltage

potential difference (pd) or voltage across the terminals of a power supply, such as a battery of cells. When the supply is not connected in circuit its terminal voltage is the same as its electromotive force (emf); however, as soon as it begins to supply current to a circuit its terminal voltage falls because some electric potential energy is lost in driving current against the supply's own internal resistance. As the current flowing in the circuit is increased the terminal voltage of the supply falls.

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termite

any member of the insect order Isoptera. Termites are soft-bodied social insects living in large colonies which include one or more queens (of relatively enormous size and producing an egg every two seconds), much smaller kings, and still smaller soldiers, workers, and immature forms. Termites build galleried nests of soil particles that may be 6 m/20 ft high.

Termites may dispose of a quarter of the vegetation litter of an area, and their fondness for wood (as in houses and other buildings) brings them into conflict with humans. The wood is broken down in their stomachs by numerous micro-organisms living in symbiosis with their hosts. Some species construct adjustable air vents in their nests, and one species moistens the inside of the nest with water to keep it cool. One group of African termites, the Macrotermitinae, constructs fungus gardens, within the nest, by infecting its own faeces with a special fungus that digests the faeces and renders them edible. Fossilized termite nests found in Arizona, USA, have been estimated to be about 220 million years old.

Termites in the rainforest mostly excavate huge underground nests and feed on rotting vegetation. In one UK study in Cameroon (1993-98) soil-dwelling termites, many of which were discovered to be new species, were found to have a greater biomass than any other animal group.

termite: environment

Termite nests may house two million termites and reach heights of up to 6 m/6.6 yd. A skyscraper built to the same scale would be 8 km/5 mi high.

termite: reproduction

The female termite queen has more than 2,000 ovarioles (egg-producing follicles). The female of the tsetse fly, in contrast, has only one.

termite: soldier defence

The soldiers of Australian termite *Nasutitermes exitiosus* spray an irritant glue at attackers from nozzles on the front of their heads. As the attacker struggles to wipe away the substance, it succeeds only in covering its legs with glue.

termite: worker defence

Termites of the *Ruptitermes* genus do not have a soldier caste to protect the worker ants. Instead, each worker has a store of a toxic sticky secretion in its abdomen. If attacked, it constricts a muscle in its abdomen that causes it to explode, spraying the attacker with the noxious substance.

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tern

any of various lightly built seabirds in the gull family Laridae, order Charadriiformes, with pointed wings and bill, and usually a forked tail. Terns plunge-dive after aquatic prey. They are 20–50 cm/8–20 in long, and usually coloured in combinations of white and black. They are extensively distributed, especially in temperate climates.

species

The **common tern** *Sterna hirundo* has white underparts, grey upper wings, and a black crown on its head. The **Arctic tern** *Sterna paradisea* migrates from northern parts of Greenland, North America, and Europe to the Antarctic, thereby ensuring most of its life is spent in daylight. The **Antarctic tern** *Sterna vittata* has a striking blood-red beak; it does not migrate.

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terrane

tract of land with a distinct geological character. The term **exotic terrane** is commonly used to describe a rock mass that has a very different history from others near by. The exotic terranes of the Western Cordillera of North America represent old island chains that have been brought to the North American continent by the movements of plate tectonics, and welded to its edge.

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terrapin

general name for any turtle that frequents fresh or brackish water. The name is sometimes specifically used for the tidewater diamondback terrapins (genus *Malaclemys*) of eastern North America.

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terrestrial planet

any of the four small, rocky inner planets of the Solar System: Mercury, Venus, Earth, and Mars. The Moon is sometimes also included, although it is a satellite of the Earth and not strictly a planet.

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terrier

any of various breeds of highly intelligent, active dogs. They are usually small. Types include the bull, cairn, fox, Irish, Scottish, Sealyham, Skye, and Yorkshire terriers. They were originally bred for hunting rabbits and following quarry such as foxes down into burrows.

The small Parson Jack Russell terrier was recognized by the Kennel Club in 1990 as a variant of the fox terrier.

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territorial behaviour

in biology, any behaviour that serves to exclude other members of the same species from a fixed area or territory. It may involve aggressively driving out intruders, marking the boundary (with dung piles or secretions from special scent glands), conspicuous visual displays, characteristic songs, or loud calls.

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territory

in animal behaviour, a fixed area from which an animal or group of animals excludes other members of the same species. Animals may hold territories for many different reasons; for example, to provide a constant food supply, to monopolize potential mates, or to ensure access to refuges or nest sites.

The size of a territory depends in part on its function: some nesting and mating territories may be only a few square metres, whereas feeding territories may be as large as hundreds of square kilometres.

Tertiary period

period of geological time 65 to 1.64 million years ago, divided into five epochs: Palaeocene, Eocene, Oligocene, Miocene, and Pliocene. During the Tertiary period, mammals took over all the ecological niches left vacant by the extinction of the dinosaurs, and became the prevalent land animals. The continents took on their present positions, and climatic and vegetation zones as we know them became established. Within the geological time column the Tertiary follows the Cretaceous period and is succeeded by the Quaternary period.

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tesla

symbol T

SI unit of magnetic flux density. One tesla represents a flux density of one weber per square metre, or 10^4 gauss. It is named after the Croatian-born US physicist Nikola Tesla.

Tesla, Nikola (1856-1943)

Croatian-born US physicist and electrical engineer who invented fluorescent lighting, the Tesla induction motor (1882-87), and the Tesla coil, and developed the alternating current (AC) electrical supply system.

The **Tesla coil** is an air core transformer with the primary and secondary windings tuned in resonance to produce high-frequency, high-voltage electricity. Using this device, Tesla produced an electric spark 40 m/135 ft long in 1899. He also lit more than 200 lamps over a distance of 40 km/25 mi without the use of intervening wires. Gas-filled tubes are readily energized by high-frequency currents and so lights of this type were easily operated within the field of a large Tesla coil. Tesla soon developed all manner of coils which have since found numerous applications in electrical and electronic devices.

Tesla, Nikola

Go to site

Short biography of the electrical inventor plus quotations by and about Tesla, anecdotes, a photo gallery, and links to other sites of interest.

---

testa

outer coat of a seed, formed after fertilization of the ovule. It has a protective function and is usually hard and dry. In some cases the coat is adapted to aid dispersal, for example by being hairy. Humans have found uses for many types of testa, including the fibre of the cotton seed.

---

test cross

in genetics, a breeding experiment used to discover the genotype of an individual organism. By crossing with a double recessive of the same species, the offspring will indicate whether the test individual is homozygous or heterozygous for the characteristic in question. In peas, a tall plant under investigation would be crossed with a double recessive short plant with known genotype tt. The results of the cross will be all tall plants if the test plant is TT. If the test plant is in fact Tt then there will be some short plants (genotype tt) among the offspring.

---

test data

data designed to test whether a new computer program is functioning correctly. The test data are carefully chosen to ensure that all possible branches of the program are tested. The expected results of running the data are written down and are then compared with the actual results obtained using the program.

---

testis

plural testes

organ that produces sperm in male (and hermaphrodite) animals. In vertebrates it is one of a pair of oval structures that are usually internal, but in mammals (other than elephants and marine mammals), the paired testes (or testicles) descend from the body cavity during development, to hang outside the abdomen in a scrotal sac. The testes also secrete the male sex hormone androgen.

---

testosterone

hormone secreted chiefly by the testes, but also by the ovaries and the cortex of the adrenal glands. It promotes the development of secondary sexual characteristics in males at puberty. It is also needed for the development of the male sex organs and for male fertility. The hormone is partly responsible for the difference in behaviour that may be seen between males and females. In animals with a breeding season, the onset of breeding behaviour is accompanied by a rise in the level of testosterone in the blood.

Synthetic or animal testosterone is used to treat inadequate development of male characteristics or (illegally) to aid athletes' muscular development. Like other sex hormones, testosterone is a steroid.

---

tetanus

or lockjaw

acute disease caused by the toxin of the bacillus *Clostridium tetani*, which usually enters the body through a wound. The bacterium is chiefly found in richly manured soil. Untreated, in seven to ten days tetanus produces muscular spasm and rigidity of the jaw spreading to other parts of the body, convulsions, and death. There is a vaccine, and the disease may be treatable with tetanus antitoxin and antibiotics.

Neonatal (newborn) tetanus is the most common form of tetanus in the developing world. It is caused by cutting the umbilical cord with non-sterile instruments. It affects around half a million newborns per year (2006), with a very high fatality rate (95% if untreated, 25-90% with treatment).

Childhood Infections - Tetanus

Go to site

Important information on the signs and symptoms of tetanus, the incubation, duration, and treatment of the illness. Specific reference is made to neonatal tetanus that affects new born infants as a result of inefficient surgical techniques during delivery.

---

tetany

in medicine, muscle spasm caused by reduction in the concentration of calcium circulating in the blood. In the absence of calcium, the muscles become hyperexcitable and will go into spasm on the slightest stimulus. It is treated with calcium salts and vitamin D.

Tethys Sea

sea that in the Mesozoic era separated Laurasia from Gondwanaland. The formation of the Alpine fold mountains caused the sea to separate into the Mediterranean, the Black, the Caspian, and the Aral seas.

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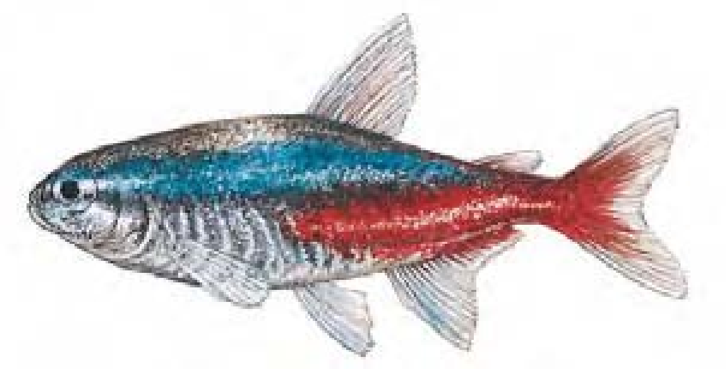
tetra

any of various brightly coloured tropical freshwater bony fishes of the family Characidae, formerly placed in the genus *Tetragonopterus*. Tetras are found mainly in tropical South America, and also in Africa.

tetra



(Image © Research Machines plc)

A popular aquarium fish, the tetra is about 8 cm/3 in long and beautifully coloured.

---

tetrachloromethane

or carbon tetrachloride; CCl_4

chlorinated organic compound that is a very efficient solvent for fats and greases, and was at one time the main constituent of household dry-cleaning fluids and of fire extinguishers used with electrical and petrol fires. Its use became restricted after it was discovered to be carcinogenic and it has now been largely removed from educational and industrial laboratories.

---

tetracycline

one of a group of antibiotic compounds having in common the four-ring structure of chlortetracycline, the first member of the group to be isolated. They are prepared synthetically or obtained from certain bacteria of the genus *Streptomyces*. They are broad-spectrum antibiotics, effective against a wide range of disease-causing bacteria.

---

tetrahedron

plural tetrahedra

in geometry, a solid figure (polyhedron) with four triangular faces; that is, a pyramid on a triangular base. A regular tetrahedron has equilateral triangles as its faces.

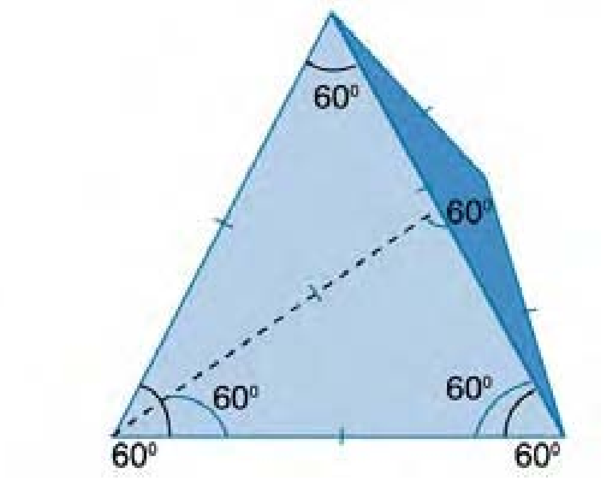
The volume (V) of a tetrahedron is given by

$V = 1/3Bh$

where B is the area of the base and h is the perpendicular height.

In chemistry and crystallography, tetrahedra describe the shapes of some molecules and crystals; for example, the carbon atoms in a crystal of diamond are arranged in space as a set of interconnected regular tetrahedra.

tetrahedron



(Image © Research Machines plc)

A regular tetrahedron is a pyramid on a triangular base with all its sides equal in length.

---

tetrapod

(Greek 'four-legged')

type of vertebrate. The group includes mammals, birds, reptiles, and amphibians. Birds are included because they evolved from four-legged ancestors, the forelimbs having become modified to form wings. Even snakes are tetrapods, because they are descended from four-legged reptiles.

---

text editor

in computing, a program that allows the user to edit text on the screen and to store it in a file. Text editors are similar to word processors, except that they lack the ability to format text into paragraphs and pages and to apply different typefaces and styles.

---

texting

sending text messages by phone; see text messaging.

---

text messaging

or texting, messaging, SMSing

sending text messages by mobile phone. Text messaging has evolved its own abbreviated versions of written language due to the limited number of characters allowed per text message. The text messaging service is also referred to as SMS (short message service).

---

textured vegetable protein

manufactured meat substitute; see TVP.

TGV

abbreviation for train à grande vitesse, 'high-speed train'

French electrically powered train that provides the world's fastest rail service. Since it began operating in 1981, it has carried more than 100 million passengers between Paris and Lyon, at average speeds of 214 kph/133 mph. In 1990, a TGV broke the world speed record, reaching a speed of 515.3 kph/320.2 mph (about half that of a passenger jet aircraft) on a stretch of line near Tours.

In 1990 a second service, the Atlantique, was launched, running from Paris to Le Mans and Tours. A third linking Paris with the Channel Tunnel, Brussels, and Cologne opened in 1993. The TGV network now extends to the Mediterranean, Switzerland, and Britanny. A new route is planned eastwards to Strasbourg, opening in 2006.

---

thalassaemia

or Cooley's anaemia

any of a group of chronic hereditary blood disorders that are widespread in the Mediterranean countries, Africa, the Far East, and the Middle East. They are characterized by an abnormality of the red blood cells and bone marrow, with enlargement of the spleen. The genes responsible are carried by about 100 million people worldwide. The diseases can be diagnosed prenatally.

---

thalidomide

hypnotic drug developed in the 1950s for use as a sedative. When taken in early pregnancy, it caused malformation of the fetus (such as abnormalities in the limbs) in over 5,000 recognized cases, and the drug was withdrawn.

In 1995 US researchers announced trials using thalidomide derivatives for a variety of immune disorders, including AIDS, cancer, and graft-versus-host disease – it was already used routinely in the treatment of leprosy. In 1997 it was approved for that purpose by the US Food and Drug Administration.

---

thallium

chemical symbol Tl

(Greek thallos 'young green shoot')

soft, bluish-white, malleable, metallic element, atomic number 81, relative atomic mass 204.38. It is a poor conductor of electricity. Its compounds are poisonous and are used as insecticides and rodent poisons; some are used in the optical-glass and infrared-glass industries and in photocells.

Discovered spectroscopically by its green line, thallium was isolated and named by William Crookes in 1861.

---

thallus

any plant body that is not divided into true leaves, stems, and roots. It is often thin and flattened, as in the body of a seaweed, lichen, or liverwort, and the gametophyte generation (prothallus) of a fern.

Some flowering plants (angiosperms) that are adapted to an aquatic way of life may have a very simple plant body which is described as a thallus (for example, duckweed *Lemna*).

---

thaumatin

naturally occurring, non-carbohydrate sweetener derived from the bacterium *Thaumatococcus danielli*. Its sweetness is not sensed as quickly as that of other sweeteners, and it is not as widely used in the food industry.

theodolite

instrument for the measurement of horizontal and vertical angles, used in surveying. It consists of a small telescope mounted so as to move on two graduated circles, one horizontal and the other vertical, while its axes pass through the centre of the circles. See also triangulation.

theorem

mathematical proposition that can be deduced by logic from a set of axioms (basic facts that are taken to be true without proof). Advanced mathematics consists almost entirely of theorems and proofs, but even at a simple level theorems are important.

theory

in science, a set of ideas, concepts, principles, or methods used to explain a wide set of observed facts. Among the major theories of science are relativity, quantum theory, evolution, and plate tectonics.

therm

unit of energy defined as 10^5 British thermal units; equivalent to 1.055×10^8 J. It is no longer in scientific use.

thermal capacity

another name for heat capacity

thermal conductivity

ability of a substance to conduct heat. Good thermal conductors, like good electrical conductors, are generally materials with many free electrons, such as metals. A poor conductor, called an insulator, has low conductivity.

Thermal conductivity is expressed in units of joules per second per metre per kelvin (J s^{-1} m^{-1} K^{-1}). For a block of material of cross-sectional area a and length l, with temperatures T_1 and T_2 at its end faces, the thermal conductivity λ equals $Hl/at(T_2 - T_1)$, where H is the amount of heat transferred in time t.

thermal dissociation

reversible breakdown of a chemical compound into simpler substances by heating it (see dissociation). The splitting of ammonium chloride into ammonia and hydrogen chloride is an example. On cooling, they recombine to form the salt.

thermal expansion

expansion that is due to a rise in temperature. It can be expressed in terms of linear, area, or volume expansion.

The coefficient of linear expansion α is the fractional increase in length per degree temperature rise; area, or superficial, expansion β is the fractional increase in area per degree; and volume, or cubic, expansion γ is the fractional increase in volume per degree. To a close approximation, $\beta = 2\alpha$ and $\gamma = 3\alpha$.

thermal prospection

an expensive remote-sensing method used in aerial reconnaissance, based on weak variations in temperature which can be found above buried structures whose thermal properties are different from those of their surroundings.

thermal reactor

nuclear reactor in which the neutrons released by fission of uranium-235 nuclei are slowed down in order to increase their chances of being captured by other uranium-235 nuclei, and so induce further fission. The material (commonly graphite or heavy water) responsible for doing so is called a **moderator**. When the fast newly emitted neutrons collide with the nuclei of the moderator's atoms, some of their kinetic energy is lost and their speed is reduced. Those that have been slowed down to a speed that matches the thermal (heat) energy of the surrounding material are called **thermal neutrons**, and it is these that are most likely to induce fission and ensure the continuation of the chain reaction. See nuclear reactor and nuclear energy.

---

thermic lance

cutting tool consisting of a tube of mild steel, enclosing tightly packed small steel rods and fed with oxygen. On ignition, temperatures above 3,000°C/5,400°F are produced and the thermic lance becomes its own sustaining fuel. It rapidly penetrates walls and a 23-cm/9-in steel door can be cut through in less than 30 seconds.

---

thermionic tube

electronic tube, used in telegraphy and telephony and in radio and radar, using space conduction by thermionically emitted electrons from an electrically heated cathode. Classification is into diode, triode, and multi-electrode tubes, but in most applications they have been replaced by transistors.

---

thermistor

resistor whose resistance changes significantly when its temperature changes. The resistance of a semiconductor thermistor decreases with increase of temperature. As temperature rises, the resistance of the material decreases so that the current passing through a thermistor increases rapidly. They are used to electronically detect changes in temperature (electrical thermometers), as in fire alarms and thermostats. They also are used in lamp filaments and electric motors to stop large currents flowing through them when they are initially turned on.

When a lamp is switched on, the thermistor is cold initially and conducts poorly and has a high resistance. As the bulb heats up, the **intrinsic conduction** of the thermistor improves because the increasing thermal energy of vibrating atoms liberates electrons. These electrons flow more freely as current as the resistance of the lamp's thermistor decreases. The resistance of metals increases with temperature. When a metal is heated, the atoms vibrate more, thus impeding the flow of electrons.

---

thermite process

method used in incendiary devices and welding operations. It uses a powdered mixture of aluminium and (usually) iron oxide, which, when ignited, gives out enormous heat. The oxide is reduced to iron, which is molten at the high temperatures produced. This can be used to make a weld. The process was discovered in 1895 by German chemist Hans Goldschmidt (1861-1923).

---

thermocouple

electric temperature measuring device consisting of a circuit having two wires made of different metals welded together at their ends. A current flows in the circuit when the two junctions are maintained at different temperatures (Seebeck effect). The electromotive force generated - measured by a millivoltmeter - is proportional to the temperature difference.

thermocouple

To remember the direction in which the current flows in a thermocouple made from antimony and bismuth metals:

a b c

The current flows from the **a**ntimony to the **b**ismuth through the **c**old junction

---

thermodynamics

branch of physics dealing with the transformation of heat into and from other forms of energy. It is the basis of the study of the efficient working of engines, such as steam and internal combustion engines. The three laws of thermodynamics are: (1) energy can be neither created nor destroyed, heat and mechanical work being mutually convertible; (2) it is impossible for an unaided self-acting machine to convey heat from one body to another at a higher temperature; and (3) it is impossible by any procedure, no matter how idealized, to reduce any system to the absolute zero of temperature (0 K/-273.15°C/-459.67°F) in a finite number of operations. Put into mathematical form, these laws have widespread applications in physics and chemistry.

---

thermography

photographic recording of heat patterns. It is used medically as an imaging technique to identify 'hot spots' in the body - for example, tumours, where cells are more active than usual. Thermography was developed in the 1970s and 1980s by the military to assist night vision by detecting the body heat of an enemy or the hot engine of a tank. It uses detectors sensitive to infrared (heat) radiation.

---

thermoluminescence

TL

release, in the form of a light pulse, of stored nuclear energy in a mineral substance when heated to perhaps 500°C/930° F. The energy originates from the radioactive decay of uranium and thorium, and is absorbed by crystalline inclusions within the mineral matrix, such as quartz and feldspar. The release of TL from these crystalline substances is used in archaeology to date pottery, and by geologists in studying terrestrial rocks and meteorites.

thermoluminescent dating

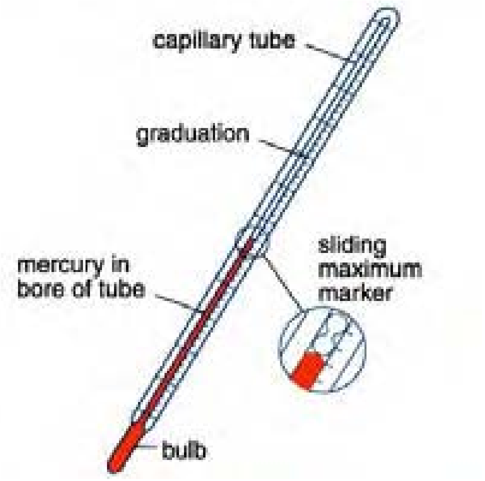
Crystalline substances found their way into the clay fabric of ancient pottery as additives designed to strengthen the material and allow it to breathe during kiln-firing at 600°C and above. Firing erased the huge level of TL energy accrued in geological times and sets a 'time-zero' for fresh energy accumulation over archaeological times, the TL intensity measured today being proportional to the pottery's age. TL can date inorganic materials, including stone tools left as burnt flint, older than about 50,000–80,000 years, although it is regarded as less precise in its accuracy than radiocarbon dating.

---

thermometer

instrument for measuring temperature. There are many types, designed to measure different temperature ranges to varying degrees of accuracy. Each makes use of a different physical effect of temperature. Expansion of a liquid is employed in common **liquid-in-glass thermometers**, such as those containing mercury or alcohol. The more accurate **gas thermometer** uses the effect of temperature on the pressure of a gas held at constant volume. A **resistance thermometer** takes advantage of the change in resistance of a conductor (such as a platinum wire) with variation in temperature. Another electrical thermometer is the thermocouple. Mechanically, temperature change can be indicated by the change in curvature of a **bimetallic strip** (as commonly used in a thermostat).

thermometer



(Image © Research Machines plc)

Maximum and minimum thermometers are universally used in weather-reporting stations. The maximum thermometer, shown here, includes a magnet that fits tightly inside a capillary tube and is moved up the tube by the rising mercury. When the temperature falls, the magnet remains in position, thus enabling the maximum temperature to be recorded.

---

thermopile

instrument for measuring radiant heat, consisting of a number of thermocouples connected in series with alternate junctions exposed to the radiation. The current generated (measured by an ammeter) is proportional to the radiation falling on the device.

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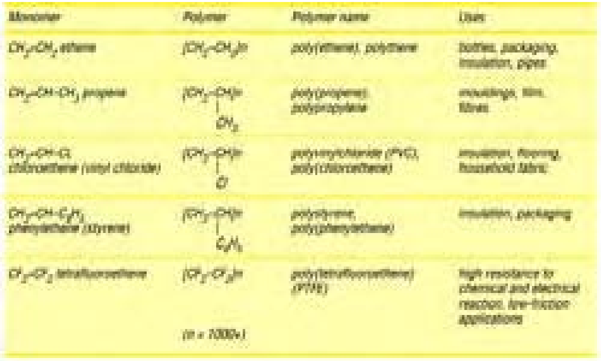
thermoplastic

or thermosoftening plastic

type of plastic that always softens on repeated heating. Thermoplastics include polyethene (polyethylene), polystyrene, nylon, and polyester.

thermoplastic



Monomer	Polymer	Polymer name	Uses
$CH_2=CH_2$ ethene	$[CH_2-CH_2]n$	poly(ethene), polythene	bottles, packaging, insulation, pipes
$CH_2=CH-CH_3$ propene	$[CH_2-CH]n$ CH_3	poly(propene), polypropylene	mouldings, film, fibres
$CH_2=CH-Cl$ chloroethene (vinyl chloride)	$[CH_2-CH]n$ Cl	polyvinylchloride (PVC), poly(chloroethene)	insulation, flooring, household fabric
$CH_2=CH-C_6H_5$ phenylethene (styrene)	$[CH_2-CH]n$ C_6H_5	polystyrene, poly(phenylethene)	insulation, packaging
$CF_2=CF_2$ tetrafluoroethene	$[CF_2-CF_2]n$ (n = 1000s)	poly(tetrafluoroethene) (PTFE)	high resistance to chemical and electrical reaction, low-friction applications

(Image © Research Machines plc)

Examples of thermosoftening plastics, their basic monomer origins, polymer names, and everyday uses.

Thermos

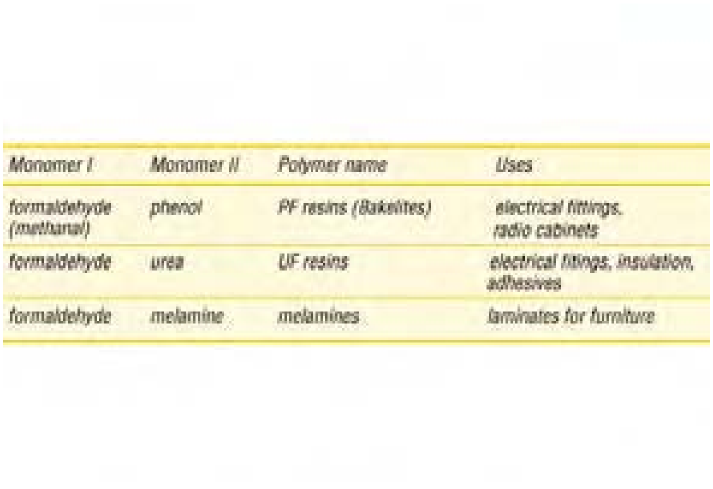
originally a trademarked name for a container for keeping things either hot or cold for several hours. It has two silvered glass walls enclosing a vacuum, filled into a metal or plastic outer case. This design reduces heat transfer by radiation (prevented by the silvering) and conduction (prevented by the vacuum). A vacuum flask is therefore equally efficient at keeping cold liquids cold, or hot liquids hot. It was invented by the British scientist James Dewar (1842-1923) in about 1872 to store liquefied gases.

---

thermoset

type of plastic that remains rigid when set, and does not soften with heating. Thermosets have this property because the long-chain polymer molecules cross-link with each other to give a rigid structure. Examples include Bakelite, resins, melamine, and urea-formaldehyde resins.

thermoset



Monomer I	Monomer II	Polymer name	Uses
formaldehyde (methanal)	phenol	PF resins (Bakelites)	electrical fittings, radio cabinets
formaldehyde	urea	UF resins	electrical fittings, insulation, adhesives
formaldehyde	melamine	melamines	laminates for furniture

(Image © Research Machines plc)

Unlike thermoplastics, thermosets remain rigid when set and do not soften when heated.

---

thermosphere

layer in the Earth's atmosphere above the mesosphere and below the exosphere. Its lower level is about 80 km/50 mi above the ground, but its upper level is undefined. The ionosphere is located in the thermosphere. In the thermosphere the temperature rises with increasing height to several thousand degrees Celsius. However, because of the thinness of the air, very little heat is actually present.

---

thermostat

temperature-controlling device that makes use of feedback. It employs a temperature sensor (often a bimetallic strip) to operate a switch or valve to control electricity or fuel supply. Thermostats are used in central heating, ovens, and engine cooling systems.

At the required preset temperature (for example of a room or gas oven), the movement of the sensor switches off the supply of electricity to the room heater or gas to the oven. As the room or oven cools down, the sensor turns back on the supply of electricity or gas.

---

thiamine

or vitamin B_1

a water-soluble vitamin of the B complex. It is found in seeds and grain. Its absence from the diet causes the disease beriberi.

1394

in computing, high-speed external serial bus system designed to connect computers and consumer electronics devices such as camcorders, digital television sets, DVD players, scanners, and colour printers. One 1394 port can connect up to 63 devices.

The development of FireWire was started in the 1990s by Apple Computer. It was finally specified as a standard in 2003 by the Institute of Electronic and Electrical Engineers. The system is also used by Sony Corporation who call it i.Link. 1394 was designed in part to provide a replacement for the SCSI bus and has been widely adopted as a standard connection interface for digital video cameras, but it also has many other applications.

1394 Trade Association

Go to site

Authoritative guide to the IEEE (Institute of Electronic and Electrical Engineers) 1394 standard for the connection of audiovisual devices to computers. This trade association site promotes and develops the 1394 interface technology, and publishes details of relevant news articles and upcoming events.

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35 mm

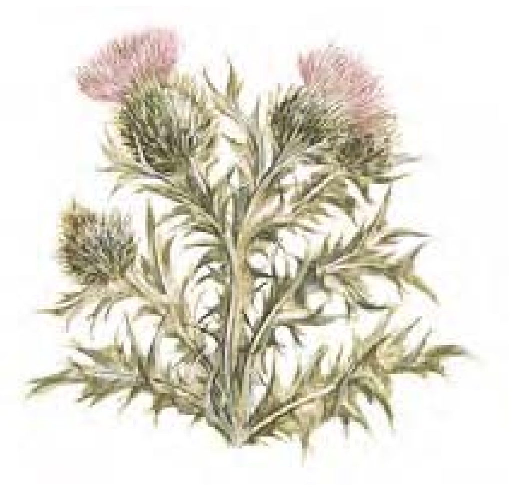
width of photographic film, the most popular format for the camera today. The 35-mm camera falls into two categories, the SLR and the rangefinder.

---

thistle

any of a group of prickly plants with spiny stems, soft cottony purple flower heads, and deeply indented leaves with prickly edges. The thistle is the national emblem of Scotland. (Genera include *Carduus*, *Carlina*, *Onopordum*, and *Cirsium*; family Compositae.)

thistle



(Image © Research Machines plc)

Some thistles are garden plants whilst others are troublesome weeds. Some varieties are used, in the young, nonspiny stage, as animal fodder.

Thomson, George Paget (1892-1975)

English physicist who shared the Nobel Prize for Physics in 1937 for his work on interference phenomena in the scattering of electrons by crystals which helped to confirm the wavelike nature of particles. He was knighted in 1943.

In the USA, C J Davisson made the same discovery independently, earlier the same year, using a different method.

Thomson, J(oseph) J(ohn) (1856-1940)

English physicist. He discovered the electron in 1897. His work inaugurated the electrical theory of the atom, and his elucidation of positive rays and their application to an analysis of neon led to the discovery of isotopes. He was awarded the Nobel Prize for Physics in 1906 for his theoretical and experimental work on the conduction of electricity by gases. He was knighted in 1908.

Using magnetic and electric fields to deflect positive rays, Thomson found in 1912 that ions of neon gas are deflected by different amounts, indicating that they consist of a mixture of ions with different charge-to-mass ratios. English chemist Frederick Soddy had earlier proposed the existence of isotopes and Thomson proved this idea correct when he identified, also in 1912, the isotope neon-22. This work was continued by his student Francis Aston.

---

thorax

part of the body in four-limbed vertebrates containing the heart and lungs, and protected by the ribcage. It is separated from the abdomen by the diaphragm. During breathing (ventilation) the volume inside the thorax is changed. This then causes air to move in or out of the air passages that lead to the lungs. The volume of the thorax is altered by the contraction of muscles in the diaphragm and the contraction of muscles between the ribs – the intercostal muscles.

In arthropods, the thorax is the middle part of the body, between the head and abdomen. In insects the thorax bears the legs and wings. The thorax of spiders and crustaceans, such as lobsters, is fused with the head, to form the cephalothorax.

---

thorium

chemical symbol Th

dark-grey, radioactive, metallic element of the actinide series, atomic number 90, relative atomic mass 232.038. It occurs throughout the world in small quantities in minerals such as thorite and is widely distributed in monazite beach sands. It is one of the fissile elements (others include uranium and plutonium) and its longest-lived isotope has a half-life of 1.39×10^{10} years. Thorium is used to strengthen alloys. It was discovered by Jöns Berzelius in 1828 and was named by him after the Norse god Thor.

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thorn apple

or jimson weed

annual plant belonging to the nightshade family, native to America and naturalized worldwide. It grows to 2 m/6 ft in northern temperate and subtropical areas and has white or violet trumpet-shaped flowers followed by capsulelike fruits that split to release black seeds. All parts of the plant are poisonous. (*Datura stramonium*, family Solanaceae.)

Thorndike, Edward Lee (1874-1949)

US educational psychologist whose experiments in behaviour of cats and dogs in a 'puzzle box' brought him to the conclusion that learning was improved when it achieved a satisfactory result. He extended this theory to human learning and found that students were encouraged by good results, but that being wrong did not teach them to correct their errors.

---

threadworm

or pinworm

parasitic nematode that may infest the human gut. Threadworms are relatively harmless and found mainly in children.

Three Age System

the division of prehistory into the Stone Age, Bronze Age, and Iron Age, first proposed by the Danish archaeologist Christian Thomsen 1816-19. Subsequently, the Stone Age was subdivided into the Old (Palaeolithic) and the New (Neolithic). The Middle (Mesolithic) Stone Age was added even later, and the Copper (Chalcolithic) Age inserted between the New Stone Age and the Bronze Age.

The system was first published as a classification of Danish antiquities 1836. Thomsen's pupil Jens Worsaae pioneered the adoption of the system in Europe and added further subdivisions within each age. Although a valuable and valid classification system for prehistoric material, the Three Age System did not provide dates but a relative sequence of developmental stages, which were not necessarily followed in that order by different societies.

threshing

agricultural process of separating cereal grains from the plant. Traditionally, the work was carried out by hand in winter months using the flail, a jointed beating stick. Today, threshing is done automatically inside the combine harvester at the time of cutting.

From the late 18th century, through the work of Andrew Meikle and others, machine threshing slowly overtook the flail and made rapid progress after 1850.

threshing

(Image © Research Machines plc)

A threshing machine being used to separate grain from chaff at a small farm close to Esfahan, Iran. In the near-desert conditions of central Iran, irrigation is required to grow crops and fertile land is scarce. Agricultural holdings are small and machines such as the combine harvester, which would thresh as well as cut the grain, are very uncommon.

thrift

or sea pink

any of several perennial low-growing coastal plants. The common sea pink *A. maritima* occurs in clumps on seashores and cliffs throughout Europe. The leaves are small and linear and the dense round heads of pink flowers rise on straight stems. (Genus *Armeria*, family Plumbaginaceae.)

thrips

any of a number of tiny insects of the order Thysanoptera, usually with feathery wings. Many of the 3,000 species live in flowers and suck their juices, causing damage and spreading disease. Others eat fungi, decaying matter, or smaller insects.

throat

in human anatomy, the passage that leads from the back of the nose and mouth to the trachea and oesophagus. It includes the pharynx and the larynx, the latter being at the top of the trachea. The word 'throat' is also used to mean the front part of the neck, both in humans and other vertebrates; for example, in describing the plumage of birds. In engineering, it is any narrowing entry, such as the throat of a carburettor.

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thrombocyte

in medicine, another name for a platelet.

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thrombolysis

in medicine, the breakdown of blood clots due to the activity of enzymes. Naturally occurring enzymes limit the size of the clot. Enzymes, such as streptokinase, may be given to dissolve clots following thromboembolism.

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thrombosis

condition in which a blood clot forms in a vein or artery, causing loss of circulation to the area served by the vessel. If it breaks away, it often travels to the lungs, causing pulmonary embolism.

Thrombosis in veins of the legs is often seen in association with phlebitis, and in arteries with atheroma. Thrombosis increases the risk of heart attack and stroke. It is treated by surgery and/or anticoagulant drugs.

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thrush

any bird of the large family Turdidae, order Passeriformes, found worldwide and known for their song. Thrushes are usually brown with speckles of other colours. They are 12-30 cm/5-12 in long.

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thrush

infection usually of the mouth (particularly in infants), but also sometimes of the vagina, caused by a yeastlike fungus (*Candida*). It is seen as white patches on the mucous membranes.

Thrush, also known as **candidiasis**, may be caused by antibiotics removing natural antifungal agents from the body. It is treated with antifungal preparations.

Candidiasis

Go to site

Thorough source of information about thrush. Causes, symptoms, and both conventional and unorthodox treatments are described in medical, but generally understandable, language. There is also useful information on a variety of forms of prophylaxis. This is essential reading for anybody troubled by candidiasis.

Thrust 2

jet-propelled car in which British driver Richard Noble set a world land speed record in the Black Rock desert of Nevada, USA, on 4 October 1983. The record speed was 1,019.4 kph/633.468 mph. In 1996 Noble attempted to break the sound barrier in *Thrust SCC*. *Thrust SCC* has two Rolls-Royce Spey engines (the same kind used in RAF Phantom jets) that provide 110,000 horsepower; it weighs 6,350 kg/13,970 lb, and is 16.5 m/54 ft in length. It was driven by RAF fighter pilot Andy Green to break the sound barrier in September 1997, setting a speed of 1,149.272 kph/714.144 mph.

Thrust: Breaking the Land Speed Record

introduction

The attempt to break the sound barrier in a car, and in doing so establish a new land speed record, began in 1991. The idea was sparked off in the mind of Richard Noble, the UK driver who had established a new record of 960.9 kph/600.6 mph, when Craig Breedlove - the US rival whose record Noble had just broken - announced that he intended to break the sound barrier. Noble recalled later: 'From that moment, I knew we had to mount a challenge. I could not let Breedlove beat me to what is the last great challenge to man.'

the history behind land speed record attempts

The history of the land speed record began on 18 December 1898, when Gaston Chasseloup-Laubat of France, driving an electric vehicle at Acheres, achieved 62.792 kph/39.245 mph. Since 15 September 1924, it has been held either by a Briton or an American - increasing 32 times from its value then of 234 kph/146 mph.

how the speed is measured

The measurement process has become increasingly precise: it now uses laser interferometry for timing and distance. Today, a valid attempt must be made twice over a measured mile. The two runs, one in each direction, must be completed within one hour; the final speed is the average of the two runs. For a jet-fuelled car such as Noble's, or Craig Breedlove's *Spirit of America*, that 'turnaround' time represented a considerable challenge, even though covering the distance itself takes only a few seconds.

work begins on Thrust

In June 1994 work started on *Thrust SSC* ('SuperSonic Car'). By the time Noble had succeeded in his mission, it had cost £5 million. In many ways it was a revolutionary design, but the black *Thrust SSC* could hardly be called pretty. The Rolls-Royce jet engines, with their long tubular intakes and afterburners mounted either side of the needle-shaped body, came from a Phantom jet fighter. The steering was done by the rear wheels - a bit like a supermarket shopping trolley or forklift truck - the feasibility of which was first tested on a Mini. The car was driven by Andy Green, normally a Tornado jet pilot with the UK Royal Air Force.

the team heads for Nevada

After testing during June 1997 in the Jordanian desert, the *Thrust SSC* team left for Black Rocks, Nevada, in September. They were short of cash - a call for £200,000 was made as the team left - but determined to break the record. Also heading there was Craig Breedlove, with the *Spirit of America II*. He too intended to break the record and go supersonic. The thin air of Black Rock's high-altitude setting, and its flat, dry desert provides the ideal location for speed attempts, even though the teams had to drive more than 160 km/100 mi every day from their lodgings to the site.

Craig Breedlove's many attempts and successes at breaking the record

Breedlove has a long history of setting the land speed record: he broke the 640 kph/400 mph, 800 kph/500 mph, and 960 kph/600 mph barriers. In October 1996 his car was hurtling across the Black Rock desert at 1,080 kph/675 mph, within seconds of setting a new record, when it crashed. Breedlove survived. The car didn't. Craig Breedlove's 1997 version was powered by a single 48,000 horsepower fighter jet engine. In early testing he managed 549 kph/343 mph. But there was intense speculation among observers and engineers about whether Breedlove's car was stable enough. He admitted that if he was not confident enough to ride in it, he would try to pilot the car by a remote control link at up to 1,120 kph/700 mph - an idea that Noble insisted was dangerous.

testing, checking, and repairing

Because the tiniest fault could be deadly at high speeds, the teams spent long hours checking and repairing any problems that turned up in low-speed testing. Such is the sophistication of modern cars that some of the 'repairs' involved computer code - controlling the suspension and engines - rather than anything physical. But after nearly a month, the *Thrust SSC*, driven by Green, was ready to make a serious attempt.

Thrust goes supersonic

The attempt to break the record succeeded on 25 September when the car broke Noble's 1993 record of 1,013 kph/633 mph by the remarkable margin of 130 kph/81 mph, as Green drove the car at 1,120/700mph on the first run and 1,165 kph/728 mph on the second for a 1,142 kph/714 mph average. The Queen sent her congratulations from Buckingham Palace. But the team had greater aims. The car had only been using 70 % of its power: they were convinced it could go supersonic. The media were interested in what the experience was like. Green replied: 'The world looks the same at that speed. The mountains are still in the distance, the ground just moves past you a little faster.' The training runs went on. Then on Monday 13 October the car broke the speed of sound on each run - but a parachute failure meant the car rolled more than a mile past its intended stopping place. It took 61 minutes to complete the second run - rendering it invalid as a record by 60 seconds, according to the international rules. The speeds were 1,222.669 kph/764.168 mph - or 1.007 % above the speed of sound - and 1,216.245 kph/760.153 mph. But on Wednesday 15 October, during the first run at 9.07 a.m. local time, the car hit 1,214.932 kph/759.333mph. The return speed of 1,225.774 kph/766.109 mph, completed in the time limit, set the new record at 1,220.354 kph/762.721 mph.

congratulations for the team

Among the first to congratulate the team was the UK prime minister Tony Blair, who sent a message calling it 'a triumph in which the nation can share and take pride. This success is an excellent example of Britain at its best'. Noble flew back to the UK, and welcomed the team when they returned with the car on 30 October. 'I think we were all actually quite pleased that it went so smoothly,' he said. And did he have any more plans - for 800 mph and upwards, perhaps? He refused to be drawn. 'We have got something planned but there's a lot of research to do first,' he replied.

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thulium

chemical symbol Tm

soft, silver-white, malleable and ductile, metallic element of the lanthanide series, atomic number 69, relative atomic mass 168.94. It is the least abundant of the rare earth metals, and was first found in gadolinite and various other minerals. It is used in arc lighting.

The X-ray-emitting isotope Tm-170 is used in portable X-ray units. Thulium was named by Swedish chemist Per Cleve in 1879 after the northland, Thule.

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thumb sucking

harmless habit of infancy. Thumb sucking is normally given up before the child reaches school age but it may persist as part of the sleep routine or if the child is experiencing problems, such as loneliness or unhappiness.

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thunderstorm

severe storm of very heavy rain, thunder, and lightning. Thunderstorms are usually caused by the intense heating of the ground surface during summer. The warm air rises rapidly to form tall cumulonimbus clouds with a characteristic anvil-shaped top. Electrical charges accumulate in the clouds and are discharged to the ground as flashes of lightning. Air in the path of lightning becomes heated and expands rapidly, creating shock waves that are heard as a crash or rumble of thunder.

The rough distance between an observer and a lightning flash can be calculated by timing the number of seconds between the flash and the thunder. A gap of three seconds represents about a kilometre; five seconds represents about a mile.

thunderstorm

There are an estimated 44,000 thunderstorms worldwide every day.

Thunderstorms and Tornadoes

Go to site

Striking photographs, one of a 21-cm/8-in hailstone, another of the anvil-shaped cloud typical of a severe thunderstorm, illustrate this hyperlinked description of some dramatic weather events. Part of a much larger physical geography site set up by a Canadian university, the page gives a clear explanation of the various types of thunderstorm and the conditions that bring them about.

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thylacine

another name for the Tasmanian wolf.

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thyme

any of several herbs belonging to the mint family. Garden thyme *T. vulgaris*, native to the Mediterranean, grows to 30 cm/1 ft high and has small leaves and pinkish flowers. Its aromatic leaves are used for seasoning in cookery. (Genus *Thymus*, family Labiatae.)

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thymus

organ in vertebrates, situated in the upper chest cavity in humans. The thymus processes lymphocyte cells to produce T-lymphocytes (T denotes 'thymus-derived'), which are responsible for binding to specific invading organisms and killing them or rendering them harmless.

The thymus reaches full size at puberty, and shrinks thereafter; the stock of T-lymphocytes is built up early in life, so this function diminishes in adults, but the thymus continues to function as an endocrine gland, producing the hormone thymosin, which stimulates the activity of the T-lymphocytes.

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thyristor

type of rectifier, an electronic device that conducts electricity in one direction only. The thyristor is composed of layers of semiconductor material sandwiched between two electrodes called the anode and cathode. The current can be switched on by using a third electrode called the gate.

Thyristors are used to control mains-driven motors and in lighting dimmer controls.

---

thyroid

endocrine gland of vertebrates, situated in the neck in front of the trachea. It secretes several hormones, principally thyroxine, an iodine-containing hormone that stimulates growth, metabolism, and other functions of the body. The thyroid gland may be thought of as the regulator gland of the body's metabolic rate. If it is overactive, as in hyperthyroidism, the sufferer feels hot and sweaty, has an increased heart rate, diarrhoea, and weight loss. Conversely, an underactive thyroid leads to myxoedema, a condition characterized by sensitivity to the cold, constipation, and weight gain. In infants, an underactive thyroid leads to cretinism, a form of mental retardation.

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thyrotoxicosis

synonym for hyperthyroidism.

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thyroxine

hormone containing iodine that is produced by the thyroid gland. It is used to treat conditions that are due to deficiencies in thyroid function, such as myxoedema.

Tibetan mastiff

large breed of dog regarded as the ancestor of many present breeds. It is a very powerful animal with a long black or black and tan coat. It is about 71 cm/28 in in height and 60 kg/132 lb in weight.

Tibetan mastiffs were used in Tibet as watchdogs and are mentioned in old Chinese literature and by Marco Polo.

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tibia

anterior of the pair of bones in the leg between the ankle and the knee. In humans, the tibia is the shinbone. It articulates with the femur above to form the knee joint, the fibula externally at its upper and lower ends, and with the talus below, forming the ankle joint.

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tick

any of the arachnid family Ixodoidae, order Acarina, of large bloodsucking mites. They have flat bodies protected by horny shields. Many carry and transmit diseases to mammals (including humans) and birds.

life cycle

During part of their existence they parasitize animals and birds, for which they have developed a rostrum or beak composed of two barbed harpoons above and a dart below. Their eggs are laid on rough herbage and hatch into white six-legged larvae, which climb up the legs of passing animals and in some species complete their life history on the animal's skin, but in others return to the grass for a period, dropping from the host when engorged with blood.

Ticks cause irritation and anaemia, and can also transmit typhus, Lyme disease, rickettsia, and relapsing fever.

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tidal energy

energy derived from the tides. The tides mainly gain their potential energy from the gravitational forces acting between the Earth and the Moon. If water is trapped at a high level during high tide, perhaps by means of a barrage across an estuary, it may then be gradually released and its associated gravitational potential energy exploited to drive turbines and generate electricity. Several schemes have been proposed for the Bristol Channel, in southwestern England, but environmental concerns as well as construction costs have so far prevented any decision from being taken.

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tidal heating

in astrophysics, process in which one body is heated internally by tidal stresses set up by the gravitational pull of another body. Tidal heating is common among the moons of the giant planets, and is the heat source for volcanic activity on Io, one of the moons of Jupiter.

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tidal power station

hydroelectric power plant that uses the 'head' of water created by the rise and fall of the ocean tides to spin the water turbines. The world's first commercial-scale tidal power station is located on the estuary of the River Rance in the Gulf of St Malo, Brittany, France, and has been in use since 1966. It produces 240 megawatts and can generate electricity on both the ebb and flow of the tide.

In 2003 the world's first commercial subsea power station became operational in Norway. The power station produces 300 kW of electricity using only the rise and fall of the sea to generate electricity, by means of a device called a tidal mill. This installation was the first power station using tidal power to be connected to a commercial electricity grid; it supplied enough electricity to power 30 houses in the nearby town of Hammerfest.

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tidal wave

common name for a tsunami.

Tidbinbilla

space tracking station in Australia, just south of Canberra. It provides tracking facilities and command transmissions in support of NASA's crewed and uncrewed spacecraft, including the Galileo and

Cassini probes and the Gamma-Ray Observatory.

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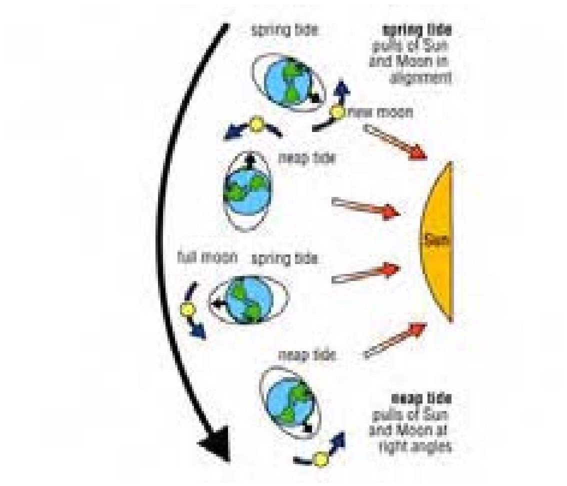
tide

rhythmic rise and fall of the sea level in the Earth's oceans and their inlets and estuaries due to the gravitational attraction of the Moon and, to a lesser extent, the Sun, affecting regions of the Earth unequally as it rotates. Water on the side of the Earth nearest to the Moon feels the Moon's pull and accumulates directly below the Moon, producing a high tide.

High tide occurs at intervals of 12 hr 24 min 30 sec. The maximum high tides, or spring tides, occur at or near new and full Moon when the Moon and Sun are in line and exert the greatest combined gravitational pull. Lower high tides, or neap tides, occur when the Moon is in its first or third quarter and the Moon and Sun are at right angles to each other.

tide



(Image © Research Machines plc)

The gravitational pull of the Moon is the main cause of the tides. Water on the side of the Earth nearest the Moon feels the Moon's pull and accumulates directly under the Moon. When the Sun and the Moon are in line, at new and full Moon, the gravitational pull of Sun and Moon are in line and produce a high spring tide. When the Sun and Moon are at right angles, lower neap tides occur.

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tiger

largest of the great cats, *Panthera tigris* (family Felidae, order Carnivora), formerly found in much of central and South Asia, from Siberia south to Sumatra, but nearing extinction (5,000 in 1997) because of hunting and the high prices paid for the pelt, as well as the destruction of its natural habitat.

The male tiger can grow to 3.6 m/12 ft long, while the female averages about 2.6 m/8.5 ft. It weighs up to 300 kg/660 lb, and has a yellow-orange coat with black stripes. Tigers are solitary, and largely nocturnal. They will eat carrion, but generally kill for themselves. Their food consists mainly of deer, antelopes, and smaller animals, but they sometimes kill wild boar. Human-eating tigers are rare and are the result of weakened powers or shortage of game.

tiger

Between 1900 and 1998 the world tiger population decreased by a staggering 95%.

tiger

(Image © Corel)

The Bengal tiger is a subspecies of tiger found in India. The tiger is classified as an endangered species: in 1996 there were only 4,000 Bengal tigers left in the world.

Bengal Tiger

Go to site

Illustrated guide to the Bengal tiger including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

Care2's Race for the Big Cats 2

Go to site

Online sponsorship campaign for endangered big cats run by Care2.com, an organization that raises money for US wildlife charities such as the Wildlife Conservation Society and the National Wildlife Federation. The site is packed with fascinating feline facts and a trivia quiz as well as links to the Wildlife Conservation Society's Web site. There are plenty of images of the cats, making it an ideal reference tool for children in particular to learn about endangered wildlife.

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tiger beetle

brightly coloured beetle with long legs and antennae. The most striking feature is their large eyes. Most adult tiger beetles are in shades of blue, bronze, or green, with yellow or white markings. They are typically found on sand or dry soils. Some 2,000 species have been recorded, mostly in the tropics.

The adults move rapidly and fly readily. The larvae live in burrows in the soil, where they lie in wait with their powerful mandibles, or jaws, ready to grab any insect that passes by.

classification

Tiger beetles are members of the family Cicindelidae, order Coleoptera, class Insecta, phylum Arthropoda. The main genus is *Cicindela*.

tiger beetle

Tiger beetles run so fast in pursuit of their prey that their eyes are unable to gather enough light to see, and they go temporarily blind. As a consequence they must keep stopping to reorientate. Their great speed compensates for these pauses, enabling them to hunt successfully.

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till

or boulder clay

deposit of clay, mud, gravel, and boulders left by a glacier. It is unsorted, with all sizes of fragments mixed up together, and shows no stratification; that is, it does not form clear layers or beds.

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tilt-rotor aircraft

type of vertical takeoff aircraft, also called a convertiplane.

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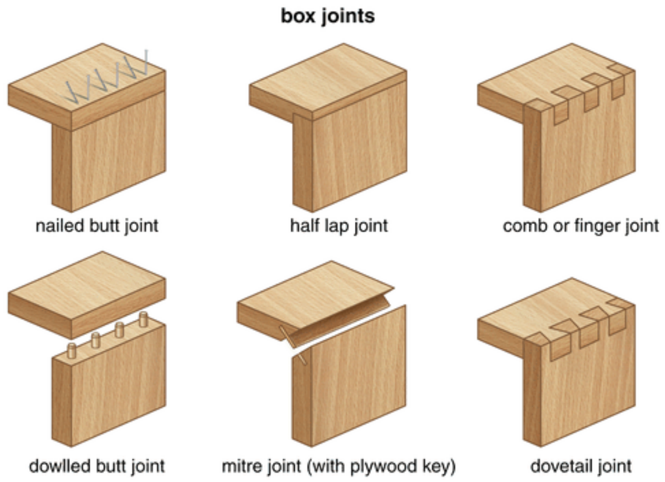
timber

wood used in construction, furniture, and paper pulp.
Hardwoods include tropical mahogany, teak, ebony, rosewood, temperate oak, elm, beech, and eucalyptus. All except eucalyptus are slow-growing, and world supplies are almost exhausted.
Softwoods comprise the conifers (pine, fir, spruce, and larch), which are quick to grow and easy to work but inferior in quality of grain.
White woods include ash, birch, and sycamore; all have light-coloured timber, are fast-growing, and can be used as veneers on cheaper timber.

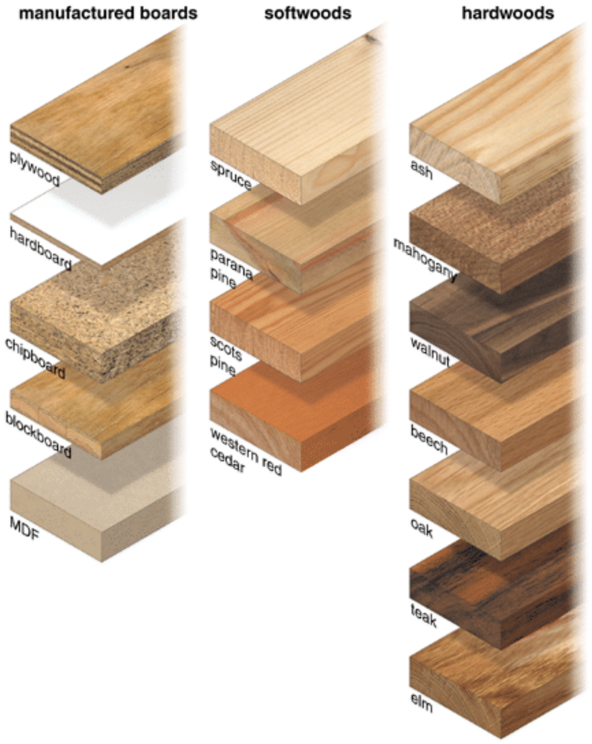
timber


box joints
nailed butt joint
half lap joint
comb or finger joint
dowlled butt joint
mitre joint (with plywood key)
dovetail joint

(Image © Research Machines plc)

Wooden structures usually need to be jointed at the corners. Frame joints are used in assembling structures and box joints are used where the pieces of timber are wide.

timber


manufactured boards
softwoods
hardwoods
plywood
hardboard
chipboard
blockboard
MDF
spruce
parana pine
scots pine
western red cedar
ash
mahogany
walnut
beech
oak
teak
elm

(Image © Research Machines plc)

Types of hard and soft woods and also manufactured boards, such as chipboard and MDF. Hardwoods come from broadleaf trees and softwoods from evergreens.

timber

(Image © Research Machines plc)

Stocks of tropical hardwood planks in a timber yard, awaiting shipment for use in furniture or building.

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time

continuous passage of existence, recorded by division into hours, minutes, and seconds. Formerly the measurement of time was based on the Earth's rotation on its axis, but this was found to be irregular. Therefore the second, the standard SI unit of time, was redefined in 1956 in terms of the Earth's annual orbit of the Sun, and in 1967 in terms of a radiation pattern of the element caesium.

Walk Through Time: The Evolution of Time Measurement

Go to site

Designed by the National Institute of Standards and Technology (NIST) Physics Laboratory to provide a historic understanding of the evolution of time measurement. There are sections on 'Ancient calendars', 'Early clocks', 'World time scales', the 'Atomic age', and 'The revolution in timekeeping'. The site also explains Greenwich Mean Time and world time zones. Visitors can synchronize their clocks to NIST time.

Times Beach

town in Missouri, USA, that accidentally became contaminated with dioxin, and was bought by the Environmental Protection Agency in 1983 for cleansing.

---

time-sharing

in computing, a way of enabling several users to access the same computer at the same time. The computer rapidly switches between user terminals and programs, allowing each user to work as if he or she had sole use of the system.

Time-sharing was common in the 1960s and 1970s before the spread of cheaper computers, and is now making something of a comeback, with the advent of **application service providers**.

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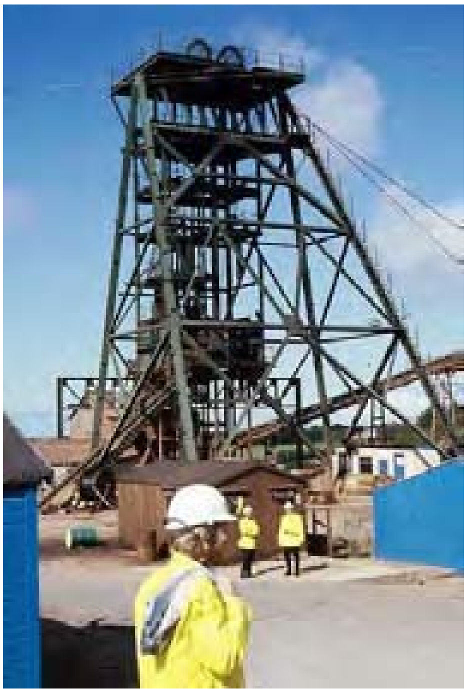
tin

chemical symbol Sn

soft, silver-white, malleable and somewhat ductile, metallic element, symbol Sn, atomic number 50, relative atomic mass 118.69. Its chemical symbol comes from the Latin *stannum*. Tin exhibits allotropy, having three forms: the familiar lustrous metallic form above 13.2°C/55.8°F, a brittle form above 161°C/321.8°F, and a grey powder form below 13.2°C/55.8°F (commonly called tin pest or tin disease). The metal is quite soft (slightly harder than lead) and can be rolled, pressed, or hammered into extremely thin sheets; it has a low melting point. In nature it occurs rarely as a free metal. It resists corrosion and is therefore used for coating and plating other metals.

Tin and copper smelted together form the oldest desired alloy, bronze; since the Bronze Age (3500 BC) that alloy has been the basis of both useful and decorative materials. Tin is also alloyed with metals other than copper to make solder and pewter. It was recognized as an element by Antoine Lavoisier, but the name is very old and comes from the Germanic form *zinn*. The mines of Cornwall were the principal Western source of tin until the 19th century, when rich deposits were found in South America, Africa, South-East Asia, and Australia. Tin production is concentrated in Malaysia, Indonesia, Brazil, and Bolivia.

tin



(Image © Research Machines plc)

Pendarves tin mine, Cornwall. Tin has been mined in Cornwall for thousands of years, but the Cornish tin-mining industry peaked during the 19th century, and has since declined. Foreign competition in the 20th century made Cornish ore increasingly unprofitable. The last working mines, including this one at Pendarves near Camborne, closed a few years ago. A few sites have been reopened as heritage centres.

tinamou

fowl-like bird of the family Tinamidae, in the South American order Tinamiformes, of which there are some 45 species. They are up to 40 cm/16 in long, and their drab colour provides good camouflage. They are excellent runners but poor flyers and are thought to be related to the ratites (flightless birds). Tinamous are mainly vegetarian, but sometimes eat insects. They escape predators by remaining still or by burrowing through dense cover.

Several females lay eggs in one nest; one hen may also lay eggs in nests guarded by different males. The males build the nests and incubate the eggs.

Tinbergen, Niko(laas) (1907-1988)

Dutch-born British zoologist who was awarded a Nobel Prize for Physiology or Medicine in 1973 for his work in animal behaviour patterns. He specialized in the study of instinctive behaviour in animals, and was one of the founders of ethology, the scientific study of animal behaviour in natural surroundings. He shared the prize with Konrad Lorenz (with whom he worked on several projects) and Karl von Frisch.

Tinbergen investigated other aspects of animal behaviour, such as learning, and also studied human behaviour, particularly aggression, which he believed to be an inherited instinct that developed when humans changed from being predominantly herbivorous to being hunting carnivores.

Tinea

in medicine, species of fungus that causes ringworm.

tinnitus

in medicine, constant buzzing or ringing in the ears. The phenomenon may originate from prolonged exposure to noisy conditions (drilling, machinery, or loud music) or from damage to or disease of the middle or inner ear. The victim may become overwhelmed by the relentless noise in the head.

In some cases there is a hum at a frequency of about 40 Hz, which resembles that heard by people troubled by environmental hum but may include whistles and other noises resembling a machine workshop. Being in a place where external noises drown the internal ones gives some relief, and devices may be worn that create pleasant, soothing sounds to override them.

Approximately 20% of Europeans and North Americans will experience tinnitus at some period in their lives. Treatment often involves counselling and teaching the sufferer how to cope with the noise.

Objective tinnitus is a very rare form in which other people can also hear the noises. This may be caused by muscle spasms in the inner ear or throat, or abnormal resonance of the eardrum and ossicles.

Tinnitus

Go to site

Good source of practical information and advice for those with ringing in the ears. The causes of the condition are described and various coping mechanisms are set out.

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tin ore

mineral from which tin is extracted, principally cassiterite, SnO_2. The world's chief producers are Malaysia, Thailand, and Bolivia.

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tinplate

milled steel coated with tin, the metal used for most 'tin' cans. The steel provides the strength, and the tin provides the corrosion resistance, ensuring that the food inside is not contaminated. Tinplate may be made by electroplating or by dipping in a bath of molten tin.

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tire

US spelling of tyre, an inflatable rubber hoop fitted round the rims of bicycle, car, and other road-vehicle wheels.

Tiselius, Arne Wilhelm Kaurin (1902-1971)

Swedish chemist who developed a powerful method of chemical analysis known as electrophoresis. He applied his new techniques to the analysis of animal proteins. He was awarded the Nobel Prize for Chemistry in 1948 for his researches in electrophoresis and adsorption analysis, and discoveries concerning serum proteins.

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tissue

in biology, any kind of cellular fabric that occurs in an organism's body. It is a group of similar cells that are carrying out a function in a plant or animal. Several kinds of tissue can usually be distinguished, each consisting of cells of a particular kind bound together by cell walls (in plants) or extracellular matrix (in animals). Thus, nerve and muscle are different kinds of tissue in animals, as are parenchyma and sclerenchyma in plants. Tissues of different kinds may be found in a distinct structure, which is then called an organ. The leaf of a plant or the heart of a mammal is an organ.

One example of tissue is the epithelium. Epithelial tissue is made up of epithelial cells of several kinds, such as ciliated epithelial cells and cells producing mucus. Epithelial cells line the air passages and the gut. In the air passages the epithelial tissue protects the walls from dust and micro-organisms that are trapped in the mucus and swept up to the mouth by the beating, hair-like cilia. In the gut, the epithelium protects the wall by producing mucus, but there are no ciliated cells. The mucus also helps food move along. In addition, digestive enzymes which digest food are produced by the epithelium.

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tissue culture

process by which cells from a plant or animal are removed from the organism and grown under controlled conditions in a sterile medium containing all the necessary nutrients. Tissue culture can provide information on cell growth and differentiation, and is also used in plant propagation and drug production.

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tissue plasminogen activator

tPA

naturally occurring substance in the body tissues that activates the enzyme plasmin that is able to dissolve blood clots. Human tPA, produced in bacteria by genetic engineering, has, like streptokinase, been used to dissolve blood clots in the coronary arteries of heart-attack victims. It has been shown to be more effective than streptokinase when used in conjunction with heparin, but it is much more expensive.

Titan

in astronomy, largest moon of the planet Saturn, with a diameter of 5,150 km/3,200 mi and a mean distance from Saturn of 1,222,000 km/759,000 mi. It was discovered in 1655 by Dutch mathematician and astronomer Christiaan Huygens, and is the second-largest moon in the Solar System (only Ganymede, of Jupiter, is larger).

Titan is the only moon in the Solar System with a substantial atmosphere (mostly nitrogen), topped with smoggy orange clouds that obscure the surface, which may be covered with liquid ethane lakes. Its surface atmospheric pressure is greater than Earth's. NASA's Cassini space probe reached Saturn in 2004 and its subprobe *Huygens* landed on Titan in January 2005. It has long been thought that Titan might have lakes or even oceans of liquid methane or ethane, but there is currently no evidence to confirm this, either from the probes or from Earth-based observations.

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titanium

chemical symbol Ti

strong, lightweight, silver-grey, metallic element, atomic number 22, relative atomic mass 47.90. The ninth most abundant element in the Earth's crust, its compounds occur in practically all igneous rocks and their sedimentary deposits. It is very strong and resistant to corrosion, so it is used in building high-speed aircraft and spacecraft; it is also widely used in making alloys, as it unites with almost every metal except copper and aluminium. Titanium oxide is used in high-grade white pigments.

Titanium bonds with bone in a process called **osseointegration**. As the body does not react to the titanium it is valuable for permanent implants such as prostheses.

The element was discovered in 1791 by English mineralogist William Gregor (1761-1817) and was named by German chemist Martin Klaproth in 1796 after the Titans, the giants of Greek mythology. It was not obtained in pure form until 1925.

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titanium ore

any mineral from which titanium is extracted, principally ilmenite ($FeTiO_3$) and rutile (TiO_2). Brazil, India, and Canada are major producers. Both these ore minerals are found either in rock formations or concentrated in heavy mineral sands.

Titan rocket

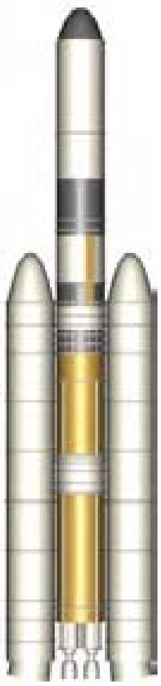
family of US space rockets, developed from the Titan intercontinental missile. Two-stage Titan rockets launched the *Gemini* project crewed missions. More powerful Titans, with additional stages and strap-on boosters, such as the Titan-Centaur, were used to launch spy satellites and space probes, including the Viking and Voyager probes, Mars Observer, and Cassini. The last Titan rockets were launched in 2005.

Titan rocket

(Image © NASA)

The Titan rocket that put *Gemini 12* astronauts James Lovell and Buzz Aldrin into orbit on 11 November 1966. Among their tasks was docking with the Agena target vehicle launched an hour previously.

Titan rocket



(Image © Research Machines plc)

The Lockheed-Martin Titan rocket. A Titan 4B was launched in October 2001, carrying an undisclosed cargo, likely to be some form of spy satellite.

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titmouse

any of a family (Paridae) of small birds of the order Passeriformes, found worldwide except in South America and Australia. There are 65 species, all agile and hardy, and often seen hanging upside down from twigs to feed. In North America many of the species are called chickadees.

North American species include the tufted titmouse *Parus bicolor*, with a gray crest, and the black-capped chickadee *P. atricapillus*.

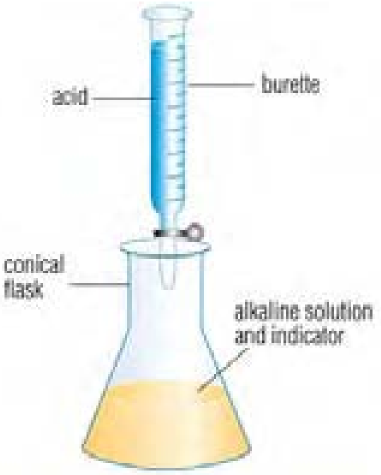
---

titration

in analytical chemistry, a technique to find the concentration of one compound in a solution by determining how much of it will react with a known amount of another compound in solution.

One of the solutions is measured by pipette into the reaction vessel. The other is added a little at a time from a burette. The end-point of the reaction is determined with an indicator or an electrochemical device.

titration



(Image © Research Machines plc)

A method used to find the concentration of an acid or an alkali. Typically a burette is filled with an acid of unknown concentration which is slowly (drop by drop) added to a known volume of an alkali of a known concentration, mixed with an indicator (such as phenolphthalein). The volume of acid need to neutralize the alkali in the flask can be used to calculate the concentration of the acid.

TLR camera

twin-lens reflex camera that has a viewing lens of the same angle of view and focal length mounted above and parallel to the taking lens.

TNT

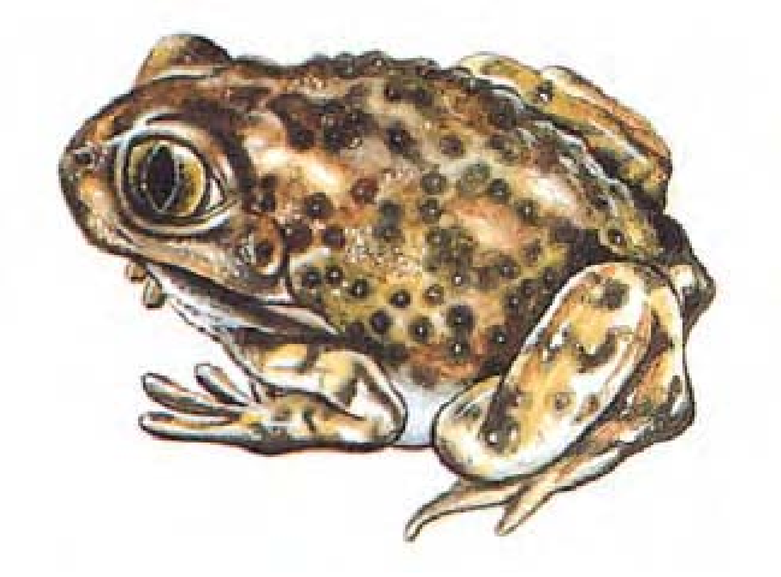
abbreviation for **trinitrotoluene**, $CH_3C_6H_2(NO_2)_3$, a powerful high explosive. It is a yellow solid, prepared in several isomeric forms from toluene by using sulphuric and nitric acids.

---

toad

any of the more terrestrial warty-skinned members of the tailless amphibians (order Anura). The name commonly refers to members of the genus *Bufo*, family Bufonidae, which are found worldwide, except for Australia (where the marine or cane toad*B. marinus* has been introduced), Madagascar, and Antarctica. They differ from frogs chiefly by the total absence of teeth, and in certain other anatomical features.

toad



(Image © Research Machines plc)

The western spadefoot toad of the plains and sandy areas of the western USA is an expert burrower. On each hind foot it has a wedge-shaped spade. It spends the day in its burrow, coming out only at night. It breeds in temporary rainpools and therefore has an accelerated breeding cycle: the eggs hatch after two days, and the metamorphosis from tadpole to adult takes less than six weeks.

---

toadflax

any of a group of small plants belonging to the snapdragon family, native to Western Europe and Asia. Toadflaxes have spurred, two-lipped flowers, commonly purple or yellow, and grow 20-80 cm/8-32 in tall. (Genus *Linaria*, family Scrophulariaceae.)

---

toadstool

common name for many umbrella-shaped fruiting bodies of fungi (see fungus). The term is normally applied to those that are inedible or poisonous.

---

tobacco

any of a group of large-leaved plants belonging to the nightshade family, native to tropical parts of the Americas. The species *Nicotiana tabacum* is widely cultivated in warm, dry climates for use in cigars and cigarettes, and in powdered form as snuff. (Genus *Nicotiana*, family Solanaceae.) When it is smoked, it burns and the smoke is inhaled.

The leaves are cured, or dried, and matured in storage for two to three years before use. Introduced to Europe as a medicine in the 16th century, tobacco has been recognized from the 1950s as a major health hazard; see cancer. Burning tobacco gives off around 4,000 different compounds, at least 60 of which are cancerous. The leaves also yield nicotine, a colourless oil, one of the most powerful poisons known, and addictive in humans. It is used in insecticides.

Worldwide, the tobacco conglomerations make a net profit of US$6 billion each year. A US Supreme Court decision in 1992 ruled that tobacco companies can be held legally responsible for the dangerous effects of smoking on health; conglomerations spend US$50 million a year on legal advice to avoid paying out compensation to victims. However, in March 1996, the Liggett Group became the first tobacco company to agree to settle smoking-related claims.

tobacco

(Image © Research Machines plc)

The tobacco fields of Kentucky make this state the largest producer of the crop in the USA. Tobacco is grown throughout the state and is the most valuable farm product. At harvest time the tobacco is cut and left in the fields before being gathered for processing.

Nicotiana Tobacum

Go to site

Provided by the University of Washington, this site contains a selection of images of different types of tobacco plants, including a close-up of the leaves, of the head, and of a group of plants. There are also a number of links to related sites.

---

tocopherol

or vitamin E

fat-soluble chemical found in vegetable oils. Deficiency of tocopherol leads to multiple adverse effects on health. In rats, vitamin E deficiency has been shown to cause sterility.

Todd, Alexander Robertus (1907-1997)

Baron Todd

Scottish organic chemist who was awarded the Nobel Prize for Chemistry in 1957 for his work on the role of nucleic acids in genetics. He also synthesized vitamins B_1, B_{12}, and E. He was knighted in 1954 and became baron in 1962.

---

tog

unit of measure of thermal insulation used in the textile trade; a light summer suit provides 1.0 tog.

The tog value of an object is equal to ten times the temperature difference (in °C) between its two surfaces when the flow of heat is equal to one watt per square metre; one tog equals 0.645 clo.

---

toilet

place where waste products from the body are excreted. Simple latrines, with sewers to carry away waste, have been found in the Indus Valley and ancient Babylon; the medieval garderobe is essentially the same, even though flushing lavatories had been known to Roman civilizations.

---

tokamak

Russian acronym for toroidal magnetic chamber, an experimental machine conceived by Soviet physicist Andrei Sakharov and developed in the Soviet Union to investigate controlled nuclear fusion. It consists of a doughnut-shaped chamber surrounded by electromagnets capable of exerting very powerful magnetic fields. The fields are generated to confine a very hot (millions of degrees) plasma of ions and electrons, keeping it away from the chamber walls. See also JET.

---

toluene

or methyl benzene; $C_6H_5CH_3$

colourless, inflammable liquid, insoluble in water, derived from petroleum. It is used as a solvent, in aircraft fuels, in preparing phenol (carbolic acid, used in making resins for adhesives, pharmaceuticals, and as a disinfectant), and the powerful high explosive TNT.

---

tomato

annual plant belonging to the nightshade family, native to South America. It is widely cultivated for its shiny, round, red fruit containing many seeds (technically a berry), which is widely used in salads and cooking. (*Lycopersicon esculentum*, family Solanaceae.)

A genetically engineered tomato, the first genetically engineered food for sale, appeared in shops in California and Chicago in May 1994.

Tomatoes

Go to site

Plenty of fun facts about tomatoes from the British Tomato Growers' Association. The site includes a basic history of the tomato, information about its nutritional benefits and notes on the different varieties of tomato available.

Tombaugh, Clyde William (1906-1997)

US astronomer who discovered the planet Pluto, the most distant planet in the Solar System, in 1930.

Dr Clyde Tombaugh Profile

Go to site

Description of the life and work of the discoverer of Pluto, astronomer Dr Clyde Tombaugh. The Web site contains not only a profile and biographical information, but also holds a lengthy interview with Tombaugh from 1991 accompanied by a large number of photographs, video sequences, and audio clips.

---

tomography

technique of using X-rays or ultrasound waves to procure images of structures deep within the body for diagnostic purposes. In modern medical imaging there are several techniques, such as the CAT scan (computerized axial tomography).

---

ton

symbol t

unit (symbol t) of mass. The **short ton**, used in the USA and Canada, is 2,000 lb/907 kg. The **long ton**, used in the UK, is 2,240 lb/1,016 kg. The **metric ton** or **tonne** is 1,000 kg/2,205 lb.

---

ton

in shipping, a unit of volume (called a register ton) equal to 100 cubic feet/2.8 cubic meters.
Gross tonnage measures the total internal volume of a ship.
Net register tonnage is the amount of gross tonnage (in register tons) used for carrying cargo or passengers.
Displacement tonnage is the weight of the vessel, in terms of the number of long tons of sea water displaced when the ship is loaded to its load line; it is used to describe warships, and one displacement ton equals 35 cubic feet/1 cubic meter.

---

tongue

in tetrapod vertebrates, a muscular organ usually attached to the floor of the mouth. It has a thick root attached to a U-shaped bone (hyoid), and is covered with a mucous membrane containing nerves and taste buds. It is the main organ of taste. The tongue directs food to the teeth and into the throat for chewing and swallowing. In humans, it is crucial for speech; in other animals, for lapping up water and for grooming, among other functions. In some animals, such as frogs, it can be flipped forwards to catch insects; in others, such as anteaters, it serves to reach for food found in deep holes.

---

tonsillitis

inflammation of the tonsils.

Childhood Infections - Tonsillitis

Go to site

Useful information about tonsillitis. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection, how it can be treated both at home and professionally, and what to do should the symptoms occur.

---

tonsils

in higher vertebrates, masses of lymphoid tissue situated at the back of the mouth and throat (palatine tonsils), and on the rear surface of the tongue (lingual tonsils). The tonsils contain many lymphocytes and are part of the body's defence system against infection.

The adenoids are sometimes called pharyngeal tonsils.

---

tooth

in vertebrates, one of a set of hard, bonelike structures in the mouth, used for biting and chewing food, and in defence and aggression. In humans, the first set (20 milk teeth) appear from age six months to two and a half years. The permanent dentition replaces these from the sixth year onwards, the wisdom teeth (third molars) sometimes not appearing until the age of 25 or 30. Adults have 32 teeth: two incisors, one canine (eye tooth), two premolars, and three molars on each side of each jaw. Each tooth consists of an enamel coat (hardened calcium deposits), dentine (a thick, bonelike layer), and an inner pulp cavity, housing nerves and blood vessels. Mammalian teeth have roots surrounded by cementum, which fuses them into their sockets in the jawbones.

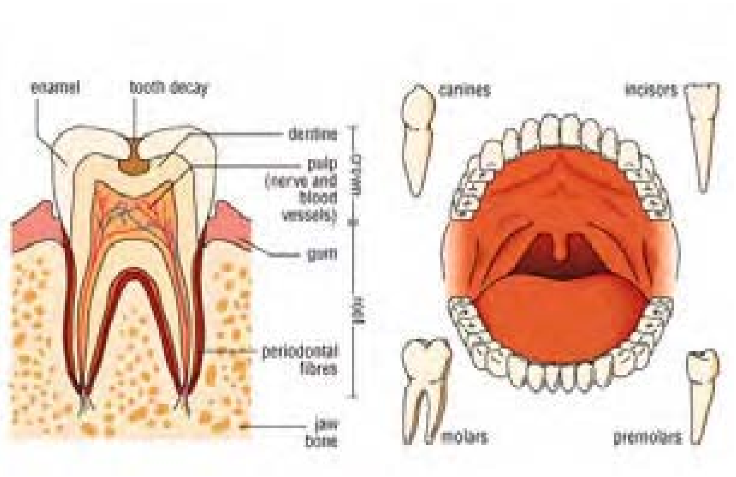
The neck of the tooth is covered by the gum, while the enamel-covered crown protrudes above the gum line.

The chief diseases of teeth are misplacements resulting from defect or disturbance of the tooth-germs before birth, eruption out of their proper places, and caries (decay).

tooth

About one in every 2,000 babies is born with a tooth. Louis XIV of France was born with two teeth, which may explain why he had had eight nurses by the time he moved on to solid foods.

tooth



(Image © Research Machines plc)

Adults have 32 teeth: two incisors, one canine, two premolars, and three molars on each side of each jaw. Each tooth has three parts: crown, neck, and root. The crown consists of a dense layer of mineral, the enamel, surrounding hard dentine with a soft centre, the pulp.

---

toothache

in medicine, dental pain commonly due to inflammation of the pulp or the tooth or the fibrous tissue supporting the tooth in the bone socket. It is most frequently due to caries when the cavity is close to the pulp.

Infection of the pulp can lead to the formation of an abscess. Chronic toothache can occur when the substance of the tooth beneath the enamel (dentine) is unprotected because of loss of enamel due to decay or receding gums. The pain is often associated with temperature changes or sweet foods.

---

topaz

mineral, aluminium fluorosilicate, $Al_2(F_2SiO_4)$. It is usually yellow, but pink if it has been heated, and is used as a gemstone when transparent. It ranks 8 on the Mohs scale of hardness.

---

tope

slender shark *Galeorhinus galeus* ranging through temperate and tropical seas. Dark grey above and white beneath, it reaches 2 m/6 ft in length. The young are born well-formed, sometimes 40 at a time.

---

topography

surface shape and composition of the landscape, comprising both natural and artificial features, and its study. Topographical features include the relief and contours of the land; the distribution of mountains, valleys, and human settlements; and the patterns of rivers, roads, and railways.

---

topology

in computing, the arrangement of devices in a network. The most common is the bus topology, where all the computers are interconnected using a single, open-ended cable. Most modern network solutions use either a ring or bus layout, but with physical characteristics that resemble a star layout.

---

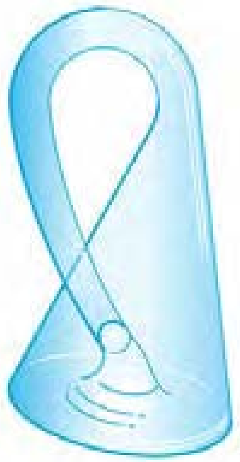
topology

branch of geometry that deals with those properties of a figure that remain unchanged even when the figure is transformed (bent, stretched) - for example, when a square painted on a rubber sheet is deformed by distorting the sheet.

Topology has scientific applications, as in the study of turbulence in flowing fluids.

The topological theory, proposed in 1880, that only four colours are required in order to produce a map in which no two adjoining countries have the same colour, inspired extensive research, and was proved in 1972 by Kenneth Appel and Wolfgang Haken.

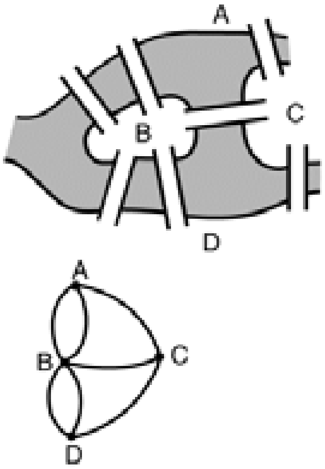
topology



(Image © Research Machines plc)

Some properties of a geometric figure remain unchanged when it is distorted; for example the two lines still intersect.

topology



(Image © Research Machines plc)

The Könisberg bridge problem. The challenge is to cross each of the seven bridges (top) over the River Pregol'a in Königsberg (now Kaliningrad, Russia) once only and return to one's starting point. Representing the puzzle as a topological network (bottom) shows that this is impossible.

Topology in Mathematics

Go to site

History of topology in mathematical situations. Starting from the earliest application of the four colour theorem in mathematics, this Web site chronicles both the developments and the developers through to the formulation of the complete 1912 topology theory of Brouwer. Also included are several references for further reading and links to the biographies of those involved in the subject.

---

topsoil

upper, cultivated layer of soil, which may vary in depth from 8 to 45 cm/3 to 18 in. It contains organic matter - the decayed remains of vegetation, which plants need for active growth - along with a variety of soil organisms, including earthworms.

---

tor

isolated mass of rock, often granite, left upstanding on a hilltop after the surrounding rock has been broken down. Weathering takes place along the joints in the rock, reducing the outcrop into a mass of rounded blocks.

tor

(Image © Garret Nagle)

Granite is a hard, igneous rock. However, it is eroded by freeze-thaw weathering and by hydrolysis (a form of chemical erosion). The granite is broken down most effectively where there are more joints or cracks in the rock, and it is most resistant where there are fewer joints. The unweathered rock forms a tor, an upstanding, isolated mass of rock, like this one on Dartmoor.

---

tornado

extremely violent revolving storm with swirling, funnel-shaped clouds, caused by a rising column of warm air propelled by strong wind. A tornado can rise to a great height, but with a diameter of only a few hundred yards or less. Tornadoes move with wind speeds of 100-300 mph/160-480 kph, destroying everything in their path. They are common in the central USA and Australia.

A series of tornadoes killed 47 people, destroyed 2,000 homes, and caused $500 million worth of damage in Oklahoma, Nebraska, Kansas, and Texas in May 1999.

---

torpedo

or electric ray

any species of the order Torpediniformes of mainly tropical rays (cartilaginous fishes), whose electric organs between the pectoral fin and the head can give a powerful shock. They can grow to 180 cm/6 ft in length.

The electric ray *Torpedo nobiliana* is found on both sides of the Atlantic.

---

torpor

in medicine, a condition of mental and physical inactivity which interferes with normal life. It is found in people suffering from fever and in elderly people with arterial diseases.

---

torque

turning effect of force on an object. A turbine produces a torque that turns an electricity generator in a power station. Torque is measured by multiplying the force by its perpendicular distance from the turning point.

---

torr

unit of pressure equal to 1/760 of an atmosphere, used mainly in high-vacuum technology.

One torr is equivalent to 133.322 pascals, and for practical purposes is the same as the millimetre of mercury. It is named after the Italian physicist Evangelista Torricelli.

Torricelli, Evangelista (1608-1647)

Italian physicist who established the existence of atmospheric pressure and devised the mercury barometer in 1644.

In 1643 Torricelli filled a long glass tube, closed at one end, with mercury and inverted it in a dish of mercury. Atmospheric pressure supported a column of mercury about 76 cm/30 in long; the space above the mercury was a vacuum. Noticing that the height of the mercury column varied slightly from day to day, he came to the conclusion that this was a reflection of variations in atmospheric pressure.

Torricelli, Evangelista

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of Evangelista Torricelli. In addition to biographical information, you will find a list of references about Torricelli and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Torricelli. There is also an image of him, which can be enlarged, and a map of his birthplace.

---

torsion

in physics, the state of strain set up in a twisted material; for example, when a thread, wire, or rod is twisted, the torsion set up in the material tends to return the material to its original state. The **torsion balance**, a sensitive device for measuring small gravitational or magnetic forces, or electric charges, balances these against the restoring force set up by them in a torsion suspension.

---

tortoise

any member of the family Testudinidae, the land-living members of the order Chelonia, which includes all turtles, terrestrial or aquatic. The shell of tortoises is generally more domed than that of aquatic turtles; their hind legs are stumpy and columnar; the front legs are often shovel-shaped for digging. Tortoises are herbivorous and occur in the warmer regions of all continents except Australia. Tortoises range in size from 4 in/10 cm to 5 ft/150 cm, and some are known to live for 150 years.

The sex of a tortoise is difficult to determine, except when the female is on heat. Mating can last up to five hours. Eggs are laid in warm earth in great numbers, and are not incubated by the mother.

Best-known in the pet trade is the small spur-thighed tortoise *Testudo graeca* found in Asia Minor, the Balkans, and North Africa. It was extensively exported, often in appalling conditions, until the 1980s, when strict regulations were introduced to prevent its probable extinction. The giant tortoises of the Galapagos in the Pacific and the Seychelles in the Indian Ocean may reach a length of 5 ft/150 cm and weigh over 500 lbs/225 kg, and can yield about 200 lbs/90 kg of meat; hence its almost complete extermination by sailors in passing ships.

North American tortoises are represented by four species of gopher tortoises (genus *Gophenus*) living in the southwestern USA and Mexico.

Tortoiseshell is the semitransparent shell of the marine hawksbill turtle.

tortoise beetle

leaf-feeding beetle usually found in the tropics. The outer margins of its wing covers and the prothorax (shield) are drawn out to form a convex shield a bit like the outline of a tortoise. They are often brilliantly coloured with a metallic sheen.

The larvae generally have spiky outgrowths, and they cover themselves with excrement or cast skins as methods of camouflage.

classification

Tortoise beetles comprise the subfamily Cassidinae, family Chrysomelidae, order Coleoptera, class Insecta, phylum Arthropoda.

torus

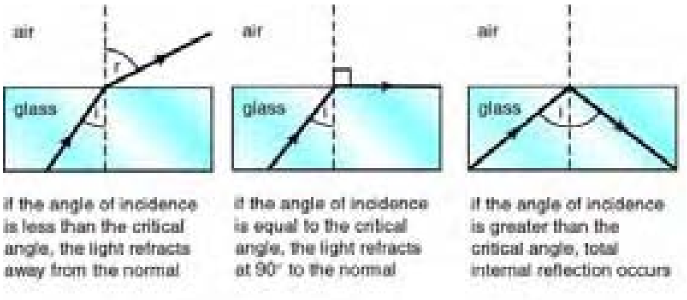
in nuclear physics, ring-shaped chamber used to contain plasma in nuclear fusion reactors such as the Joint European Torus (JET) reactor.

total internal reflection

complete reflection of a beam of light that occurs from the surface of an optically 'less dense' material. For example, a beam from an underwater light source can be reflected from the surface of the water, rather than escaping through the surface. Total internal reflection can only happen if a light beam hits a surface at an angle greater than the critical angle for that particular pair of materials.

Total internal reflection is used as a means of reflecting light inside prisms and optical fibres. Light is contained inside an optical fibre not by the cladding around it, but by the ability of the internal surface of the glass-fibre core to reflect 100% of the light, thereby keeping it trapped inside the fibre.

total internal reflection


air
r
glass
i
if the angle of incidence is less than the critical angle, the light refracts away from the normal
air
glass
i
if the angle of incidence is equal to the critical angle, the light refracts at 90° to the normal
air
glass
i
if the angle of incidence is greater than the critical angle, total internal reflection occurs

(Image © Research Machines plc)

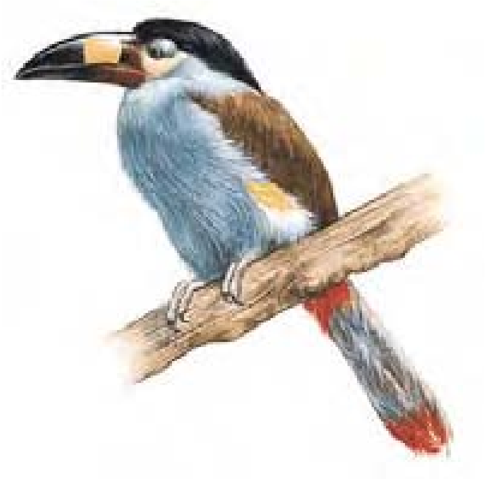
Total internal reflection occurs at the boundary of two transparent substances when a) the incident ray is in the substance with the higher refractive index and b) the angle of incidence exceeds a particular angle known as the critical angle. The critical angle for glass is 42° and for water, about 48°.

toucan

any South and Central American forest-dwelling bird of the genus *Ramphastos*, family Ramphastidae, order Piciformes. Toucans have very large, brilliantly coloured beaks and often handsome plumage. They live in small flocks and eat fruits, seeds, and insects. They nest in holes in trees, where the female lays 2-4 eggs; both parents care for the eggs and young. There are 37 species, ranging from 30 cm/1 ft to 60cm/2ft in size.

In the true toucans the ground colour of the plumage is generally black; the throat, breast and rump are adorned with yellow, red and white; the body is short and thick; the tail is rounded or even and can be turned up over the back when the bird goes to roost. The largest are about 60 cm/24 in long.

toucan



(Image © Research Machines plc)

The toucan has a large, brightly coloured bill, which accounts for almost half its body length. The bill is very light and strong, being constructed of honeycomb material.

touch

sensation produced by specialized nerve endings in the skin. Some respond to light pressure, others to heavy pressure. Temperature detection may also contribute to the overall sensation of touch. Many animals, such as nocturnal ones, rely on touch more than humans do. Some have specialized organs of touch that project from the body, such as whiskers or antennae.

touch screen

in computing, an input device allowing the user to communicate with the computer by touching a display screen with a finger. In this way, the user can point to a required menu option or item of data. Touch screens are used less widely than other pointing devices such as the mouse or joystick. A typical application is in public houses, where sales staff simply need to touch the items sold on the screen; a total is displayed for the customer, while the computing system connected to the screen calculates remaining stock levels.

Typically, the screen is able to detect the touch either because the finger presses against a sensitive membrane or because it interrupts a grid of light beams crossing the screen surface.

touch sensor

in a computer-controlled robot, a device used to give the robot a sense of touch, allowing it to manipulate delicate objects or move automatically about a room. Touch sensors provide the feedback necessary for the robot to adjust the force of its movements and the pressure of its grip. The main types include the strain gauge and the microswitch.

touraco

or turaco

any fruit-eating African bird of the family Musophagidae, order Cuculiformes. They have a small high bill, notched and serrated mandibles, a long tail, erectile crest, and short, rounded wings. The largest are 70 cm/28 in long.

Many of them are brilliantly coloured with glossy blue, red, violet and green plumage. There are about 18 species including the **violet plantain-eater** *Muscophaga violacea* and the **white-cheeked touraco** *Touraco leucotis*, which resembles a multicoloured magpie.

Tourette's syndrome

or Gilles de la Tourette syndrome

rare neurological condition characterized by multiple tics and vocal phenomena such as grunting, snarling, and obscene speech, named after French physician Georges Gilles de la Tourette (1859-1904). It affects one to five people per 10,000, with males outnumbering females by four to one, and the onset is usually around the age of six. There are no convincing explanations of its cause, and it is usually resistant to treatment.

Canadian researchers proved in 1999 that the tics that characterize the syndrome are not involuntary reflexes but result instead from an irresistible urge. This indicates that Tourettes is not a simple motor disorder but is instead more closely related to obsessive compulsive disorders.

Facts About Tourette Syndrome

Go to site

Large source of sympathetically-written information for those suffering from the neurological disorder or those living with them. A history of the syndrome and earlier misunderstanding of its causes is included. Written by a Tourettes sufferer, there is a full description of its many forms of apparently bizarre behaviour and a good bibliography.

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tourmaline

hard, brittle mineral, a complex silicate of various metals, but mainly sodium aluminium borosilicate.

Small tourmalines are found in granites and gneisses. The common varieties range from black (schorl) to pink, and the transparent gemstones may be colourless (achromatic), rose pink (rubellite), green (Brazilian emerald), blue (indicolite, verdelite, Brazilian sapphire), or brown (dravite).

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tourniquet

in medicine, a cuff that can be tightened around the upper end of the thigh or the arm to close the arteries to the limb and stop the flow of blood. Tourniquets are rarely used in modern medicine because gangrene may result. Direct pressure to the point of bleeding is simpler, safer, and at least as effective as a tourniquet.

Townes, Charles Hard (1915-)

US physicist who shared the Nobel Prize for Physics in 1964 for his work in 1953 to design and construct the first maser.

---

toxaemia

another term for blood poisoning; **toxaemia of pregnancy** is another term for pre-eclampsia.

---

toxicity tests

tests carried out on new drugs, cosmetics, food additives, pesticides, and other synthetic chemicals to see whether they are safe for humans to use. They aim to identify potential toxins, carcinogens, teratogens, and mutagens.

Traditionally such tests use live animals such as rats, rabbits, and mice. Animal tests have become a target for criticism by antivivisection groups, and alternatives have been sought. These include tests on human cells cultured in a test tube and on bacteria.

In Europe in 1990, 4,365 animals were used for testing cosmetic products, out of a total of 276,674 animals used to test products other than pharmaceuticals. Including pharmaceuticals, a total of around 3.2 million animals were used in experimentation. The US Office of Technology Assessment estimates that around 1.6 million animals are used annually in government research laboratories, of which 90% are rats or mice.

In October 1999 the British government announced that it would not issue licences for animal testing until it was satisfied that alternative tests were unsatisfactory to test toxins. The licence, known as LD_{50}, involves determining the chemical dose of a toxin that will kill half of the laboratory animals tested. Despite widespread belief among industrialized nations that the test is unnecessary and cruel, the test remains standard in the USA and Japan.

---

toxicology

branch of medicine dealing with the study of poisons. This includes the chemical nature of poisons, their origin and preparation, their physiological action, tests to recognize them, pathological changes due to their presence, their antidotes, and the recognition of them by post-mortem evidence.

---

toxic shock syndrome

rare condition marked by rapid onset of fever, vomiting, and low blood pressure, sometimes leading to death. It is caused by a toxin of the bacterium *Staphylococcus aureus*, normally harmlessly present in the body. It is seen most often in young women using tampons during menstruation.

Toxic shock caused by the superbug MRSA (methicillin-resistant *Staphylococcus aureus*) has been infecting new-born children in Japan since 1995. It is probably more widespread, but because the syndrome has long been believed to affect only teenagers and adults, many cases may have been incorrectly diagnosed.

Childhood Infections - Toxic Shock Syndrome

Go to site

Useful information about toxic shock syndrome. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection, how it can be treated both at home and professionally, and what to do should the symptoms occur.

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toxic waste

hazardous waste, especially when it has been dumped.

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toxin

any poison produced by another living organism (usually a bacterium) that can damage the living body. In vertebrates, toxins are broken down by enzyme action, mainly in the liver.

toxin

The purple cone shell's venom acts extremely fast. It can paralyse a fish within less than two seconds. The venom is administered by a spearlike hollow tooth with which the cone shell can stab even the quickest of fish.

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toxocariasis

human infestation with the larvae of roundworms, sometimes present in dogs and cats. Symptoms include fever, rash, aching joints and muscles, vomiting and convulsions; there may be enlargement of the liver and damage to the lungs. Small children are most at risk.

Childhood Infections - Toxocariasis

Go to site

Useful information about toxocariasis. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection, how it can be treated both at home and professionally, and what to do should the symptoms occur.

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toxoplasmosis

disease transmitted to humans by animals, often in pigeon or cat excrement, or in undercooked meat. It causes flulike symptoms and damages the central nervous system, eyes, and visceral organs. It is caused by a protozoan, *Toxoplasma gondii*. Congenital toxoplasmosis, transmitted from an infected mother to her unborn child, can lead to blindness and retardation.

Childhood Infections - Toxoplasmosis

Go to site

Useful information about toxoplasmosis. There is a detailed description of the infection, its symptoms, and its duration. There are also notes on the prevention of the infection, how it can be treated both at home and professionally, and what to do should the symptoms occur.

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trace

in computing, a method of checking that a computer program is functioning correctly by causing the changing values of all the variables involved to be displayed while the program is running. In this way it becomes possible to narrow down the search for a bug, or error, in the program to the exact instruction that causes the variables to take unexpected values.

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trace element

chemical element necessary in minute quantities for the health of a plant or animal. For example, magnesium, which occurs in chlorophyll, is essential to photosynthesis, and iodine is needed by the thyroid gland of mammals for making hormones that control growth and body chemistry.

---

tracer

in science, a small quantity of a radioactive isotope (form of an element) used to follow the path of a substance. Certain chemical reactions or physical or biological processes can then be monitored. The location (and possibly concentration) of the tracer is usually detected by using a Geiger-Muller counter.

For example, the activity of the thyroid gland can be monitored by giving the patient an injection containing a small dose of a radioactive isotope of iodine, which is selectively absorbed from the bloodstream by the gland.

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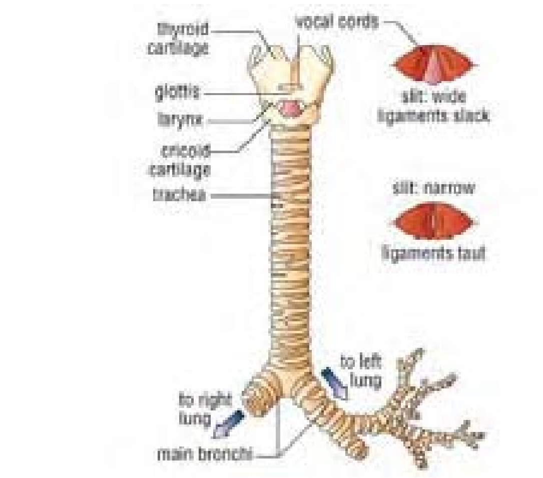
trachea

tube that forms an airway in air-breathing animals. In land-living vertebrates, including humans, it is also known as the **windpipe** and runs from the larynx to the upper part of the chest. Its diameter is about 1.5 cm/0.6 in and its length 10 cm/4 in. It is strong and flexible, and reinforced by rings of cartilage. In the upper chest, the trachea branches into two tubes: the left and right bronchi, which enter the lungs. Insects have a branching network of tubes called tracheae, which conduct air from holes (spiracles) in the body surface to all the body tissues. The finest branches of the tracheae are called tracheoles.

Some spiders also have tracheae but, unlike insects, they possess gill-like lungs (book lungs) and rely on their circulatory system to transport gases throughout the body.

trachea



(Image © Research Machines plc)

The human trachea, or windpipe. The larynx, or voice box, lies at the entrance to the trachea. The two vocal cords are membranes that normally remain open and still. When they are drawn together, the passage of air makes them vibrate and produce sounds.

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tracheid

cell found in the water-conducting tissue (xylem) of many plants, including gymnosperms (conifers) and pteridophytes (ferns). It is long and thin with pointed ends.

The cell walls are thickened by lignin, except for numerous small rounded areas, or pits, through which water and dissolved minerals pass from one cell to another. Once mature, the cell itself dies and only its walls remain.

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tracheotomy

or tracheostomy

surgical opening in the windpipe (trachea), usually created for the insertion of a tube to enable the patient to breathe. It is done either to bypass an airway impaired by disease or injury, or to safeguard air supply during surgery or a prolonged period of mechanical ventilation.

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trachoma

chronic eye infection, resembling severe conjunctivitis. The conjunctiva becomes inflamed, with scarring and formation of pus, and there may be damage to the cornea. It is caused by a bacterium (chlamydia), and is a disease of dry tropical regions. Although it responds well to antibiotics, numerically it remains the biggest single cause of blindness worldwide. In 2001 alone, 6 million people worldwide went blind through trachoma and a further 540 million were at risk. A 2004 study estimated that 18–24% of global blindness (7–9 million people) is caused by trachoma.

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track

in computing, part of the magnetic structure created on a disk surface during disk formatting so that data can be stored on it. The disk is first divided into circular tracks and then each circular track is divided into a number of sectors.

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tradescantia

any of a group of plants native to North and Central America, with variegated or striped leaves. The spiderwort *T. virginiana* is a cultivated garden plant; the wandering jew *T. albiflora* is a common house plant, with green oval leaves tinged with pink, purple or silver-striped. They are named after English botanist John Tradescant the Younger. (Genus *Tradescantia*, family Commelinaceae.)

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trade wind

prevailing wind that blows towards the Equator from the northeast and southeast. Trade winds are caused by hot air rising at the Equator and the consequent movement of air from north and south to take its place. The winds are deflected towards the west because of the Earth's west-to-east rotation.

The unpredictable calms known as the doldrums lie at their convergence.

The trade-wind belts move north and south about 5° with the seasons. The name is derived from the obsolete expression 'blow trade' meaning to blow regularly, which indicates the trade winds' importance to navigation in the days of cargo-carrying sailing ships.

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tragopan

any of several species of bird of the genus *Tragopan*, a short-tailed pheasant living in wet forests along the southern Himalayas. Tragopans are brilliantly coloured with arrays of spots, long crown feathers and two blue erectile crests. All have been reduced in numbers by destruction of their habitat. The western tragopan is the rarest, as a result of extensive deforestation.

Males inflate coloured wattles and throat pouches in their spring courtship displays.

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trance

mental state in which the subject loses the ordinary perceptions of time and space, and even of his or her own body.

In this highly aroused state, often induced by rhythmic music, 'speaking in tongues' (glossolalia) may occur; this usually consists of the rhythmic repetition of apparently meaningless syllables, with a euphoric return to normal consciousness. It is also practised by American Indian and Australian Aboriginal healers, Afro-Brazilian spirit mediums, and in shamanism.

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tranquillizer

common name for any drug for reducing anxiety or tension (anxiolytic), such as benzodiazepines, barbiturates, antidepressants, and beta-blockers. The use of drugs to control anxiety is becoming much less popular, because most of the drugs available are capable of inducing dependence.

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transactinide element

any of a series of eight radioactive, metallic elements with atomic numbers that extend beyond the actinide series, those from 104 (rutherfordium) upwards. They are grouped because of their expected physical and chemical similarities (they are all bivalent), the properties differing only slightly with atomic number. All have half-lives of less than two minutes.

Trans-Alaskan Pipeline

one of the world's greatest civil engineering projects, the construction of a pipeline to carry petroleum (crude oil) 1,285 km/800 mi from northern Alaska to the ice-free port of Valdez. It was completed in 1977 after three years' work and much criticism by ecologists. In 1997 the Pipeline delivered more than 20% of US oil production.

The engineers had to elevate nearly half the pipeline on supports above ground level to avoid thawing the permafrost (permanently frozen ground), which would have caused much environmental damage. They also had to cross 600 rivers and streams and two mountain ranges, and allow for earthquakes.

---

transcription

in living cells, the process by which the information for the synthesis of a protein is transferred from the DNA strand on which it is carried to the messenger RNA strand involved in the actual synthesis.

It occurs by the formation of base pairs when a single strand of unwound DNA serves as a template for assembling the complementary nucleotides that make up the new RNA strand.

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transducer

device that converts one form of energy into another. For example, a thermistor is a transducer that converts heat into an electrical voltage, and an electric motor is a transducer that converts an electrical voltage into mechanical energy. Transducers are important components in many types of sensor, converting the physical quantity to be measured into a proportional voltage signal.

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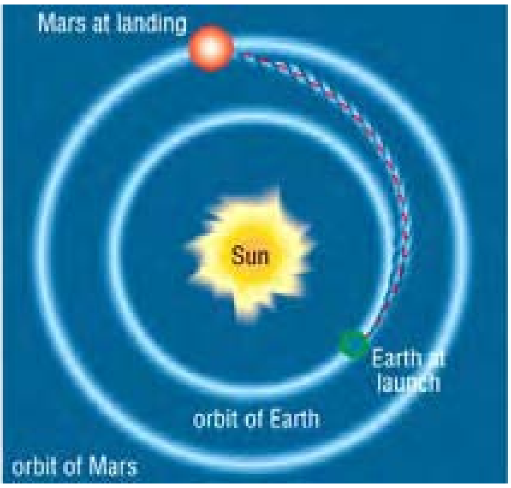
transfer orbit

elliptical path followed by a spacecraft moving from one orbit to another, designed to save fuel although at the expense of a longer journey time.

Space probes have often travelled to other planets on transfer orbits. A probe aimed at Venus has to be 'slowed down' relative to the Earth, so that it enters an elliptical transfer orbit with its perigee (point of closest approach to the Sun) at the same distance as the orbit of Venus; towards Mars, the vehicle has to be 'speeded up' relative to the Earth, so that it reaches its apogee (furthest point from the Sun) at the same distance as the orbit of Mars.
Geostationary transfer orbit is the highly elliptical path followed by satellites to be placed in geostationary orbit around the Earth (an orbit coincident with Earth's rotation). A small rocket is fired at the transfer orbit's apogee to place the satellite in geostationary orbit.

Such transfer orbits are too costly in energy to be used to visit the outer planets. For such journeys a probe gets a 'gravity assist' from other planets. For example, after the Cassini probe was launched it travelled inwards towards the Sun to fly by Venus twice. The 'slingshot' effect of the planet's gravity boosted the probe outwards, so that it flew by the Earth and later by Jupiter, getting a gravity assist each time. Cassini arrived at Saturn after a journey of over six years.

transfer orbit



(Image © Research Machines plc)

The transfer orbit used by a spacecraft when travelling from Earth to Mars. The orbit is chosen to minimize the fuel needed by the spacecraft; the craft is in free fall for most of the journey.

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transformation

in mathematics, a mapping or function, especially one which causes a change of shape or position in a geometric figure. Reflection, rotation, enlargement, and translation are the main geometrical transformations.

Two or more transformations performed on one shape are called **combined transformations**. The transformation of a shape from A to B can be reversed by an **inverse transformation** from B back onto A.

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transformer

device in which, by electromagnetic induction, an alternating current (AC) of one voltage is transformed to another voltage, without change of frequency. Transformers are widely used in electrical apparatus of all kinds, and in particular in power transmission where high voltages and low currents are utilized.

A transformer has two coils, a primary for the input and a secondary for the output, wound on a common iron core. The ratio of the primary to the secondary voltages is directly proportional to the number of turns in the primary and secondary coils; the ratio of the currents is inversely proportional.

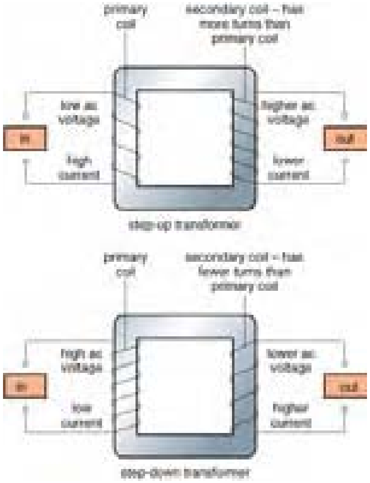
step-up transformer

This type of transformer has more turnings on the secondary coil than on the primary coil and therefore the voltage induced in the secondary coil is larger than the primary coil voltage. If the number of turns on the primary coil is N_P and the number of turns on the secondary coil is N_S, and the respective voltages are V_P and V_S, then $N_S/N_P = V_S/V_P$. For example, if there are 200 turnings on the primary coil and 2,000 turnings on the secondary coil, then the voltage induced in the secondary coil is ten times larger than the primary coil voltage.

step-down transformer

This type of transformer has more turnings on the primary coil than on the secondary coil and therefore the voltage induced in the secondary coil is smaller than the primary coil voltage. The same formula applies as for a step-up transformer, so if there are 2,000 turnings on the primary coil and 200 turnings on the secondary coil, then the voltage induced in the secondary coil is ten times smaller than the primary coil voltage.

transformer



(Image © Research Machines plc)

A step-up transformer increases voltage and has more turns on the secondary coil than on the primary. A step-down transformer decreases voltage and has more turns on the primary coil than on the secondary. If the numbers of turns in the primary and secondary coils are n_1 and n_2, the primary and secondary voltages are V_1 and V_2, and the primary and secondary currents are I_1 and I_2, then the relationships between these quantities may be expressed as: $V_1/V_2 = I_2/I_1 = n_1/n_2$.

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transfusion

intravenous delivery of blood or blood products (plasma, red cells) into a patient's circulation to make up for deficiencies due to disease, injury, or surgical intervention.

Cross-matching is carried out to ensure the patient receives the right blood group. Because of worries about blood-borne disease, there is a growing interest in autologous transfusion with units of the patient's own blood 'donated' over the weeks before an operation.

Blood is rarely transfused whole. Blood cells and platelets are separated and resuspended in solution. Plasma can be frozen and is used to treat clotting deficiencies.

Blood transfusion, first successfully pioneered in humans in 1818, remained a high risk until the discovery of blood groups, by Austrian-born immunologist Karl Landsteiner in 1900, which indicated the need for compatibility of donated blood.

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transgenic organism

plant, animal, bacterium, or other living organism that has had a foreign gene added to it by means of genetic engineering. In terms of laboratory research, transgenic manipulations of organisms have become well-established scientific procedures which are finding progressively more applications in the health and food industries.

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transhumance

seasonal movement by pastoral farmers of their livestock between areas of different climate. There are three main forms: in **Alpine** regions, such as Switzerland, cattle are moved to high-level pastures in summer and returned to milder valley pastures in winter; in **Mediterranean** lands, summer heat and drought make it necessary to move cattle to cooler mountain slopes; in **West Africa**, the nomadic herders of the Fulani peoples move cattle south in search of grass and water in the dry season and north in the wet season to avoid the tsetse fly.

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transistor

solid-state electronic component, made of semiconductor material, with three or more electrical contacts that can regulate a current passing through it. A transistor can act as an amplifier, oscillator, photocell, or switch, and (unlike earlier thermionic valves) usually operates on a very small amount of power. Transistors commonly consist of a tiny sandwich of germanium or silicon, alternate layers having different electrical properties because they are impregnated with minute amounts of different impurities.

A crystal of pure germanium or silicon would act as an insulator (nonconductor). By introducing impurities in the form of atoms of other materials (for example, boron, arsenic, or indium) in minute amounts, the layers may be made either **n-type**, having an excess of electrons, or **p-type**, having a deficiency of electrons. This enables electrons to flow from one layer to another in one direction only. Transistors have had a great impact on the electronics industry, and thousands of millions are now made each year. They perform many of the functions of the thermionic valve, but have the advantages of greater reliability, long life, compactness, and instantaneous action – no warming-up period being necessary. They are widely used in most electronic equipment, including portable radios and televisions, computers, and satellites, and are the basis of the integrated circuit (silicon chip). They were invented at Bell Telephone Laboratories in the USA in 1948 by John Bardeen and Walter Brattain, developing the work of William Shockley.

Transistorized! The History of the Invention of the Transistor

Go to site

Superb, in-depth history of the invention of the transistor. This attractive Web site has lots of interesting, well-researched articles, biographies of key people, an event time line, audio and video clips, and more.

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transistor-transistor logic

TTL

in computing, the type of integrated circuit most commonly used in building electronic products. In TTL chips the bipolar transistors are directly connected (usually collector to base). In mass-produced items, large numbers of TTL chips are commonly replaced by a small number of uncommitted logic arrays (ULAs), or logic gate arrays.

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transit

in astronomy, passage of a smaller object across the visible disc of a larger one. Transits of the inferior planets occur when they pass directly between the Earth and the Sun, and are seen as tiny dark spots against the Sun's disc.

Other forms of transit include the passage of a satellite or its shadow across the disc of Jupiter and the passage of planetary surface features across the central meridian of that planet as seen from Earth. The passage of an object in the sky across the observer's meridian is also known as a transit.

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transition metal

any of a group of metallic elements that have incomplete inner electron shells and exhibit variable valency – for example, cobalt, copper, iron, and molybdenum. They form a long block in the middle of the periodic table of the elements, between groups 2 and 3. They are excellent conductors of electricity, and generally form highly coloured compounds.

They include most of the hard, dense, and less reactive metals used as building materials, such as iron, lead, and copper. The precious metals, gold, platinum, and silver are also transition metals. They are rare, beautiful and costly, and so unreactive that they can be used as jewellery. Transition metals and their compounds are often used in industry as catalysts. For example, iron is used as a catalyst in the Haber process to produce ammonia. They are also used to make alloys.

transition metals

To remember the first row of transition metals in the periodic table:

Scandinavian **TV** **c**orrupts **m**any **F**rench **c**oalmen's **n**ieces and **c**ousins

Sc, **T**i, **V**, **C**r, **M**n, **F**e, **C**o, **N**i, **C**u, Zn

translation

in biology, alternative name for protein biosynthesis. The term 'translation' emphasizes the aspect that the genetic information encoded as a sequence of nucleotides in DNA and in messenger RNA is 'translated' into a sequence of amino acids in a peptide chain, according to the rules of the genetic code. See also transcription.

translation program

in computing, a program that translates another program written in a high-level language or assembly language into the machine-code instructions that a computer can obey. See assembler, compiler, and interpreter.

translocation

in genetics, the exchange of genetic material between chromosomes. It is responsible for congenital abnormalities, such as Down's syndrome.

transmission electron microscope

TEM

most powerful type of electron microscope, with a resolving power ten times better than that of a scanning electron microscope and a thousand times better than that of an optical microscope. A fine electron beam passes through the specimen, which must therefore be sliced extremely thinly – typically to about one-thousandth of the thickness of a sheet of paper (100 nanometres). The TEM can resolve objects 0.001 micrometres (0.04 millionth of an inch) apart, a gap that is 100,000 times smaller than the unaided eye can see.

A TEM consists of a tall, evacuated column at the top of which is a heated filament that emits electrons. The electrons are moved at uniform high velocity down the column by a high voltage (around 100,000 volts) and pass through the slice of specimen at a point roughly half-way down. Because the density of the specimen varies, the 'shadow' of the beam falls on a fluorescent screen near the bottom of the column and forms an image. A camera is mounted beneath the screen to record the image.

The electron beam is controlled by magnetic fields produced by electric coils, called electron lenses. One electron lens, called the condenser, controls the beam size and brightness before it strikes the specimen. Another electron lens, called the objective, focuses the beam on the specimen and magnifies the image about 50 times. Other electron lenses below the specimen then further magnify the image.

The **high voltage transmission electron microscope** (HVEM) uses voltages of up to 3 million volts to accelerate the electron beam. The largest of these instruments is as tall as a three-storey building.

The first experimental TEM was built in 1931 by German scientists Max Knoll and Ernest Ruska of the Technische Hochschule, Berlin, Germany. They produced a picture of a platinum grid magnified 117 times. The first commercial electron microscope was built in England in 1936.

transparency

in photography, a picture on slide film. This captures the original in a positive image (direct reversal) and can be used for projection or printing on positive-to-positive print material, for example by the Cibachrome or Kodak R-type process.

Slide film is usually colour but can be obtained in black and white.

transpiration

loss of water from a plant by evaporation. Most water is lost by diffusion of water vapour from the leaves through pores known as stomata to the outside air. The primary function of stomata is to allow gas exchange between the plant's internal tissues and the atmosphere. Transpiration from the leaf surfaces causes a continuous upward flow of water from the roots via the xylem, which is known as the transpiration stream. This replaces the water that is lost, and allows minerals absorbed from the soil to be transported through the xylem to the leaves. This is important because many plant cells need the minerals as nutrients.

Sap: Early Experiment on Transpiration

sap flow in plants

Stephen Hales was a man of many scientific interests and, apparently, of settled habits. After scientific education at Cambridge, he was appointed vicar of Teddington, England in 1709, holding the post until he died in 1761. Perhaps he preferred a settled life so he could follow his many scientific interests. Amongst his investigations, he refined William Harvey's ideas on blood circulation in animals. This involved gruesome experiments on horses, dogs, and frogs. In one, he attached a vertical tube 3.3 m/11 ft long to a horse's blood vessel to measure how high the blood rose – he was measuring blood pressure.

circulation in plants?

In about 1724, Hales began studying the circulation of sap in plants. He showed how water is drawn in at the roots, transported to the leaves, and then transpired. Several pieces of this jigsaw were already in place. After the microscope was developed in the mid 17th century, it was found that plants contained tubes running along the length of the stem, some full of water and some full of air. This suggested some sort of circulation system, comparable to that in animals. Common sense suggested that plants take in water through the roots, the moisture travelling to all parts of the plant. Around 1670 the Italian Marcello Malpighi had shown that a plant's food substances were built up in the leaves. There must be a downward transport of these substances to other parts of the plant. Since these substances were sometimes stored in tubers, the downward flow must reach the roots.

Hales' experiments

The questions Hales addressed were: was there a closed circulation, as in animals, and what powered it? He undertook three crucial experiments. In the first, he established that the water was drawn upwards by the leaves. His notebook records:

'July 27 (1716). I fixed an apple branch ... to a tube. I filled the tube with water, and then immersed the whole branch ... into a vessel full of water. The water subsided 6 inches in the first two hours (being the filling of the sap vessels) and 6 inches the following night.'

Hales concluded that this showed the great drawing power of 'perspiration'. Evaporation from the leaves pulled the sap upwards, rather than pressure pushing from the roots. The next step was simple: by putting a leafy plant in a closed vessel, and collecting the transpired liquid, he confirmed that the material that transpired into the air was water. Water was indeed flowing up the stem and being expired from the leaves.

Hales' apple branch

The third experiment was more complicated. Hales needed to discover whether the upward movement of the water was balanced by an equal downward flow; water might be absorbed from the air by the leaves, making the flow a continuous circulation. His notebook records a beautifully simple and conclusive experiment:

'August 20 (1716). At 1 p.m. I took an apple branch nine foot long, 13/4 inch diameter, with proportional lateral branches. I cemented it fast to one end of a vertical U tube; but first I cut away the bark, and last year's ringlet of wood, near the bottom of the branch. I then filled the tube with water, which was 22 feet long and 1/2 inch diameter. The water was very freely imbibed, at a rate of 31/2 inch in a minute. In half an hour's time I could plainly perceive the lower part of the cut to be moister than before; when at the same time the upper part of the wound looked white and dry.'

'The water must necessarily ascend from the tube, through the innermost wood, because the last year's wood was cut away, for 3 inches all round the stem; and consequently, if the sap in its natural course descended by the last year's ringlet of wood, between that and the bark (as many have thought) the water should have descended by last year's wood, or the bark, and so have moistened the upper part of the gap; but, on the contrary, the lower part was moistened, and not the upper part.'

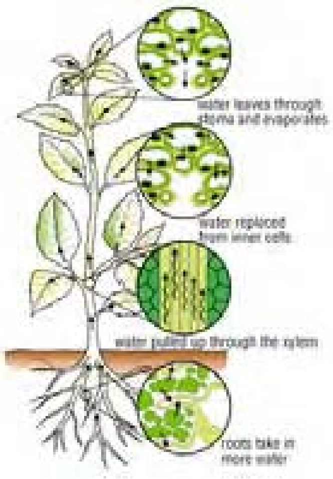
There was no sign of descending water, and hence no circulation of water within the plant. Hales had already shown that the sunflower transpires water 17 times faster than a man, bulk for bulk; if there was a circulation, it would have to be enormously fast.

further discoveries about the workings of plants

Hales continued his work on plant physiology. He showed that plants take in part of the air (carbon dioxide) which is used in their nutrition. He measured growth rates. His interests were wide-ranging: from preservation of foods, water purification, and ventilation of ships and buildings, to the best way of supporting pie crusts.

In 1779 Dutch doctor Jan Ingen-Housz established two distinct processes in plants: respiration, in which oxygen is absorbed and carbon dioxide is exhaled, as in animal respiration; and photosynthesis, in which carbon dioxide is taken in to make food, and oxygen is given out. It is the daily ebb and flow of these processes that transports water and food around a plant.

transpiration



(Image © Research Machines plc)

The loss of water from a plant by evaporation is known as transpiration. Most of the water is lost through the surface openings, or stomata, on the leaves. The evaporation produces what is known as the transpiration stream, a tension that draws water up from the roots through the xylem, water-carrying vessels in the stem.

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transplant

in medicine, the transfer of a tissue or organ from one human being to another or from one part of the body to another (skin grafting). In most organ transplants, the operation is for life-saving purposes. The immune system tends to reject foreign tissue, so careful matching and immunosuppressive drugs must be used, though these are not always successful.

Corneal grafting, which may restore sight to a diseased or damaged eye, was pioneered in 1905, and is the oldest successful human transplant procedure. Of the internal organs, kidneys were first transplanted successfully in the early 1950s and remain most in demand. Modern transplantation also encompasses the heart, lungs, liver, pancreatic tissue, bone, bone-marrow, and ovarian tissue.

Most transplant material is taken from cadaver donors, usually those suffering death of the brainstem, or from frozen tissue banks. In rare cases, kidneys, corneas, and part of the liver may be obtained from living donors. The 1990 Nobel Prize for Medicine or Physiology was awarded to two US surgeons, Donnall Thomas and Joseph Murray, for their pioneering work on organ and tissue transplantation.

First Organ Transplants

early transplant procedures

Although transplantation may sound wholly contemporary, it is not really all that new. The term 'transplant', for instance, is thought to have been coined by the renowned 18th-century Scottish surgeon John Hunter (1728–93) in describing animal experiments. The oldest transplant procedure is corneal grafting, pioneered by an eye surgeon called Eduard Zirm in the small town of Olmutz in Moravia in 1905.

animal transplant operations

Throughout the early years of this century experimentation continued in animals. An early pioneer was the French-American surgeon Alexis Carrel, working at the Rockefeller Institute in New York. Besides switching around dogs' hearts, he developed the techniques of surgical anastomosis – reconnecting severed blood vessels – which would be essential to major surgery in general and certainly to transplant operations. Carrel received the Nobel prize for this work in 1912 and, two years later, informed the International Surgical Association: 'The surgical side of transplantation of organs is completed as we are now able to perform transplantation of organs with perfect ease ... All our efforts must now be directed toward the biological methods which will prevent the reaction of the organism against foreign tissue.'

first human transplant operations

However, almost two decades were to pass before anyone tried transplanting organs in human beings. Between 1933 and 1939 the Russian surgeon Voronoy, working in the Ukraine, made six attempts to graft cadaver kidneys into very sick patients, all of which failed. Next, in 1946, US surgeons used a cadaver graft in a bid to save a patient who was in acute kidney failure due to septicaemia. This worked only in that the patient's own kidneys resumed their function within two days.

organ rejection

The major problem was that of rejection, the body's destructive response to 'foreign' tissue. Although the phenomenon was widely recognized by the mid 20th century, no one understood how it came about. So, in 1953, when surgeons in Paris made the first attempt at grafting a kidney from a living donor – mother to son – the organ functioned well for three weeks, until rejection set in.

first successful organ transplant

Finally, the world's first truly successful organ transplant took place in December 1954, when surgeons at the Peter Bent Brigham Hospital in Boston opted for the only formula where rejection does not occur:

a transplant between identical twins. They removed one of Robert Herrick's kidneys and grafted it into his brother, Richard, who was dying of kidney failure. Robert made an uneventful recovery and lived quite normally with a single kidney; Richard lived for a further eight years.

kidney transplantation

This historic operation established the procedure still in use today, whereby in most cases the non-functioning kidneys are left in place and the donor kidney is inserted in the recipient's lower abdomen, usually on the right-hand side; it is connected via the ureter to the bladder. Once the blood vessels are anastomosed (connected together) and circulation is established, the grafted kidney may begin producing urine before the surgeons have had time to close (though some may not function for several weeks). However, following the success in Boston, further attempts at kidney grafting ended in failure, except in the case of identical twins. The survival rate hardly improved even when patients were exposed to total body irradiation to knock out the immune system and given anti-cancer drugs against rejection. Now, with their own body defences obliterated, most kidney recipients died from infection.

anti-rejection drugs

A number of developments in the early 1960s however, began to transform renal grafting from an experimental procedure into a viable option for end-stage kidney disease. First came the introduction of tissue typing – matching donor and recipient for compatibility in order to minimize the strength of the immune response. Then, in 1962, came the major breakthrough: the appearance of azathioprine, the first effective anti-rejection drug. The following year a steroid drug, prednisone, was added and the two-drug combination formed the basis of immunosuppressive treatment for many years.

liver transplantation

Meanwhile, pioneering attempts to transplant other organs proved considerably more problematic. The first human being to undergo liver transplantation, a three-year-old boy with biliary atresia, died on the operating table in Denver, Colorado, in 1963. Few patients undergoing this formidable procedure – one of the most challenging in the entire surgical repertoire – survived in the early years.

heart transplantation

In 1967, researchers at Stanford University in California, who had been experimenting with cardiac transplantation for years, were pipped at the post when the South African surgeon Christiaan Barnard performed the world's first human heart transplant. The patient, 54-year-old Louis Washkansky, seemed to spend most of the remaining 18 days of his life in front of television cameras before finally dying from pneumonia. Further attempts were made at various centres but the results were so disastrous that heart transplantation had to virtually be abandoned for more than a decade.

infection and rejection

Still the twin spectres haunting the transplant scene were infection and rejection. It was very hard to get the formula right. Except in the case of kidney grafting, where there was the fall-back of dialysis, if organ recipients received insufficient immunosuppression they died of rejection; or, if the immune system was knocked out completely, they succumbed to infection. It was mainly the arrival of the powerful new anti-rejection drug cyclosporin – available from 1980 onwards – that transformed the picture.

the situation today

Today there is a whole range of life-saving transplants available – kidney, liver, heart, lung(s), pancreas, and small bowel. Except for kidney transplants, none of these procedures would be possible without the life-support technology developed over the last few decades. Ventilators, for instance, are used to maintain the brainstem-dead donors who are the main source of organs for grafting; the ventilator, too, sustains the recipient's breathing during and immediately after surgery. The heart-lung machine, introduced in 1953, is essential in major transplants where the recipient's own circulation has to be interrupted.

grafts

With all this high-profile activity, too often overlooked are the more humdrum grafts – of tissues such as skin, bone, joints, nerves and corneas – which can restore mobility, sensation or sight or prevent loss of a limb. Other than blood, bone is now the most frequently grafted tissue worldwide.

Transplantation and Donation

Go to site

This site includes information about organ and tissue transplantation and donation, the latest research developments, and answers to commonly asked questions. It is supported by articles and reports from medical professionals.

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transsexual

person who identifies himself or herself completely with the opposite sex, believing that the wrong sex was assigned at birth. Unlike **transvestites**, who desire to dress in clothes traditionally worn by the opposite sex, transsexuals think and feel emotionally in a way typically considered appropriate to members of the opposite sex, and may undergo surgery to modify external sexual characteristics.

In 1995 Dutch researchers identified a structural difference between the brains of transsexual men and other men. Within the brain a small cluster of cells, the bed nucleus of the stria terminalis (BST), is smaller in women than men. Transsexual males in the study were found to have a female-sized BST. Research is continuing into the significance of this finding.

Trans-Siberian Railway

the world's longest single-service railway, connecting the cities of European Russia with Omsk, Novosibirsk, Irkutsk, and Khabarovsk, and terminating at Nakhodka on the Pacific coast east of Vladivostok. The line was built between 1891 and 1915, and has a total length of 9,289 km/5,772 mi, from Moscow to Vladivostok.

The greater part of the Trans-Siberian Railway was completed in record time in the period 1891–99. The line opened up the regions of Siberia and the Far East to extensive Russian colonization. It also enabled large-scale geological prospecting of the Kuznetsk, Karaganda, Ekibastuz and Cheremkhovo coal basins and of the Amur and Kolyma gold deposits to be carried out, which laid the basis for the economic development of Siberia. The Trans-Mongolian Railway branches off at Lake Baikal and travels via the Mongolian capital Ulan-Bator to Beijing. At Tarskaya, almost 3,000 km west of Vladivostok, the Trans-Siberian meets the Trans-Manchurian Railway, which reaches Beijing via Harbin. A new northern rail route across Siberia, the Baikal-Amur Mainline (BAM), stretching 3,102 km/1,928 mi from Ust-Kut to the Pacific, was officially opened in 1991 after seventeen years' work.

Across Russia on the Trans-Siberian Railroad

Go to site

Detailed journal of a trip on the famous railway from Moscow to Vladivostock. A day-by-day account of the 6,000 mile journey is accompanied by a large selection of photographs and useful information for anyone who would like to try it for themselves.

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transuranic element

or transuranium element

chemical element with an atomic number of 93 or more – that is, with a greater number of protons in the nucleus than has uranium. All transuranic elements are radioactive. Neptunium and plutonium are found in nature; the others are synthesized in nuclear reactions.

Research in transuranics is pursued mainly at the Lawrence radiation laboratories of the University of California at Berkeley; the Joint Institute for Nuclear Research in Dubna, USSR; and the Institute for Heavy-Ion Research in Darmstadt, Germany. These institutes have produced a number of new elements over the last few decades, in the quest to reach a predicted 'island of stability' at higher atomic numbers.

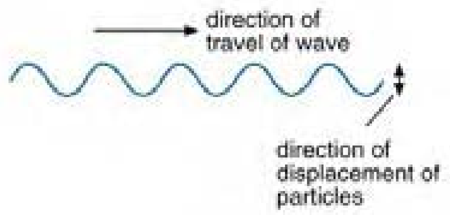
---

transverse wave

wave in which the displacement of the medium's particles, or in electromagnetic waves the direction of the electric and magnetic fields, is at right angles to the direction of travel of the wave motion.

Various methods are used to reproduce waves, such as a ripple tank or a rope, in order to understand their properties. If one end of a rope is moved in an up and down motion (the other end being fixed), a wave travels along the rope. The particles in the rope oscillate at right angles to the direction of the wave, moving up and down as the wave travels along the rope. This is known as a transverse wave. The rope remains as it was after the wave has travelled along the rope; waves carry energy from one place to another but they do not transfer matter. Examples of transverse waves are water waves and electromagnetic waves.

transverse wave



(Image © Research Machines plc)

The diagram illustrates the motion of a transverse wave. Light waves are examples of transverse waves: they undulate at right angles to the direction of travel and are characterized by alternating crests and troughs. Simple water waves, such as the ripples produced when a stone is dropped into a pond, are also examples of transverse waves.

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trapezoid

in geometry, a four-sided plane figure (quadrilateral) with only two sides parallel. If the parallel sides have lengths a and b and the perpendicular distance between them is h (the height of the trapezoid), its area $A=1/2h(a+b)$.

An isosceles trapezoid has its sloping sides (legs) equal, is symmetrical about a line drawn through the midpoints of its parallel sides, and has equal base angles.

---

trauma

in psychiatry, a painful emotional experience or shock with lasting psychic consequences; in medicine, any physical damage or injury.

In psychiatric terms a trauma may have long-lasting effects, during which an insignificant event triggers the original distress. A person then may have difficulties in normal life, such as in establishing relationships or sleeping. In psychological terms this is known as **post-traumatic stress disorder**. It can be treated by psychotherapy.

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travel medicine

see immunization for travel.

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treadmill

wheel turned by foot power (often by a domesticated animal) and used, for instance, to raise water from a well or grind grain.

---

tree

perennial plant with a woody stem, usually a single stem (trunk), made up of wood and protected by an outer layer of bark. It absorbs water through a root system. There is no clear dividing line between shrubs and trees, but sometimes a minimum achievable height of 6 m/20 ft is used to define a tree.

angiosperms

A treelike form has evolved independently many times in different groups of plants. Among the angiosperms, or flowering plants, most trees are dicotyledons. This group includes trees such as oak, beech, ash, chestnut, lime, and maple, and they are often referred to as broad-leaved trees because their leaves are broader than those of conifers, such as pine and spruce. In temperate regions angiosperm trees are mostly deciduous (that is, they lose their leaves in winter), but in the tropics most angiosperm trees are evergreen. There are fewer trees among the monocotyledons, but the palms and bamboos (some of which are treelike) belong to this group.

gymnosperms

The gymnosperms include many trees and they are classified into four orders: Cycadales (including cycads and sago palms), Coniferales (the conifers), Ginkgoales (including only one living species, the ginkgo, or maidenhair tree), and Taxales (including yews). Apart from the ginkgo and the larches (conifers), most gymnosperm trees are evergreen.

tree ferns

There are also a few living trees in the pteridophyte group, known as tree ferns. In the swamp forests of the Carboniferous era, 300 million years ago, there were giant treelike horsetails and club mosses in addition to the tree ferns.

oldest trees

The world's oldest living trees are found in the Pacific forest of North America, some more than 2,000 years old.

conservation

According to a 1998 report by the World Conservation Monitoring Centre (WCMC) and the World Conservation Union, approximately 8,750 tree species (around 10% of all known tree species) are in danger of extinction. In the 20th century 77 species became extinct and 7 more species were reduced to fewer than a dozen specimens.

tree

(Image © Research Machines plc)

The mass of flowers that appear on the branches of fruit trees in spring, before the growth of new leaves, is known as blossom. Apple blossom ranges in colour from white to dark pink and appears in mid to late spring.

British Trees Home Page

Go to site

Introductory guide to native British trees. It can be searched by common name or Latin name, and there is a photographic collection of the mature trees, as well as seeds and flowers in various stages of their development.

Wonderful World of Trees

Go to site

Well-structured site leading you down interesting pathways where you can learn about a year in the life of a tree, uses for trees, and how to identify different species.

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tree creeper

small, short-legged bird of the family Certhiidae, which spirals with a mouselike movement up tree trunks searching for food with its thin down-curved beak.

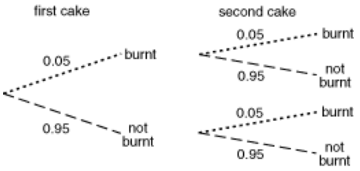
The **common tree creeper** *Certhia familiaris* is 12 cm/5 in long, brown above, white below, and is found across Europe, northern Asia, and North America.

---

tree diagram

in probability theory, a branching diagram consisting only of arcs and nodes (but not loops curving back on themselves), which is used to establish probabilities. Each branch represents a possible outcome of one event. These possible outcomes are known as mutually exclusive events. The final probability depends on the path taken through the tree.

For example, when two cakes are baked the probability that one cake will not be burnt is 0.95. The tree diagram shows all the possible outcomes:



The outcome of each cake can be described as an independent event as they have no effect on each other. Each path through the tree gives a different outcome. In this case there are four outcomes.

The dotted path gives the outcome of both cakes burning. The probabilities are multiplied to obtain this outcome:

Probability of both cakes burning = 0.05 × 0.05 = 0.0025

The dashed path gives the outcome of both cakes not burning:

Probability of both cakes not burning = 0.95 × 0.95 = 0.9025

The probability of one cake burning has two outcomes: (i) the first burnt and second not burnt, and (ii) the first not burnt and the second burnt. These probabilities are:

(i) 0.05 × 0.95 = 0.0475 and (ii) 0.95 × 0.05 = 0.0475

The two probabilities are added together to obtain the probability of one cake burning = 0.0475 + 0.0475 = 0.095.

The four probabilities should add up to 1.

Probabilities of independent events are always multiplied, characterized by *and*, for example, first cake burnt and second cake burnt. Probabilities of mutually exclusive events are always added, characterized by *or*, for example, first cake burnt or not burnt.

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tree rings

rings visible in the wood of a cut tree; see annual rings.

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trefoil

any of several clover plants of a group belonging to the pea family, the leaves of which are divided into three leaflets. The name is also used for other plants with leaves divided into three lobes. (Genus *Trifolium*, family Leguminosae.)

Bird's-foot trefoil *Lotus corniculatus*, also belonging to the pea family, is a low-growing perennial found in grassy places throughout Europe, northern Asia, parts of Africa, and Australia. It has five leaflets to each leaf, but the first two are bent back so it appears to have only three. The yellow flowers, often tinged orange or red, are borne in heads with only a few blooms. Hop trefoil *T. campestre* has leaves with only three leaflets and tight-packed round heads of yellow flowers about 1.5 cm/0.6 in across. It also grows in grassy places throughout Europe, western Asia, North Africa, and North America. In Australia, Austral trefoil *Lotus australis* is a widespread native with pink or white flowers. It is suspected of being poisonous.

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trematode

parasitic flatworm with an oval non-segmented body, of the class Trematoda, including the fluke.

---

tremor

minor earthquake.

Trevithick, Richard (1771-1833)

English engineer, constructor of a steam road locomotive in 1801, the first to carry passengers, and probably the first steam engine to run on rails in 1804.

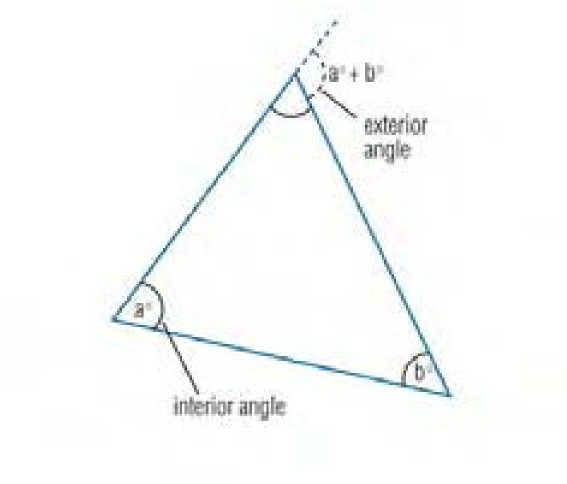
He also built steamboats, river dredgers, and threshing machines.

---

triangle

in geometry, a three-sided plane figure, the sum of whose interior angles is 180°. Triangles can be classified by the relative lengths of their sides. A **scalene triangle** has three sides of unequal length. An **isosceles triangle** has at least two equal sides; it has one line of symmetry. An **equilateral triangle** has three equal sides (and three equal angles of 60°); it has three lines of symmetry.

angles in triangles



(Image © Research Machines plc)

The exterior angle of a triangle is equal to the sum of the opposite interior angles.

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triangle of forces

method of calculating the force (the resultant) produced by two other forces. It is based on the fact that if the strengths of three forces acting at a point are proportional to the lengths of the sides of a triangle, the forces are in equilibrium. See parallelogram of forces.

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triangulation

technique used in surveying to determine distances, using the properties of the triangle. To begin, surveyors measure a certain length exactly to provide a base line. From each end of this line they then measure the angle to a distant point, using a theodolite. They now have a triangle in which they know the length of one side and the two adjacent angles. By simple trigonometry they can work out the lengths of the other two sides.

To make a complete survey of the region, they repeat the process, building on the first triangle.

Triassic Period

period of geological time 245–208 million years ago, the first period of the Mesozoic era. The present continents were fused together in the form of the world continent Pangaea. Triassic sediments contain remains of early dinosaurs and other animals now extinct. By late Triassic times, the first mammals had evolved.

There was a mass extinction of 95% of plants at the end of the Triassic possibly caused by rising temperatures.

---

triceratops

any of a genus *Triceratops* of massive, horned dinosaurs of the order Ornithischia. They had three horns and a neck frill and were up to 8 m/25 ft long; they lived in the Cretaceous period.

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trichloromethane

technical name for chloroform.

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tricuspid valve

flap of tissue situated on the right side of the heart between the atrium and the ventricle. It prevents blood flowing backwards when the ventricle contracts.

As in all valves, its movements are caused by pressure changes during the beat rather than by any intrinsic muscular activity. As the valve snaps shut, a vibration passes through the chest cavity and is detectable as the first sound of the heartbeat.

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triggerfish

any marine bony fish of the family Balistidae, with a laterally compressed body, up to 60 cm/2 ft long, and a deep belly. They have small mouths but strong jaws and teeth. The first spine on the dorsal fin locks into an erect position, allowing them to fasten themselves securely in crevices for protection; it can only be moved by depressing the smaller third ('trigger') spine.

There are many species, found mainly in warm waters, and some are very colourful.

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triglyceride

chemical name for fat comprising three fatty acids reacted with a glycerol.

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trigonometry

branch of mathematics that concerns finding lengths and angles in triangles. In a right-angled triangle the sides and angles are related by three trigonometric ratios: sine, cosine, and tangent. Trigonometry is used frequently in navigation, surveying, and simple harmonic motion in physics.

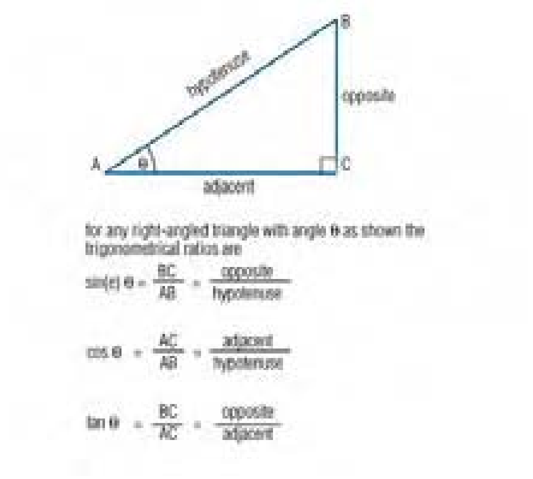
Using trigonometry, it is possible to calculate the lengths of the sides and the sizes of the angles of a right-angled triangle as long as one angle and the length of one side are known, or the lengths of two sides. The longest side, which is always opposite to the right angle, is called the **hypotenuse**. The other sides are named depending on their position relating to the angle that is to be found or used: the side opposite this angle is always termed **opposite** and that adjacent is the **adjacent**. So the following trigonometric ratios are used:

sine = opposite/hypotenuse

cosine = adjacent/hypotenuse

tangent = opposite/adjacent

trigonometry



for any right-angled triangle with angle θ as shown the trigonometrical ratios are

$$\sin(e)\ \theta = \frac{BC}{AB} = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\cos\theta = \frac{AC}{AB} = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan\theta = \frac{BC}{AC} = \frac{\text{opposite}}{\text{adjacent}}$$

(Image © Research Machines plc)

At its simplest level, trigonometry deals with the relationships between the sides and angles of triangles. Unknown angles or lengths are calculated by using trigonometrical ratios such as sine, cosine, and tangent. The earliest applications of trigonometry were in the fields of navigation, surveying, and astronomy, and usually involved working out an inaccessible distance such as the distance of the Earth from the Moon.

trigonometry

To remember the definitions of the trigonometric functions:

Soh-**cah**-**toa** or **S**ome **o**fficers **h**ave **c**urly **a**uburn **h**air **t**o **o**ffer **a**ttraction or **S**ydney **O**pera House: **c**osts **a**re **h**igher **t**han **o**riginally **a**nticipated or **S**addle **o**ur **h**orses, **c**anter **a**way **h**appily, **t**o **o**ther **a**dventures or **S**ome **o**ld **h**ulks **c**arry **a** **h**uge **t**ub **o**f **a**le or **S**ome **o**ld **h**ag **c**racked **a**ll **h**er **t**eeth **o**n **a**sparagus or **S**ome **o**ld **h**airy **c**amels **a**re **h**airier **t**han **o**thers **a**re or **S**illy **o**ld **h**arry **c**aught **a** **h**erring **t**rawling **o**ff **a**merica or **S**miles **o**f **h**appiness **c**ome **a**fter **h**aving **t**ankards **o**f **a**le! or **S**ome **o**ld **h**en **c**aught **a**nother **h**en **t**aking **o**ne **a**way

S(in) - **o**(pposite) / **h**(ypotenuse)
C(os) - **a**(djacent) / **h**(ypotenuse)
T(an) - **o**(pposite) / **a**(djacent)

Dave's Short Trig Course

Go to site

Short course in trigonometry by Dave, a professor of maths and computer science. This offers notes on trigonometry beginning with applications of trigonometry and what trigonometry is. It then moves on to explain how to do trigonometry. The site is mainly an introductory lesson, although there are a few exercises to try. This would be good for revision or to brush up on the background to trigonometry.

SOS Mathematics: Trigonometry

Go to site

Lessons on trigonometry, which start simply with the 'Measure of an angle' and move on to 'Solving trigonometric equations'. Each lesson has examples and questions, and the solutions can be viewed online. There is a lot of useful information on this site but some of it does go beyond the GCSE syllabus.

Trigonometric Functions

Go to site

History of the development of the trigonometric functions in mathematics. The site also explains the basic principles of the use of these functions and details the role they have played in the advancement of other branches of mathematics. Biographical details of the mathematicians chiefly responsible for the discovery of trigonometry are also available here.

Trigonometry

Go to site

Essay on trigonometry. It introduces Pythagoras' theorem and trigonometric functions, and then explains the more complex sine and cosine rules for finding the angles in non-right-angled triangles.

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trillium

any of a group of perennial herbaceous woodland plants belonging to the lily family, native to Asia and North America. They have a circle, or whorl, of three leaves around the stem, at the end of which the single flower has three green sepals and three usually maroon or white petals. The nodding trillium *T. cernuum* ranges across most of the eastern half of North America. (Genus *Trillium*, family Liliaceae.)

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trilobite

any of a large class (Trilobita) of extinct, marine, invertebrate arthropods of the Palaeozoic era, with a flattened, oval body, 1-65 cm/0.4-26 in long. The hard-shelled body was divided by two deep furrows into three lobes. Some were burrowers, others were swimming and floating forms. Their worldwide distribution, many species, and the immense quantities of their remains make them useful in geological dating.

There were more than 1,500 genera of trilobites, which existed for about 300 million years. They disappeared 250 million years ago, probably due to the evolution of new predators. According to a 1997 study of fossils by a US palaeontologist, the trilobite moulted its body segments individually; this moulting may have taken several days, increasing vulnerability. The largest trilobite found was 70 cm/28 in long, and lived 445 million years ago, in what is now Hudson Bay, Canada. It was discovered by Canadian palaeontologists in 2000.

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trimester

in medicine, a stage of pregnancy lasting three months. A normal human pregnancy consists of three trimesters.

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triple bond

three covalent bonds between adjacent atoms in a chemical compound, as in the alkynes (—C≡C—).

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triple nose-leaf bat

one of many threatened bats in Africa, *Triaenops persicus* is found scattered along much of the coastal regions of East Africa and faces threats from disturbance of the caves in which it breeds. Tourism development, resulting in disturbance to coral caves which the bats inhabit, is a particular problem.

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triticale

cereal crop of recent origin that is a cross between wheat *Triticum* and rye *Secale*. It can produce heavy yields of high-protein grain, principally for use as animal feed.

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tritium

radioactive isotope of hydrogen, three times as heavy as ordinary hydrogen, with a nucleus consisting of one proton and two neutrons. It has a half-life of 12.5 years.

Triton

in astronomy, largest of Neptune's moons. It has a diameter of 2,700 km/1,680 mi, and orbits Neptune every 5.88 days in a retrograde (east to west) direction at a distance of 354,000 km/220,000 mi. It takes the same time to rotate about its own axis as it does to make one revolution of Neptune.

It is slightly larger than the planet Pluto, which it is thought to resemble in composition and appearance. Probably Triton was formerly a separate body like Pluto but was captured by Neptune. Triton was discovered in 1846 by English astronomer William Lassell (1799-1880) only weeks after the discovery of Neptune. Triton's surface, as revealed by the Voyager 2 space probe, has a temperature of 38 K (-235°C/-391°F), making it the coldest known place in the Solar System. It is covered with frozen nitrogen and methane, some of which evaporates to form a tenuous atmosphere with a pressure only 0.00001 that of the Earth at sea level. Triton has a pink south polar cap, probably coloured by the effects of solar radiation on methane ice. Dark streaks on Triton are thought to be formed by geysers of liquid nitrogen. The surface has few impact craters (the largest is Mazomba, with a diameter of 27 km/17 mi), indicating that many of the earlier craters have been erased by the erupting and freezing of water (cryovulcanism).

Triton

(Image © NASA)

Computer-generated montage of Neptune as it would appear from a spacecraft approaching its largest moon Triton. The wind- and sublimation-eroded south polar cap of Triton is shown to the bottom right. Triton's surface is mostly covered by nitrogen frost mixed with traces of condensed methane, carbon dioxide, and carbon monoxide.

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troglodyte

ancient Greek term for a cave dweller, designating certain pastoral peoples of the Caucasus, Ethiopia, and the southern Red Sea coast of Egypt.

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trogon

(Greek trogein 'to gnaw')

any species of the family Trogonidae, order Trogoniformes, of tropical birds, up to 50 cm/1.7 ft long, with resplendent plumage, living in the Americas, Africa, and Asia. They are primarily birds of forest or woodland, living in trees. Their diet consists mainly of insects and other arthropods, and sometimes berries and other fruit. Most striking is the quetzal.

The oldest known fossil trogon was found in France in 1999. The 33-million-year-old *Primotrogon wintersteini* is remarkably similar to the 38 extant trogon species, none of which are found in Europe.

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troilite

FeS

iron sulphide, mineral abundant in meteorites and probably present in the Earth's core.

Trojan

in computing, a program that looks as though it will do something entertaining or useful but actually does something unhelpful, such as reformatting the user's hard disk. Trojans are named after the Trojan horse in Greek mythology. A virus is not a Trojan, but inserting a virus into another program - such as virus checker - would make that program a Trojan.

trolleybus

bus driven by electric power collected from overhead wires. It has greater maneuverability than a streetcar.

trophic level

in ecology, the position occupied by a species (or group of species) in a food chain. The main levels are **primary producers** (photosynthetic plants), **primary consumers** (herbivores), **secondary consumers** (carnivores), and **decomposers** (bacteria and fungi).

tropical cyclone

another term for hurricane.

tropical disease

any illness found mainly in hot climates. The most significant tropical diseases worldwide are malaria, leishmaniasis, sleeping sickness, lymphatic filiarasis, and schistosomiasis. Other major scourges are Chagas's disease, leprosy, and river blindness. Malaria kills about 1.5 million people each year, and produces chronic anaemia and tiredness in 100 times as many, while schistosomiasis is responsible for 1 million deaths a year. All the main tropical diseases are potentially curable, but the facilities for diagnosis and treatment are rarely adequate in the countries where they occur.

Tropical Diseases (and How to Avoid Them)

introduction

The concept of 'tropical disease' first arose when Victorian Europeans explored the tropics and encountered diseases, in areas such as the 'white man's grave' in West Africa, with which they were unfamiliar. However, it now usually encompasses all the diseases of the tropics, including those, such as tuberculosis, which are also common in temperate regions. It is difficult for most of us to grasp the impact of tropical diseases on the human race because the numbers are so large. Of the 52 million deaths in 1996, for example, 40 million occurred in the developing world and 17 million of these (nearly three times the number killed by cancers worldwide) were caused by infectious or parasitic disease. Such disease accounts for 45% of all deaths in developing countries, compared with just over 1% in the rest of the world.

causes of tropical diseases

Disease in the tropics may be caused by poor nutrition, environmental factors and/or by living organisms such as fungi (ringworm, athlete's foot), viruses (polio, hepatitis A and B, yellow fever, some forms of meningitis), bacteria (travellers' diarrhoea, typhoid, cholera, tetanus, tuberculosis, leprosy, legionnaires' disease, other forms of meningitis), the single-celled organisms known as protozoa (malaria, sleeping sickness, amoebic dysentery, Chagas's disease, leishmaniasis) and the worms known as nematodes (elephantiasis, river blindness, Guinea worm, hookworm, *Strongyloides*), trematodes (bilharzia) and cestodes (tapeworms, hydatid disease).

transmission of disease

Each of the living organisms has to get below the surface of the skin to survive. Some of the fungi live in the keratin just below the surface but the other pathogens need to get deeper, often into the bloodstream or gut. Several of them (the bacteria causing typhoid, cholera, other causes of diarrhoea, the amoebae causing dysentery, the *Ascaris* roundworm, Guinea worm, hepatitis A virus and tapeworms) rely on us to swallow them in food or water or to ingest them accidentally as we touch our mouths with unclean hands. Other pathogens (some hepatitis B and human immunodeficiency viruses (HIV)) rely on openings in the skin, caused by accident or injection, to gain access to the bloodstream, although HIV, hepatitis B and gonorrhoea are mainly spread by sexual contact between men and women. As 30% of the populations of some towns in the tropics now carry HIV, sex (particularly unprotected sex) with a new partner is a life-threatening gamble. The bacteria causing tuberculosis are drawn into our lungs from the air and those causing leprosy are mostly passed on in sneezes. A few parasites have stages in their life cycles which simply burrow into our skin, either from the soil (hookworm, *Strongyloides*) or water (bilharzia). Some of the most successful parasites of man (those causing malaria, sleeping sickness, river blindness, elephantiasis, yellow fever and leishmaniasis) spend part of their life cycle in insects (called the vectors of the pathogens) which distribute the parasites and later transmit them to humans as the insects feed. The parasites causing malaria and elephantiasis use mosquitoes in this way, the nematodes of river blindness use blackflies (which breed in rivers, hence the name) and the trypanosomes of sleeping sickness and Chagas's disease use tsetse flies and bugs, respectively. Clean insects acquire the parasites when they feed on an infected individual. Most of the parasites do not simply use the vectors for distribution but also multiply and develop within them, the vectors acting as intermediate hosts of the parasites and humans as the definitive hosts. Freshwater snails act as the intermediate hosts of the schistosomes causing bilharzia, and pork and beef tapeworms use pigs and cattle, respectively, in a similar way.

malaria

Malaria remains one of the most important parasitic diseases of man. More than two-fifths of the world's population live in the 100 countries where transmission of malaria occurs and there are about 400 million clinical cases of malaria each year (1.5-2.7 million of them fatal). Human malaria may be caused by any of four species: *Plasmodium falciparum*, *Plasmodium vivax* and the rarer *Plasmodium ovale* and *Plasmodium malariae*. Although only one of these species (*P. falciparum*) causes fatal infections in man, it is this species which is the most common and widespread, being present in 92 of the 100 countries were malaria transmission occurs. In fact, *P. falciparum* may cause more illness and deaths in humans than any other pathogen on Earth.

contracting malaria

The malarial parasite injected by a feeding mosquito passes to the liver and multiplies there for a week or two. It then emerges, invades the red blood cells and multiplies again until the blood cells rupture and the released parasites invade more cells. It is the rupture of the infected red cells, which occurs more or less at the same time (every 2-3 days), that causes the first symptom of malaria: intermittent fever. After a while, some of the parasites breaking out of the blood cells develop into the sexual forms which are capable of infecting mosquitoes. Liver and kidney failure, severe anaemia, convulsions, coma and/or death may develop in falciparum malaria. As malarial parasites in the liver are not affected by the majority of anti-malarial drugs in the bloodstream, any traveller who is infected in the last few days of their trip returns home with viable parasites. All travellers at risk of malaria must therefore continue to take anti-malarials for 4 weeks after leaving a malarious area, so that parasites emerging from the liver to infect the blood cells are killed. Two species causing human malaria (*P. vivax* and *P. ovale*) have special stages, called hypnozoites, which can lie dormant in the liver for months and sometimes years, and cause attacks of malaria when they eventually become active.

immunity

The relationship between an individual's natural resistance to disease (their level of immunity) and the severity of their suffering is an important one. Those who live in countries where tropical diseases are common are often exposed to the diseases many times and those that survive may have high levels of immunity to them. One individual infected with *P. falciparum* may stay healthy whereas another, infected in exactly the same way but without any immunity to the infection, may die within 24 hours. This is why a traveller to such countries may suffer when all around appear healthy.

problems of diagnosis

The recent increase in the numbers of visitors to the tropics has meant that more of those from the developed world are putting themselves at risk of acquiring a tropical disease and of taking it home. Although there is usually little risk of the returned traveller passing on their disease, there is a major risk that it will not be diagnosed or treated correctly, simply because local physicians are unfamiliar with its signs and symptoms or fail to consider it. The symptoms and signs of malaria are so non-specific that local physicians often take them to indicate influenza or gastritis unless the sick traveller mentions that they have visited a malarious area in the last year or more. Of those returning to the UK or USA and eventually dying of falciparum malaria, for example, almost 50% are mis-diagnosed as cases of influenza or of another viral infection when first examined by their physicians. Fatal infectious or parasitic disease is fortunately rare in travellers to the tropics and accounts for only a small proportion of deaths in this group (most of the deaths are caused by accidents, especially road traffic accidents, while the travellers are drunk or by cardiovascular disease in the older traveller). The commonest afflictions the traveller to a developing country is likely to suffer are, in descending frequency, sunburn, diarrhoea and vomiting (usually caused by *Escherichia coli* and of a few days' duration), malaria, acute infection of the respiratory tract (with fever) and hepatitis A. The chances of acquiring some of the perhaps better known diseases, such as leprosy, are virtually nil.

precautions to take when travelling abroad

Anyone from a temperate country planning to visit a tropical country can take many steps to reduce their chances of developing a health problem as a result (prevention is always better than cure, particularly when the disease involved may be rapidly fatal and difficult to treat). It is important to be aware of the risks and how to avoid or minimize them. People should educate themselves by contacting local travel health clinics, reading recent guides or exploring the World Wide Web; one of the best Web sites on travel health is run by the 'Centers for Disease Control' in the USA (http://www.cdc.gov). Just in case a severe problem arises, travel insurance should be enough to cover the expenses of repatriation. Travellers must take appropriate advice on what drugs and other measures they should take to protect themselves against malaria. As the malarial parasites continue to develop resistance to the drugs used against them, it is important to seek up-to-date information on the best drug or drugs to use in any particular area. Use of a bednet (preferably one impregnated with insecticide), keeping the skin covered and using an insect repellent (preferably one containing DEET) and insecticides (in mosquito coils or from electronic vaporizers) not only reduces the risk of being bitten by mosquitoes carrying malarial parasites but also limits the nuisance and loss of sleep caused by other biting insects. It is possible to be vaccinated against several tropical diseases (hepatitis A and B, yellow fever, polio, typhoid) before travel. Every traveller should be immunized against tetanus but the most common cholera vaccine is no longer generally recommended as it is not very effective (a new, more effective one is now on the market). As vaccination may take several weeks it is important to seek health advice early. Once in the tropics, personal hygiene is important and care should be taken with any food or drink. Any food should be cooked adequately and preferably eaten immediately after cooking (shellfish, ice cream, and any raw foods, including salads and unpasteurized milk, are particularly hazardous). Any water to be drunk, if from a local source, is best boiled or sterilized chemically. Skin contact with fresh water should be avoided as much as possible as the water may contain the schistosome stages (cercariae) which can burrow into skin and lying directly on sand or walking barefoot should also be avoided. Most bouts of diarrhoea only last a few days even if untreated, but plenty of safe fluids should be drunk (and the use of oral rehydration salts which can be bought and taken with the traveller should also be considered) to prevent dehydration. Ice cubes (which may be made with contaminated water) are best avoided.

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tropics

area between the tropics of Cancer and Capricorn, defined by the parallels of latitude approximately 23° 30' north and south of the Equator. They are the limits of the area of Earth's surface in which the Sun can be directly overhead. The mean monthly temperature is over 20°C/68°F.

Climates within the tropics lie in parallel bands. Along the Equator is the intertropical convergence zone, characterized by high temperatures and year-round heavy rainfall. Tropical rainforests are found here. Along the tropics themselves lie the tropical high-pressure zones, characterized by descending dry air and desert conditions. Between these, the conditions vary seasonally between wet and dry, producing the tropical grasslands.

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tropism

or tropic movement

directional growth of a plant, or part of a plant, in response to an external stimulus such as gravity or light. If the movement is directed towards the stimulus it is described as positive; if away from it, it is negative. **Geotropism** for example, the response of plants to gravity, causes the root (positively geotropic) to grow downwards, and the stem (negatively geotropic) to grow upwards.

Phototropism occurs in response to light, **hydrotropism** to water, **chemotropism** to a chemical stimulus, and **thigmotropism**, or **haptotropism**, to physical contact, as in the tendrils of climbing plants when they touch a support and then grow around it.

Tropic movements are the result of greater rate of growth on one side of the plant organ than the other. Tropism differs from a nastic movement in being influenced by the direction of the stimulus.

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troposphere

lower part of the Earth's atmosphere extending about 10.5 km/6.5 mi from the Earth's surface, in which temperature decreases with height to about -60°C/-76°F except in local layers of temperature inversion. The **tropopause** is the upper boundary of the troposphere, above which the temperature increases slowly with height within the atmosphere. All of the Earth's weather takes place within the troposphere.

Troy

or Ilium

ancient city in Asia Minor (modern Hissarlik in Turkey), just south of the Dardanelles. It has a long and complex history dating from about 3000 BC to AD 1200. In 1820 the city was identified as Troy, the site of the legendary ten-year Trojan War described in Homer's epic *Iliad*, but its actual name is unknown.

Nine cities found one beneath another were originally excavated by Heinrich Schliemann 1874-90. The first fortifications appeared on the site in the Early Bronze Age. These were a stone wall with a mudbrick battlement and a gate protected by flanking towers. By the Middle Bronze Age the defences had been enlarged and required at least four gateways, two of which were protected by towers. Recent research suggests that the seventh, sacked and burned about 1270 BC, is probably the Homeric Troy. The city and its defences were rebuilt, but suffered a similar fate about 1050 BC. These two destructions, of Troy VI and VIII respectively, have been suggested as the sack of the city in the Trojan War related by the Greek poet Homer. The city of Ilium was built on the same site in the 7th century BC, and survived to the Roman period.

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troy system

system of units used for precious metals and gems. The pound troy (0.37 kg) consists of 12 ounces (each of 120 carats) or 5,760 grains (each equal to 65 mg).

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truffle

any of a group of underground fungi (see fungus), certain of which are highly valued as edible delicacies; in particular, the species *Tuber melanosporum*, generally found growing under oak trees. It is native to the Périgord region of France but is cultivated in other areas as well. It is rounded, blackish-brown, externally covered with warts, and has blackish flesh. (Order Tuberales.)

Dogs and pigs are traditionally used to sniff out truffles, but in 1990 an artificial 'nose' developed at the University of Manchester Institute of Science and Technology, England, proved more effective in tests in Bordeaux.

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trumpeter

any South American bird of the genus *Psophia*, family Psophiidae, order Gruiformes, up to 50 cm/20 in tall, related to the cranes. Trumpeters have long legs, a short bill, and dark plumage. The trumpeter swan is unrelated.

P. crepitans is a bird of lustrous and brilliantly-coloured plumage and is often domesticated. There are three species; very little is known about any of them in the wild.

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truncation error

in computing, an error that occurs when a decimal result is cut off (truncated) after the maximum number of places allowed by the computer's level of accuracy.

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trypanosomiasis

any of several debilitating long-term diseases caused by a trypanosome (protozoan of the genus *Trypanosoma*). They include sleeping sickness in Africa, transmitted by the bites of tsetse flies, and Chagas's disease in Central and South America, spread by assassin bugs.

Trypanosomes can live in the bloodstream of humans and other vertebrates. Millions of people are affected in warmer regions of the world; the diseases also affect cattle, horses, and wild animals, which form a reservoir of infection.

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trypsin

enzyme in the vertebrate gut responsible for the digestion of protein molecules. It is secreted by the pancreas but in an inactive form known as trypsinogen. Activation into working trypsin occurs only in the small intestine, owing to the action of another enzyme, enterokinase, secreted by the wall of the duodenum. Unlike the digestive enzyme pepsin, found in the stomach, trypsin does not require an acid environment.

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tsetse fly

any of a number of blood-feeding African flies of the genus *Glossina*, some of which transmit the disease nagana to cattle and sleeping sickness to human beings. Tsetse flies may grow up to 1.5 cm/0.6 in long.

There are 22 species of tsetse fly in sub-Saharan Africa.

Tsiolkovsky (or Tsiolkovskii), Konstantin Eduardovich (1857-1935)

Russian scientist who developed the theory of space flight. He published the first practical paper on astronautics in 1903, dealing with space travel by rockets using liquid propellants, such as liquid oxygen.

Tsiolkovsky

Go to site

Illustrated account of the life and work of Konstantin Tsiolkovsky. The site is that of the Konstantin E Tsiolkovsky State Museum of the History of Cosmonautics in Kaluga City, Russia. There is discussion of Tsiolkovsky's many works - primarily his far-sighted ideas for space travel, but also his philosophy. The pages contain lots of drawings from Tsiolkovsky's manuscripts.

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tsunami

(Japanese 'harbour wave')

ocean wave generated by vertical movements of the sea floor resulting from earthquakes or volcanic activity or large submarine landslides. Unlike waves generated by surface winds, the entire depth of water is involved in the wave motion of a tsunami. In the open ocean the tsunami takes the form of several successive waves, rarely in excess of 1 m/3 ft in height but travelling at speeds of 650-800 kph/400-500 mph. In the coastal shallows tsunamis slow down and build up producing huge swells over 15 m/45 ft high in some cases and over 30 m/90 ft in rare instances. The waves sweep inland causing great loss of life and damage to property.

Before each wave there may be a sudden withdrawal of water from the beach. Used synonymously with tsunami, the popular term 'tidal wave' is misleading: tsunamis are not caused by the gravitational forces that affect tides.

Double Whammy

Go to site

Part of a larger site maintained by *Scientific American*, this page explores the catastrophic impact that an asteroid's crashing into the sea would have on civilization and the environment. Animated simulations show the effects of impact and the effect that a tsunami would have on the eastern seaboard of the USA if an asteroid struck the Atlantic Ocean. Learn about the tsunami that struck Prince William Sound, Alaska, in 1964 after an underwater earthquake. The text includes hypertext links to further information and a list of related links.

Tsunami!

Go to site

Description of many aspects of tsunamis. Included are details on how a tsunami is generated and how it propagates, how they have affected humans, and how people in coastal areas are warned about them. The site also discusses if and how you may protect yourself from a tsunami and provides 'near real-time' tsunami information bulletins.

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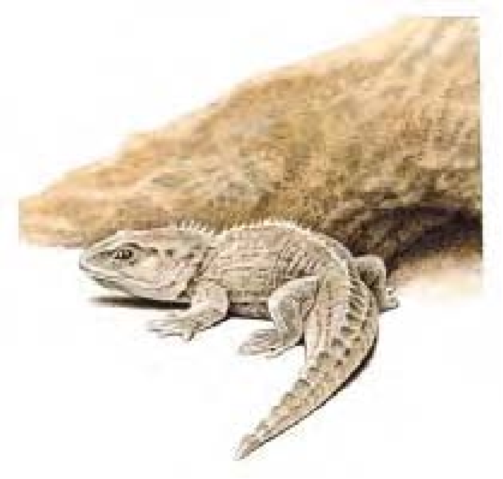
tuatara

lizardlike reptile of the genus *Sphenodon*. It grows up to 70 cm/2.3 ft long, is greenish black, and has a spiny crest down its back. On the top of its head is the pineal body, or so-called 'third eye', linked to the brain, which probably acts as a kind of light meter. It has remained unchanged for 220 million years, and is the sole survivor of the reptilian order Rhynchocephalia. It has an average lifespan of 60 years and reaches sexual maturity for a decade. It lays eggs in burrows that it shares with seabirds, and has the longest incubation period of all reptiles (up to 15 months).

S. punctatus is found on about 30 small islands off New Zealand, whereas *S. guntheri* has survived on one island only, and numbers around 300 individuals. In an attempt to found a second colony of *S. guntheri*, 50 4–6 year olds, reared in semi-natural captivity, along with 20 adults from the existing population, were released on to a new island November 1995. At the end of 1999 there were approximately 400 *S. guntheri*.

tuatara



(Image © Research Machines plc)

The lizardlike tuatara is found on some of the islands and rocky stacks off New Zealand. It is the sole remaining representative of a family of reptiles which first evolved before the dinosaurs. It has a third 'eye' on the top of its head which is sensitive to light, although is unable actually to 'see'.

---

tube

or **electron tube** in electronics, a glass tube containing gas at low pressure, which is used to control the flow of electricity in a circuit. The electron tube valve was invented by US radio engineer Lee de Forest (1873–1961). Three or more metal electrodes are inset into the tube. By varying the voltage on one of them, called the grid electrode, the current through the tube can be controlled, and the tube can act as an amplifier.

Tubes have been replaced for most applications by transistors. However, they are still used in high-power transmitters and amplifiers, and in some hi-fi systems.

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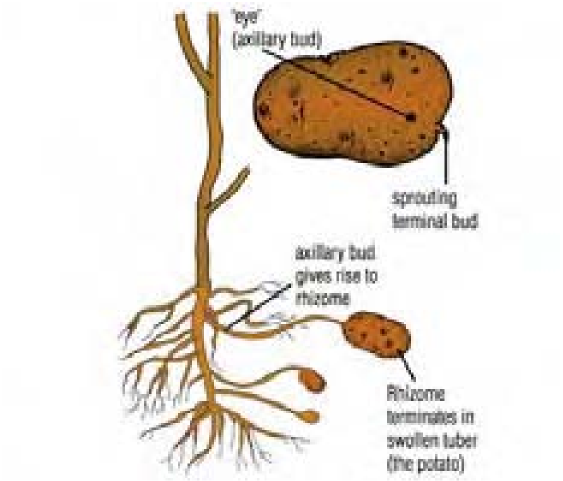
tuber

swollen region of an underground stem or root, usually modified for storing food. The potato is a **stem tuber**,

as shown by the presence of terminal and lateral buds, the 'eyes' of the potato.
Root tubers, for example dahlias, developed from adventitious roots (growing from the stem, not from other roots) lack these. Both types of tuber can give rise to new individuals and so provide a means of vegetative reproduction.

Unlike a bulb, a tuber persists for one season only; new tubers developing on a plant in the following year are formed in different places. See also rhizome.

tuber



(Image © Research Machines plc)

Tubers are produced underground from stems, as in the potato, or from roots, as in the dahlia. Tubers can grow into new plants.

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tuberculosis

TB; formerly known as consumption or phthisis

infectious disease caused by the bacillus *Mycobacterium tuberculosis*. It takes several forms, of which pulmonary tuberculosis is by far the most common. A vaccine, BCG, was developed around 1920 and the first anti-tuberculosis drug, streptomycin, in 1944. The bacterium is mostly kept in check by the body's immune system; about 5% of those infected develop the disease. Treatment of patients with a combination of anti-TB medicines for 6-8 months produces a cure rate of 80%. In 1999 there were 8 million new cases of TB and 2 million deaths. Only 5% of cases are in developed countries. Worldwide there are 16 million people with TB and 2 billion (a third of the global population) are infected with *Mycobacterium tuberculosis*.

In pulmonary TB, a patch of inflammation develops in the lung, with formation of an abscess. Often, this heals spontaneously, leaving only scar tissue. The dangers are of rapid spread through both lungs (what used to be called 'galloping consumption') or the development of miliary tuberculosis (spreading in the bloodstream to other sites) or tuberculous meningitis.

Over the last 15 years there has been a sharp resurgence in countries where the disease was in decline. The increase has been most marked in deprived inner city areas, particularly in the USA, and here there is a clear link between TB and HIV, the virus which causes AIDS. TB is the main cause of death in HIV positive individuals.

The last decade has seen the spread of drug-resistant strains of the TB bacterium. Many strains are now resistant to the two frontline drugs, isoniazid and rifampicin, and some are multi-drug resistant (MDR). Rare until its recent appearance in the USA, MDR TB is now spreading through a number of developing countries. It is untreatable and many of its victims have died. According to a 1996 WHO estimate there may be as many as 50 million people worldwide with the drug-resistant form of TB (Britain had its first case in 1995).

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tuberose

Mexican flowering plant belonging to the agave family, grown as a sweet-smelling greenhouse plant. It has spikes of scented white flowers like lilies. (*Polianthes tuberosa*, family Agavaceae.)

Tucana

constellation of the southern hemisphere, represented as a toucan. It contains the second most prominent globular cluster in the sky, 47 Tucanae, and the Small Magellanic Cloud.

Tucana is one of the 11 constellations named by Johann Bayer early in the 17th century to complement the 65 constellations delineated in ancient times.

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tucu-tuco

any member of the genus *Ctenomys*, a burrowing South American rodent about 20 cm/8 in long with a 7 cm/3 in tail. It has a large head, sensitive ears, and enormous incisor teeth.

Tucu-tucos spend most of their time below ground in a burrow system, generally one animal to a burrow. The name tucu-tuco is an attempt to imitate the bubbling call.

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tufa

or travertine

soft, porous, limestone rock, white in colour, deposited from solution from carbonate-saturated ground water around hot springs and in caves.

Undersea tufa columns, such as those in the Ikka Fjord in southwestern Greenland, that form over alkaline springs, can reach 20 m/65 ft in height and grow at about 50 cm/20 in per year. They provide a habitat for a wide variety of marine life.

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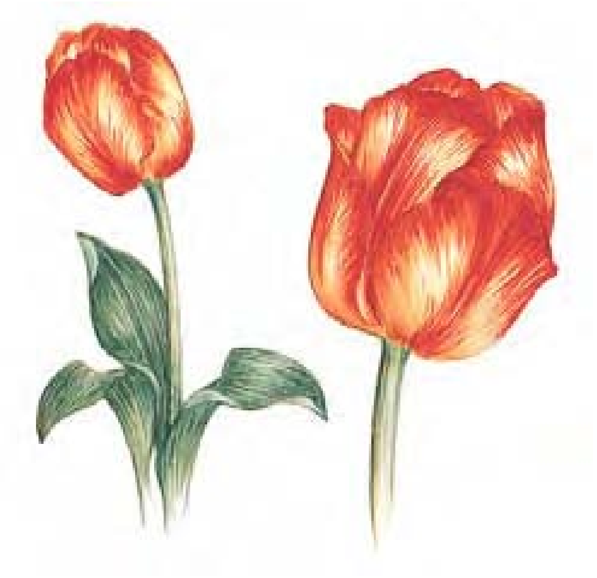
tulip

any of a group of spring-flowering bulbous plants belonging to the lily family, usually with single goblet-shaped flowers on the end of an upright stem and narrow oval leaves with pointed ends. Tulips come in a large range of shapes, sizes, and colours and are widely cultivated as a garden flower. (Genus *Tulipa*, family Liliaceae.)

T. gesnerana, from which most of the garden cultivars have been derived, probably originated in Asia Minor. It was quickly adopted in Europe from Turkey during the 16th century, and tulip collecting became a craze in 17th-century Holland – it was the subject of a novel, *The Black Tulip*, by Alexandre Dumas (*père*) in 1850. Today tulips are commercially cultivated on a large scale in the Netherlands and East Anglia, England.

The **tulip tree** (*Liriodendron tulipifera*) of the eastern USA is a member of the magnolia family, with large, tulip-shaped blooms.

tulip



(Image © Research Machines plc)

The tulip was introduced into Europe in 1572. Dutch growers developed many new varieties, resulting in tulip mania in the 1630s, when vast sums were paid for bulbs of rare colours.

Tulip Book

Go to site

Online version of P Cos's manuscript catalogue of tulips, published in 1637.

Tull, Jethro (1674-1741)

English agriculturist who in about 1701 developed a drill that enabled seeds to be sown mechanically and spaced so that cultivation between rows was possible in the growth period. His chief work, *Horse-Hoeing Husbandry*, was published in 1733.

Tull also developed a plough with blades set in such a way that grass and roots were pulled up and left on the surface to dry. Basically the design of a plough is much the same today.

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tumour

overproduction of cells in a specific area of the body, often leading to a swelling or lump. Tumours are classified as **benign** or **malignant** (see cancer). Benign tumours grow more slowly, do not invade surrounding tissues, do not spread to other parts of the body, and do not usually recur after removal. However, benign tumours can be dangerous in areas such as the brain. The most familiar types of benign tumour are warts on the skin. In some cases, there is no sharp dividing line between benign and malignant tumours.

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tuna

any of various large marine bony fishes of the mackerel family, especially the genus *Thunnus*, popular as food and game.
Albacore *T. alalunga*, **bluefin tuna** *T. thynnus*, and **yellowfin tuna** *T. albacares* are commercially important.

Tuna fish gather in shoals and migrate inshore to breed, where they are caught in large numbers. The increasing use by Pacific tuna fishers of enormous driftnets, which kill dolphins, turtles, and other marine creatures as well as catching the fish, has caused protests by environmentalists; tins labelled 'dolphin-friendly' contain tuna not caught by driftnets. Thailand is a major tuna-importing and canning country.

Overfishing is causing a reduction in tuna stocks around the world. In spite of the introduction of quotas in Australia in the 1980s, the country's catch of southern bluefin tuna in 1990–91 was 5,000 tonnes – the lowest since 1962, and the species could be in danger of extinction. Tuna stocks in the Atlantic declined by almost 90% during 1970–92.

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tundra

region in high latitudes with almost no trees – they cannot grow because the ground is permanently frozen (permafrost). The vegetation consists mostly of grasses, sedges, heather, mosses, and lichens. Tundra stretches in a continuous belt across northern North America and Eurasia. Tundra is also used to describe similar conditions at high altitudes.

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tung oil

oil used in paints and varnishes, obtained from tung trees native to China. (Genus *Aleurites*, family Euphorbiaceae.)

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tungsten

chemical symbol W

(Swedish tung sten 'heavy stone')

hard, heavy, grey-white, metallic element, atomic number 74, relative atomic mass 183.85. Its chemical symbol comes from the German *Wolfram*. It occurs in the minerals wolframite, scheelite, and hubertite. It has the highest melting point of any metal (3,410°C/6,170°F) and is added to steel to make it harder, stronger, and more elastic; its other uses include high-speed cutting tools, electrical elements, and thermionic couplings. Its salts are used in the paint and tanning industries.

Tungsten was first recognized in 1781 by Swedish chemist Karl Scheele in the ore scheelite. It was isolated in 1783 by Spanish chemists Fausto D'Elhuyar (1755-1833) and his brother Juan José (1754-1796).

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tungsten ore

either of the two main minerals, wolframite $(FeMn)WO_4$ and scheelite, $CaWO_4$, from which tungsten is extracted. Most of the world's tungsten reserves are in China, but the main suppliers are Bolivia, Australia, Canada, and the USA.

Tunguska Event

explosion at Tunguska, central Siberia, Russia, in June 1908, which devastated around 6,500 sq km/2,500 sq mi of forest. It is thought to have been caused by either a cometary nucleus or a fragment of Encke's Comet about 200 m/660 ft across, or possibly an asteroid – a bright falling object was seen from 600 km/375 mi away. The explosion was equivalent to a hydrogen bomb (10–20 megatons) and produced a colossal shock wave; it was heard up to 1,000 km/625 away.

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tunicate

alternate name for sea squirt.

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tunnel

passageway through a mountain, under a body of water, or underground. Tunnelling is a significant branch of civil engineering in both mining and transport. The difficulties naturally increase with the size, length, and depth of tunnel, but with the mechanical appliances now available no serious limitations are imposed. In the 19th century there were two major advances: the use of compressed air within underwater tunnels to balance the external pressure of water; and the development of the tunnel shield to support the face and assist excavation. Granite or other hard rock presents little difficulty to modern power drills. In recent years there have been notable developments in linings (for example, concrete segments and steel liner plates), and in the use of rotary diggers and cutters and explosives.

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tunny

another name for tuna.

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turbine

engine in which steam, water, gas, or air (see windmill) is made to spin a rotating shaft by pushing on angled blades, like a fan. There are two sets of blades, the stator (does not rotate) and the rotor (does rotate). The rotating turbine shaft can be connected to an electricity generator. Turbines are among the most powerful machines.

Steam turbines are used to drive generators in power stations and ships' propellers; water turbines spin the generators in hydroelectric power plants; and gas turbines (as jet engines; see jet propulsion) power most aircraft and drive machines in industry.

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turbocharger

turbine-driven device fitted to engines to force more air into the cylinders, producing extra power. The turbocharger consists of a 'blower', or compressor, driven by a turbine, which in most units is driven by the exhaust gases leaving the engine.

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turbofan

jet engine of the type used by most airliners, so called because of its huge front fan. The fan sends air not only into the engine for combustion but also around the engine for additional thrust. This results in a faster and more fuel-efficient propulsive jet (see jet propulsion).

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turbojet

jet engine that derives its thrust from a jet of hot exhaust gases. Pure turbojets can be very powerful but use a lot of fuel.

A single-shaft turbojet consists of a shaft (rotor) rotating in a casing. At the front is a multiblade compressor, which takes in and compresses air and delivers it to one or more combustion chambers. Fuel (kerosene) is then sprayed in and ignited. The hot gases expand through a nozzle at the rear of the engine after spinning a turbine. The turbine drives the compressor. Reaction to the backward stream of gases produces a forward propulsive thrust.

See also fanjet, jet propulsion, and ramjet.

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turbot

any of various flatfishes of the flounder group prized as food, especially *Scophthalmus maximus* found in European waters. It grows up to 1 m/3 ft long and weighs up to 14 kg/30 lb. It is brownish above and whitish underneath.

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turbulence

irregular fluid (gas or liquid) flow, in which vortices and unpredictable fluctuations and motions occur. Streamlining reduces the turbulence of flow around an object, such as an aircraft, and reduces drag. Turbulent flow of a fluid occurs when the Reynolds number is high.

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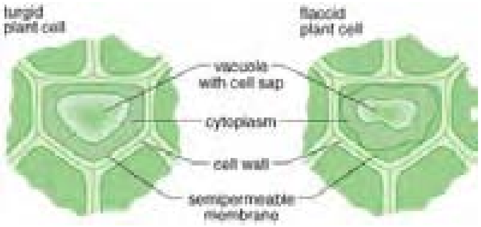
turgor

rigid condition of a plant caused by the fluid contents of a plant cell exerting a mechanical pressure against the cell wall. Turgor supports plants that do not have woody stems. Plants lacking in turgor visibly wilt. The process of osmosis plays an important part in maintaining the turgidity of plant cells.

When water moves into plant cells by osmosis it makes the cell expand. However, the cell walls are very strong and cannot expand much. So the pressure rises inside the cell - it becomes tightly filled, like a balloon. This makes the cells rigid and this helps to support parts of plants like leaves. Plant cells that are rigid like this are said to be turgid.

If a plant loses too much water, or runs short of water in the soil, it will wilt (leaves and stems droop). If this continues parts of the plant will die because of water loss.

turgor



(Image © Research Machines plc)

A turgid plant cell (left) and a flaccid plant cell. Water leaves and enters the cell by osmosis. If too much water leaves the cell, for example during drought or saline conditions, then turgor is lost and the cell becomes flaccid. As turgor gives the plant rigidity, loss of turgidity results in the plant wilting.

Turing, Alan Mathison (1912-1954)

English mathematician and logician. In 1936 he described a 'universal computing machine' that could theoretically be programmed to solve any problem capable of solution by a specially designed machine. This concept, now called the Turing machine, foreshadowed the digital computer.

Turing is believed to have been the first to suggest (in 1950) the possibility of machine learning and artificial intelligence. His test for distinguishing between real (human) and simulated (computer) thought is known as the **Turing test**: with a person in one room and the machine in another, an interrogator in a third room asks questions of both to try to identify them. When the interrogator cannot distinguish between them by questioning, the machine will have reached a state of humanlike intelligence.

Alan Turing Home Page

Go to site

Authoritative illustrated biography of the computer pioneer, plus links to related sites. This site contains information on his origins and his code-breaking work during World War II, as well as several works written by Turing himself.

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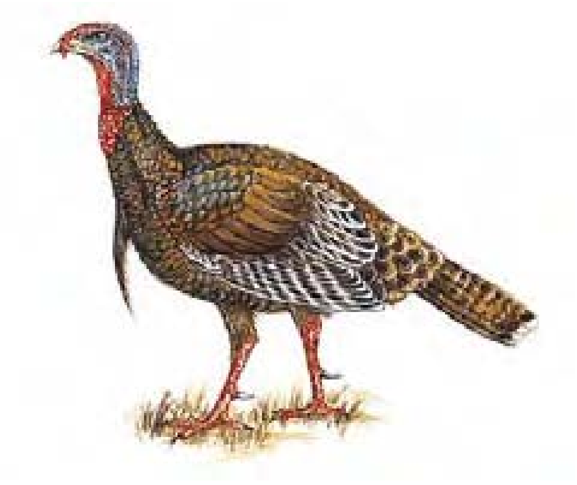
turkey

any of several large game birds of the pheasant family, Meleagrididae, order Galliformes, native to the Americas. The wild turkey *Meleagris galloparvo* reaches a length of 1.3 m/4.3 ft, and is native to North and Central American woodlands. The domesticated turkey derives from the wild species. Turkeys in the wild lay a single clutch of 12 eggs every spring, whereas domestic turkeys lay 120 over 27 weeks. Wild turkeys weigh up to 10 kg/22 lb; domestic turkeys up to 30 kg/66 lb. The ocellated turkey *Agriocharis ocellata* is found in Central America; it has eyespots on the tail.

The domesticated turkey was introduced to Europe in the 16th century. Since World War II, it has been intensively bred, in the same way as the chicken. It is gregarious, except at breeding time.

turkey



(Image © Research Machines plc)

The common turkey, native to wooded country in the USA and Mexico, is a strong flier over short distances. It roosts in trees but feeds on the ground, eating nuts, seeds, and berries, as well as insects and small reptiles.

Talking about Turkey

Go to site

Dedicated to the game bird, this site contains information on buying, storing, thawing, stuffing, and preparing a turkey. The information here guides you through such questions as whether your turkey should be fresh or frozen, how it should be roasted, and how you test it for 'doneness'. There is also a guide to carving, how to make gravy, and how to store leftovers.

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turmeric

perennial plant belonging to the ginger family, native to India and the East Indies; also the ground powder from its tuberous rhizomes (underground stems), used in curries to give a yellow colour and as a dyestuff. (*Curcuma longa*, family Zingiberaceae.)

In India it is traditionally applied in the form of a paste of powder to aid healing of cuts and grazes.

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turnaround document

output document produced by a computer that is later, after additional data has been added, used as an input document.

Examples of turnaround documents are the meter-reading cards produced by gas and electricity companies. Each card is output with customer details printed in a typeface readable by OCR (optical character recognition) software and with a standard grid suitable for OMR (optical mark recognition). The meter reader inspects the customer's meter, marks the new reading on the grid, and then returns the card to the company's billing department. There, a **universal document reader**, capable of reading both OCR and OMR data, is used to input the new information to the computer.

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turnip

biennial plant widely cultivated in temperate regions for its edible white- or yellow-fleshed root and young leaves, which are used as a green vegetable. Closely allied to it is the swede (*B. napus*). (*Brassica rapa*, family Cruciferae.)

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turnpike road

road with a gate or barrier preventing access until a toll had been paid, common from the mid-16th-19th centuries. In 1991 a plan for the first turnpike road to be built in the UK since the 18th century was announced: the privately funded Birmingham northern relief road, 50 km/31 mi long.

history

In 1706 Parliament created the first turnpike trust, a scheme by which local business people could charge a toll for using a road, using the money received to maintain the road. After 1750 there was a 'mania' for turnpikes: 870 acts were passed in the 20 years after 1751, and by 1830 there were some 1,100 trusts, created by around 4,000 separate acts, administering more than 35,000 km/56,000 mi of road. Whereas the first turnpikes had been in the counties close to London, trusts after 1750 were set up mainly in the midlands, and after 1790 were concentrated in the north of England, reflecting the changing pattern of economic growth during the Industrial Revolution. Many of the trusts were fraudulently administered, and the Turnpike Act of 1822 required trusts to keep accounts. Nevertheless, it has been estimated that, by the 1830s, the turnpikes were investing about £1.5 million a year in the UK road system. The improved roads allowed a significant increase of haulage traffic, passenger coaches, and a national postal service.

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turnstone

any small wading shorebirds of the genus *Arenaria*, order Charadriiformes, especially the ruddy turnstone *A. interpres*, which breeds in the Arctic and migrates to the southern hemisphere. It is seen on rocky beaches, turning over stones for small crustaceans and insects. It is about 23 cm/9 in long and has a summer plumage of black and chestnut above, white below; it is duller in winter.

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turpentine

solution of resins distilled from the sap of conifers, used in varnish and as a paint solvent but now largely replaced by white spirit.

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turquoise

mineral, hydrous basic copper aluminium phosphate, $CuAl_6(PO_4)_4(OH)_8 5H_2O$. Blue-green, blue, or green, it is a gemstone. Turquoise is found in Australia, Egypt, Ethiopia, France, Germany, Iran, Turkestan, Mexico, and southwestern USA. It was originally introduced into Europe through Turkey, from which its name is derived.

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turtle

small computer-controlled wheeled robot or a representation of it on a computer monitor. The turtle's movements are determined by programs written by a computer user, typically using the high-level programming language LOGO. Programming a turtle is a good way to learn programming logic and the use of procedures.

Turtle

Go to site

Description of the floor turtle and how it can be controlled using basic commands, such as 'forward' and 'right'. The development of the 'screen turtle' and 'dynamic turtles' of the 1980s is also described. In addition the site covers the use of the simple programming language LOGO.

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turtle

freshwater or marine reptile whose body is protected by a shell. Turtles are related to tortoises, and some species can grow to a length of up to 2.5 m/8 ft. Turtles often travel long distances to lay their eggs on the beaches where they were born. Many species have suffered through destruction of their breeding sites as well as being hunted for food and their shells. Unlike tortoises, turtles cannot retract their heads into their shells.

Marine turtles are generally herbivores, feeding mainly on sea grasses. Freshwater turtles eat a range of animals including worms, frogs, and fish. They are excellent swimmers, having legs that are modified to oarlike flippers but which make them awkward on land. The shell is more streamlined and lighter than that of the tortoise.

Species include the **green turtle** *Chelonia mydas*; the **loggerhead** *Caretta caretta*; the **giant leathery** or **leatherback turtle** *Dermochelys coriacea*, which can weigh half a tonne and grow up to 2.5 m/8 ft; and the **hawksbill** *Eretmochelys imbricata*, which is hunted for its shell which provides tortoiseshell, used in jewellery and ornaments, and is now endangered. Other turtles suffer because their eggs are taken by collectors and their breeding sites are regularly destroyed, often for tourist developments. The world's rarest turtle is the **Kemp's ridley**, which breeds only at a single site in the Gulf of Mexico. The total population is less than 10,000 (1998).

A new species of turtle was discovered in Mexico in 1997. It has been named *Kinosternon chimalhuaca*.

turtle

On hatching, the baby hawksbill has about a 1 in 1,000 chance of reaching adulthood.

Turtles

Go to site

Site full of information about turtles. There are pictures, information on current research programmes, a kids corner, and stills from an underwater video camera.

TVP

abbreviation for texturized vegetable protein

meat substitute usually made from soybeans. In manufacture, the soybean solids (what remains after oil has been removed) are ground finely and mixed with a binder to form a sticky mixture. This is forced through a spinneret and extruded into fibres, which are treated with salts and flavourings, wound into hanks, and then chopped up to resemble meat chunks.

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twin

one of two young produced from a single pregnancy. Human twins may be genetically identical (monozygotic), having been formed from a single fertilized egg that splits into two cells, both of which became implanted. Nonidentical (fraternal or dizygotic) twins are formed when two eggs are fertilized at the same time.

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two's complement number system

number system, based on the binary number system, that allows both positive and negative numbers to be conveniently represented for manipulation by computer.

In the two's complement system the most significant column heading (the furthest to the left) is always taken to represent a negative number.

For example, the four-column two's complement number 1101 stands for -3, since: -8 + 4 + 1 = -3.

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two-stroke cycle

operating cycle for internal combustion piston engines. The engine cycle is completed after just two strokes (up or down) of the piston, which distinguishes it from the more common four-stroke cycle. Some power mowers and lightweight motorcycles use two-stroke petrol engines, which are cheaper and simpler than four-strokes.

Most marine diesel engines are also two-stroke. In a typical two-stroke motorcycle engine, fuel mixture is drawn into the crankcase as the piston moves up on its first stroke to compress the mixture above it. Then the compressed mixture is ignited, and hot gases are produced, which drive the piston down on its second stroke. As it moves down, it uncovers an opening (port) that allows the fresh fuel mixture in the crankcase to flow into the combustion space above the piston. At the same time, the exhaust gases leave through another port.

How Two-Stroke Expansion Chambers Work

Go to site

Part of a larger site called Motorcycle Online, here is a short essay, featuring diagrams, describing the physics of how two-stroke expansion chambers work for motorcycle riders.

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typesetting

means by which text, or copy, is prepared for printing, now usually carried out by using specialized computer programs.

Text is keyed on a typesetting machine in a similar way to typing. Laser or light impulses are projected on to light-sensitive film that, when developed, can be used to make plates for printing.

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typewriter

keyboard machine that produces characters on paper. The earliest known typewriter design was patented by Henry Mill in England in 1714. However, the first practical typewriter was built in 1867 in Milwaukee, Wisconsin, USA, by Christopher Sholes, Carlos Glidden, and Samuel Soulé. By 1873 Remington and Sons, US gunmakers, had produced under contract the first typing machines for sale and in 1878 they patented the first with lower-case as well as upper-case (capital) letters. Modern typewriters comprise electronic storage and editing of text, and a variety of printing methods. Even these have been almost wholly superseded by word-processing software run on laptops or personal computers.

The first typewriter patented by Sholes included an alphabetical layout of keys, but Remington's first commercial typewriter had the QWERTY keyboard, designed by Sholes to stop the mechanical keys getting jammed together as they had in earlier alphabetical arrangements.

Other layouts include the Dvorak keyboard developed by John Dvorak in 1932, in which the most commonly used letters are evenly distributed between left and right, and are positioned under the strongest fingers. Later developments included tabulators from about 1898, portable machines about 1907, the gradual introduction of electrical operation (allowing increased speed, since the keys are touched, not depressed), proportional spacing in 1940, and the rotating typehead with stationary plates in 1962. Word processing has largely replaced the typewriter for typing letters and text.

QWERTY Connection

Go to site

Contains a large amount of information about typewriters, including a description of the very first typewriter, an explanation of why the QWERTY system was invented, and even information about collecting antique typewriters and typewriter ribbon tins!

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typhoid fever

acute infectious disease of the digestive tract, caused by the bacterium *Salmonella typhi*, and usually contracted through a contaminated water supply. It is characterized by bowel haemorrhage and damage to the spleen. Treatment is with antibiotics.

The symptoms begin 10-14 days after ingestion and include fever, headache, cough, constipation, and rash. The combined TAB vaccine protects both against typhoid and the milder, related condition known as **paratyphoid fever**.

A strain of typhoid fever emerged in the late 1990s in Tajikistan, that was resistant to all known antibiotics.

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typhoon

violent revolving storm, a hurricane in the western Pacific Ocean.

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typhus

any one of a group of infectious diseases caused by bacteria transmitted by lice, fleas, mites, and ticks. Symptoms include fever, headache, and rash. The most serious form is epidemic typhus, which also affects the brain, heart, lungs, and kidneys and is associated with insanitary overcrowded conditions. Treatment is by antibiotics.

The bacteria responsible are of the genus *Rickettsia*, especially *R. pronazekii*. A preventive vaccine exists.

typhus

Typhus claimed fewer victims in World War II than fighting. This was the first war in which this was the case since the first documented typhus epidemic in 1489.

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tyrannosaurus

any of a genus *Tyrannosaurus* of gigantic flesh-eating dinosaurs, order Saurischia, that lived in North America and Asia about 70 million years ago. They had two feet, were up to 15 m/50 ft long, 6.5 m/20 ft tall, weighed 10 tonnes, and had teeth 15 cm/6 in long.

Only a few whole skeletons are known; the most complete was discovered in 1989 in Hell Creek, Montana, and preserved in the Museum of the Rockies, Bozeman, Montana, USA.

Two distinct body types have been discovered for tyrannosaurs, indicating that one, the larger more robust form is female, as it has a wider pelvis. Estimates for the speed at which tyrannosaurs could run down their prey ranges from about 25 kph to 36 kph, but as only single footprints have only been found to date, this is impossible to verify.

US archaeologists proved in February 1997 that tyrannosaurs had a biting force of 1,400 kg/3,000 lb, by analysing bite marks in the fossil skeleton of a triceratops and using these to create replica teeth. They then measured the force necessary to reproduce the marks in a cow skeleton using the replica teeth.

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tyre

an inflatable rubber hoop fitted round the rims of bicycle, car, and other road-vehicle wheels. The first pneumatic rubber tyre was patented in 1845 by the Scottish engineer Robert William Thomson (1822-73), but it was the Scottish inventor John Boyd Dunlop of Belfast who independently reinvented pneumatic tyres for use with bicycles in 1888-89. The rubber for car tyres is hardened by vulcanization.

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tyrosine

in medicine, an amino acid. It is important in the production of catecholamines, such as adrenaline, noradrenaline, and dopamine, which are involved in the transmission of nerve impulses. It is also important in the production of thyroid hormones, such as thyroxine.

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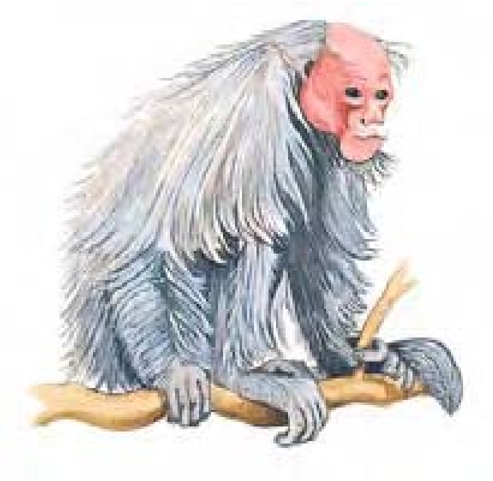
uakari

any of several rare South American monkeys of the genus *Cacajao*. There are three species, all with bald faces and long fur. About 55 cm/1.8 ft long in head and body, and with a comparatively short 15 cm/6 in tail, they rarely leap, but are good climbers, remaining in the tops of the trees in swampy forests and feeding largely on fruit. The black uakari is in danger of extinction because it is found in such small numbers already, and the forests where it lives are fast being destroyed.

uakari



(Image © Research Machines plc)

The bald uakari lives in the treetops of west Brazil, and seldom descends to the ground. It is very agile, although it rarely leaps, since it lacks a long tail to use as a counterbalance. The three species of uakari are the only New World monkeys to have short tails.

UHF

abbreviation for ultra high frequency

referring to radio waves of very short wavelength, used, for example, for television broadcasting.

UHT

abbreviation for **ultra-heat treated** or ultra-heat treatment.

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ulcer

any persistent breach in a body surface (skin or mucous membrane). It may be caused by infection, irritation, or tumour and is often inflamed. Common ulcers include aphthous (mouth), gastric (stomach), duodenal, decubitus ulcers (pressure sores), and those complicating varicose veins.

Treatment of ulcers depends on the site. Drugs are the first line of attack against peptic ulcers (those in the digestive tract), though surgery may become necessary. Bleeding stomach ulcers can be repaired without an operation by the use of endoscopy: a flexible fibre-optic tube is passed into the stomach and under direct vision fine instruments are used to repair the tissues.

ulcer

Headless bedbugs were applied to ulcers in the 16th century, and crushed bedbugs were still believed to be effective in treating ulcers in 18th-century China. It was not until this century that positive evidence was found of the antibacterial properties of insect haemolymph.

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ulna

one of the two bones found in the lower limb of the tetrapod (four-limbed) vertebrate. It articulates with the shorter radius and humerus (upper arm bone) at one end and with the radius and wrist bones at the other.

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ultrabasic

in geology, an igneous rock with a lower silica content than basic rocks (less than 45% silica). Part of a system of classification based on the erroneous concept of silica acidity and basicity. Once used widely it has now been largely replaced by the term **ultramafic**.

ultrafiltration

process by which substances in solution are separated on the basis of their molecular size. A solution is forced through a membrane with pores large enough to permit the passage of small solute molecules but not large ones.

Ultrafiltration is a vital mechanism in the vertebrate kidney: the cell membranes lining the Bowman's capsule act as semipermeable membranes, allowing water and substances of low molecular weight such as urea and salts to pass through into the urinary tubules but preventing the larger proteins from being lost from the blood.

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ultra-heat treatment

(**UHT**) preservation of milk by raising its temperature to 132°C/269°F or more. It uses higher temperatures than pasteurization, and kills all bacteria present, giving the milk a long shelf life but altering the flavour.

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ultrasonics

branch of physics dealing with the theory and application of ultrasound: sound waves occurring at frequencies too high to be heard by the human ear (that is, above about 20 kHz).

The earliest practical application of ultrasonics was the detection of submarines during World War I by reflecting pulses of sound from them (see sonar). Similar principles are now used in industry for nondestructive testing of materials and in medicine to produce images of internal organs and developing fetuses (ultrasound scanning). High-power ultrasound can be used for cleaning, welding plastics, and destroying kidney stones without surgery.

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ultrasound scanning

or ultrasonography

in medicine, the use of ultrasonic pressure waves to create a diagnostic image. It is a safe, noninvasive technique that often eliminates the need for exploratory surgery.

The sound waves transmitted through the body are absorbed and reflected to different degrees by different body tissues.

Obstetric Ultrasound

Go to site

Comprehensive, plain-English guide to obstetric ultrasound scanning. For any pregnant woman interested in knowing about the technique, this is an invaluable source of information. There is a clear explanation of what can be learnt about the foetus by the use of ultrasound. Further information on a variety of aspects of pregnancy and birth can be accessed.

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ultraviolet astronomy

study of cosmic ultraviolet emissions using artificial satellites. The USA launched a series of satellites for this purpose, receiving the first useful data in 1968. Only a tiny percentage of solar ultraviolet radiation penetrates the atmosphere, this being the less dangerous longer-wavelength ultraviolet radiation. The dangerous shorter-wavelength radiation is absorbed by gases in the ozone layer high in the Earth's upper atmosphere.

The US Orbiting Astronomical Observatory (OAO) satellites provided scientists with a great deal of information regarding cosmic ultraviolet emissions. OAO-1, launched in 1966, failed after only three days, although OAO-2, put into orbit in 1968, operated for four years instead of the intended one year, and carried out the first ultraviolet observations of a supernova and also of Uranus. OAO-3 (Copernicus), launched in 1972, continued transmissions into the 1980s and discovered many new ultraviolet sources. The International Ultraviolet Explorer, which was launched in January 1978 and ceased operation in September 1996, observed all the main objects in the Solar System (including Halley's comet), stars, galaxies, and the interstellar medium. FUSE (Far Ultraviolet Spectroscopic Explorer) is a collaboration between US universities and the Canadian and French space agencies, designed to observe at very short ultraviolet wavelengths. The Hubble Space Telescope observes at ultraviolet wavelengths as well as visible and infrared wavelengths. GALEX (Galaxy Evolution Explorer) is a US-French-Korean satellite launched in 2003 to study the UV emissions of galaxies.

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ultraviolet radiation

light rays invisible to the human eye, of wavelengths from about 4×10^{-4} to 5×10^{-6} millimetres (where the X-ray range begins). Physiologically, they are important but also dangerous, causing the formation of vitamin D in the skin and producing sunburn in excess. They are strongly germicidal and may be produced artificially by mercury vapour and arc lamps for therapeutic use.

Levels of ultraviolet radiation rose by an average of 6.8% a decade in the northern hemisphere and 9.9% in the southern hemisphere 1972-96, according to data gathered by the total ozone mapping spectrometer on the Nimbus 7 satellite. Much ultraviolet radiation may be detected with ordinary photographic plates or films. It can also be studied by its fluorescent effect on certain materials. The desert iguana, *Disposaurus dorsalis*, uses it to locate the boundaries of its territory and to find food.

Ulysses

space probe to study the Sun's poles, launched in 1990 by a US space shuttle. It is a joint project by NASA and the European Space Agency. In February 1992, the gravity of Jupiter swung Ulysses on to a path that looped it first under the Sun's south pole in 1994 and then over its north pole in 1995 to study the Sun and solar wind at latitudes not observable from the Earth. Ulysses continues to return data to Earth.

Ulysses

Go to site

Information and news of the Ulysses spacecraft. Instrument payload and scientific objectives are described in detail, as well as the mission time line and flight plan. There are useful links to relevant solar astronomy sites.

umbilical cord

connection between the embryo (or fetus) and the placenta inside the uterus of placental mammals. It has one vein and two arteries, transporting oxygen and nutrients to the developing young, and removing waste products. Blood is carried from the fetus along the umbilical cord and into the placenta. Here it is brought close to the mother's blood. Oxygen, nutrients, and antibodies from the mother diffuse (see diffusion) into the fetal blood. Waste materials from the fetus pass into the mother's blood. The fetal blood, which has been enriched with nutrients, oxygenated, and cleaned of waste, is carried back to the fetus by another blood vessel in the umbilical cord. At birth, the connection between the young and the placenta is no longer necessary. The umbilical cord drops off or is severed, leaving a scar called the navel.

umbra

central region of a shadow that is totally dark because no light reaches it, and from which no part of the light source can be seen (compare penumbra). In astronomy, it is a region of the Earth from which a complete eclipse of the Sun can be seen.

umbrella bird

any of three species of bird of tropical South and Central America, family Cotingidae, order Passeriformes, about 45 cm/18 in long. The Amazonian species *Cephalopterus ornatus*, the **ornate umbrella bird**, has an inflatable wattle at the neck to amplify its humming call, and in display elevates a long crest (12 cm/4 in) lying above the bill so that it rises umbrella-like above the head. These features are less noticeable in the female, which is brownish, while the male is blue-black.

In the **long-wattled umbrella bird** *C. penduliger*, the wattle is covered with black feathers and may reach a length of 28 cm/11 in. The wattle of *C. glabricollis* is short, bare, and red.

umbrella tree

tree native to Queensland and the Northern Territory, Australia, with large shiny leaves each made up of leaflets arranged like an open hand, and small raspberrylike clusters of red flowers at the ends of branches. It is common as an indoor plant in many countries. (*Schefflera actinophylla*.)

uncertainty principle

or indeterminacy principle

in quantum mechanics, the principle that it is impossible to know with unlimited accuracy the position and momentum of a particle. The principle arises because in order to locate a particle exactly, an observer must bounce light (in the form of a photon) off the particle, which must alter its position in an unpredictable way.

It was established by German physicist Werner Heisenberg, and gave a theoretical limit to the precision with which a particle's momentum and position can be measured simultaneously: the more accurately the one is determined, the more uncertainty there is in the other.

unconformity

surface of erosion or nondeposition eventually overlain by younger sedimentary rock strata and preserved in the geologic record. A surface where the beds above and below lie at different angles is called an **angular unconformity**. The boundary between older igneous or metamorphic rocks that are truncated by erosion and later covered by younger sedimentary rocks is called a **nonconformity**.

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unconscious

in psychoanalysis, a part of the personality of which the individual is unaware, and which contains impulses or urges that are held back, or repressed, from conscious awareness.

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undernourishment

condition that results from consuming too little food over a period of time. Like **malnutrition** – the result of a diet that is lacking in certain nutrients (such as protein or vitamins) – undernourishment is common in poor countries. Both lead to a reduction in mental and physical efficiency, a lowering of resistance to disease in general, and often to deficiency diseases such as beriberi or anaemia. In the developing world, lack of adequate food is a common cause of death.

In 1996, an estimated 195 million children under the age of five were undernourished in the world. Undernourishment is not just a problem of the developing world: there were an estimated 12 million children eating inadequately in the USA in 1992. According to UN figures there were 200 million Africans suffering from undernourishment in 1996.

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ungulate

general name for any hoofed mammal. Included are the odd-toed ungulates (perissodactyls) and the even-toed ungulates (artiodactyls), along with subungulates such as elephants.

In 1996 the fossil jaws and teeth of an early ungulate were discovered in Russia. The fossils are believed to be 85 million years old, indicating that ungulates were in existence 20 million years before the extinction of the dinosaurs.

ungulate

The aardvark, the hyrax, and the elephant look completely unalike, but in fact are more closely related to each other than to any other mammal. They are all primitive ungulates (hoofed grazing mammals).

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unicellular organism

any living being consisting of a single cell. Most are invisible without a microscope but a few, such as the giant amoeba, may be visible to the naked eye. The main groups of unicellular organisms are bacteria, archaea, protozoa, unicellular algae, and unicellular fungi or yeasts. Some become disease-causing agents (pathogens).

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unidentified flying object

UFO

any light or object seen in the sky of which the immediate identity is not apparent. Despite unsubstantiated claims, there is no evidence that UFOs are alien spacecraft. On investigation, the vast majority of sightings turn out to have been of natural or identifiable objects, notably bright stars and planets, meteors, aircraft, and satellites, or to have been perpetrated by pranksters. The term **flying saucer** was coined in 1947.

Kidnapped by UFOs?

Go to site

Companion to the US Public Broadcasting Service television programme *Nova*, this page takes a serious approach to alien abduction. It is divided into two sections: the believers and the sceptics. The debate includes renowned scientists, as well as abductees, who weigh in with their opinions on alien kidnappings. An interview with an artist abductee includes sketches of the aliens he claims to have come into contact with. The late astronomer Carl Sagan also states his position and there is a special feature on the physical evidence. Is there any? Find out here.

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unified field theory

in physics, the theory that attempts to explain the four fundamental forces (strong nuclear, weak nuclear, electromagnetic, and gravity) in terms of a single unified force.

Research into the unification of electromagnetism and gravitation was begun by Albert Einstein, but he did not succeed. By 1971 a theory developed by US physicists Steven Weinberg and Sheldon Glashow, Pakistani physicist Abdus Salam, and others, had demonstrated the link between the weak and electromagnetic forces. The next stage is to develop a theory (called the grand unified theory) that combines the strong nuclear force with the electroweak force. The final stage will be to incorporate gravity into the scheme. Work on the superstring theory indicates that this may be the ultimate 'theory of everything'.

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uniformitarianism

in geology, the principle that processes that can be seen to occur on the Earth's surface today are the same as those that have occurred throughout geological time. For example, desert sandstones containing sand-dune structures must have been formed under conditions similar to those present in deserts today. The principle was formulated by Scottish geologists James Hutton and expounded by Charles Lyell.

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unit

standard quantity in relation to which other quantities are measured. There have been many systems of units. Some ancient units, such as the day, the foot, and the pound, are still in use. SI units, the latest version of the metric system, are widely used in science.

Measurement Unit Converter

Go to site

Simple, but very effective site that allows conversion from values in any of an astonishingly wide variety of units to any other relevant unit. All you have to do is select the category, the units you want to convert from and into, and type in the value you want to convert to get a fairly immediate answer. A Java-enabled browser is required for this site to work.

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universal indicator

in chemistry, a mixture of pH indicators, used to gauge the acidity or alkalinity of a solution. Each component changes colour at a different pH value, and so the indicator is capable of displaying a range of colours, according to the pH of the test solution, from red (at pH 1, strong acid) through green (neutral) to purple (at pH 13, strong alkali).

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universal joint

flexible coupling used to join rotating shafts; for example, the drive shaft in a car. In a typical universal joint the ends of the shafts to be joined end in U-shaped yokes. They dovetail into each other and pivot flexibly about an X-shaped spider. This construction allows side-to-side and up-and-down movement, while still transmitting rotary motion.

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universe

all of space and its contents, the study of which is called cosmology. The universe is thought to be between 10 billion and 20 billion years old, and is mostly empty space, dotted with galaxies for as far as telescopes can see. These galaxies are moving further apart as the universe expands. Current theories that attempt to explain how the universe came into being and evolved are all versions of the Big Bang theory of an expanding universe originating in a single explosive event creating hydrogen and helium gases.

The most distant detected galaxies and quasars lie 10 billion light years or more from Earth. Apart from those galaxies within the Local Group, all the galaxies we see display red shifts in their spectra, indicating that they are moving away from us. The further we look into space, the greater are the observed red shifts, which implies that the more distant galaxies are receding at ever greater speeds.

This observation led to the theory of an expanding universe, first proposed in 1929 by US astronomer Edwin Hubble, and to Hubble's law, which states that the speed with which one galaxy moves away from another is proportional to its distance from it. Current data suggest that the galaxies are moving apart at a rate of 65-75 kps/40-47 mps for every million parsecs of distance (one parsec equals 3.26 light years, or 3.08 × 10^{13} km). Recent discoveries suggest that the speed of recession is accelerating rather than slowing.

Inquirer's Guide to the Universe

Go to site

Site designed for teachers and students, with pages on 'Space Science Fact' – the universe as humans know it today – and 'Space Science Fiction' – the universe as humans imagine it might be. Features include planetary fact sheets, information about planets outside the Solar System, virtual trips to black holes and neutron stars, space quotes, and a course in spaceship design.

Windows to the Universe

Go to site

Dramatic site containing lots of information about the universe. It contains sections on the Earth and the Solar System, plus myths about the universe. The articles within each section are available to read at three levels: beginner, intermediate, and advanced. There is also a 'Kid's Space' section that contains games and an 'Ask a Scientist' section.

Unix

multiuser operating system designed for mid-range computers but also used on workstations, mainframes, and supercomputers.

Unix was developed by AT&T's Bell Laboratories in the USA during the late 1960s, using the programming language C. It could therefore run on any machine with a C compiler, so ensuring its wide portability. Its wide range of functions and flexibility, together with the fact that it was available free of charge from 1976 to 1983, led to its wide use by universities and in commercial software.

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unleaded petrol

petrol manufactured without the addition of antiknock. It has a slightly lower octane rating than leaded petrol, but has the advantage of not polluting the atmosphere with lead compounds. Many cars can be converted to run on unleaded petrol by altering the timing of the engine, and most new cars are designed to do so. Cars fitted with a catalytic converter must use unleaded fuel.

Aromatic hydrocarbons and alkenes are added to unleaded petrol instead of lead compounds to increase the octane rating. After combustion the hydrocarbons produce volatile organic compounds. These have been linked to cancer, and are involved in the formation of photochemical smog. A low-lead fuel is less toxic than unleaded petrol for use in cars that are not fitted with a catalytic converter.

The use of unleaded petrol has been standard in the USA for some years.

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unsaturated compound

chemical compound in which two adjacent atoms are linked by a double or triple covalent bond. Alkenes, such as ethene, are unsaturated hydrocarbons that contain a carbon to carbon double bond.

Other examples are ketones, where the unsaturation exists between atoms of different elements (carbon and oxygen). The laboratory test for unsaturated compounds is the addition of bromine water; if the test substance is unsaturated, the bromine water will be decolorized.

---

unsaturated solution

solution that is capable of dissolving more solute than it already contains at the same temperature.

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ununnilium

symbol Uun

temporary name for a synthesized radioactive element of the transactinide series, atomic number 110, relative atomic mass 269. It was discovered in October 1994, detected for a millisecond, at the GSI heavy-ion cyclotron, Darmstadt, Germany, while lead atoms were bombarded with nickel atoms.

---

unununium

symbol Uuu

temporary name for a synthesized radioactive element of the transactinide series, atomic number 111, relative atomic mass 272. It was detected at the GSI heavy-ion cyclotron, Darmstadt, Germany, in December 1994, when bismuth-209 was bombarded with nickel.

---

upthrust

upward force experienced by all objects that are totally or partially immersed in a fluid (liquid or gas). It acts against the weight of the object, and, according to Archimedes' principle, is always equal to the weight of the fluid displaced by that object. An object will float when the upthrust from the fluid is equal to its weight.

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uraninite

uranium oxide, UO_2, an ore mineral of uranium, also known as **pitchblende** when occurring in massive form. It is black or brownish-black, very dense, and radioactive. It occurs in veins and as massive crusts, usually associated with granite rocks.

---

uranium

chemical symbol U

hard, lustrous, silver-white, malleable and ductile, radioactive, metallic element of the actinide series, atomic number 92, relative atomic mass 238.029. It is the most abundant radioactive element in the Earth's crust, its decay giving rise to essentially all radioactive elements in nature; its final decay product is the stable element lead. Uranium combines readily with most elements to form compounds that are extremely poisonous. The chief ore is pitchblende, in which the element was discovered by German chemist Martin Klaproth in 1789; he named it after the planet Uranus, which had been discovered in 1781.

Small amounts of certain compounds containing uranium have been used in the ceramics industry to make orange-yellow glazes and as mordants in dyeing; however, this practice was discontinued when the dangerous effects of radiation became known.

Uranium is one of the fissile elements (others include thorium and plutonium). It was long considered to be the element with the highest atomic number to occur naturally on Earth. The isotopes U-238 and U-235 have been used to help determine the age of the Earth.

Uranium-238, which comprises about 99% of all naturally occurring uranium, has a half-life of 4.51×10^9 years. Because of its abundance, it is the isotope from which fissile plutonium is produced in breeder nuclear reactors. The fissile isotope U-235 has a half-life of 7.13×10^8 years and comprises about 0.7% of naturally occurring uranium; it is used directly as a fuel for nuclear reactors and in the manufacture of nuclear weapons.

What is Uranium?

Go to site

Comprehensive and informative page on uranium, its properties and uses, mainly in nuclear reactors and weapons, provided by the Uranium Information Council.

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uranium ore

material from which uranium is extracted, often a complex mixture of minerals. The main ore is uraninite (or pitchblende), UO_2, which is commonly found with sulphide minerals. The USA, Canada, and South Africa are the main producers in the West.

Uranus

seventh planet from the Sun, discovered by German-born British astronomer William Herschel in 1781. It is twice as far out as the sixth planet, Saturn. Uranus has a mass 14.5 times that of Earth. The spin axis of Uranus is tilted at 98°, so that one pole points towards the Sun, giving extreme seasons.

mean distance from the Sun

2.9 billion km/1.8 billion mi

equatorial diameter

50,800 km/31,600 mi

rotation period

17 hours 12 minutes

year

84 Earth years

atmosphere

deep atmosphere composed mainly of hydrogen and helium

surface

composed primarily of rock and various ices with only about 15% hydrogen and helium, but may also contain heavier elements, which might account for Uranus's mean density being higher than that of Saturn

satellites

27 moons were known by the end of 2005

rings

11 rings, composed of rock and dust, around the planet's equator, were detected by the US space probe Voyager 2 in 1977. The rings are charcoal black and may be debris of former 'moonlets' that have broken up. The ring furthest from the planet centre (51,000 km/31,800 mi), Epsilon, is 100 km/60 mi at its widest point. In 1995, US astronomers determined that the ring particles contained long-chain hydrocarbons. Looking at the brightest region of Epsilon, they were also able to calculate the precession of Uranus as 264 days, the fastest known precession in the Solar System

Uranus has a peculiar magnetic field, in that it is tilted at 60° to the axis of spin, and is displaced about a third of the way from the planet's centre to its surface. Uranus spins from east to west, the opposite of the other planets, with the exception of Venus and possibly Pluto. The rotation rate of the atmosphere varies with latitude, from about 16 hours in mid-southern latitudes to longer than 17 hours at the equator.

Uranus

All Uranus' moons are named after characters from Shakespeare.

Uranus

(Image © NASA)

Voyager 2 image of Uranus digitally enhanced to show the haze in the planet's upper atmosphere, which appears to be organized into faint bands. No detail of the underlying cloud structure can be seen, but a faint white cloud streak is visible in the lower part of the picture.

Uranian satellites

To remember the Uranian satellites:

MAUTO

Miranda, **A**riel, **U**mbriel, **T**itania, **O**beron

Uranus

Go to site

Did you know that Uranus is tipped on its side? Find out more about Uranus, its rings, and its moons at this site. Also included are a table of statistics about the planet, photographs, and animations of its rotation.

---

urea

$CO(NH_2)_2$

waste product formed in the mammalian liver when nitrogen compounds are broken down. It is filtered from the blood by the kidneys, and stored in the bladder as urine prior to release. When purified, it is a white, crystalline solid. In industry it is used to make urea-formaldehyde plastics (or resins), pharmaceuticals, and fertilizers.

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ureter

tube connecting the kidney to the bladder. Its wall contains fibres of smooth muscle whose contractions aid the movement of urine out of the kidney.

---

urethra

in mammals, a tube connecting the bladder to the exterior. It carries urine and, in males, semen.

Urey, Harold Clayton (1893-1981)

US chemist. In 1932 he isolated heavy water and was awarded the Nobel Prize for Chemistry in 1934 for his discovery of deuterium (heavy hydrogen).

During World War II he was a member of the Manhattan Project, which produced the atomic bomb, and after the war he worked on tritium (another isotope of hydrogen, of mass 3) for use in the hydrogen bomb, but later he advocated nuclear disarmament and world government.

---

urial

or Punjab wild sheep or shapu

wild sheep that ranges from sea level near the Caspian Sea to 4,200 m/13,860 ft in Tibet. The male has massive horns up to 1 m/3.3 ft long.

classification

The urial *Ovis vignei* is in family Bovidae, in order Artiodactyla.

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uric acid

$C_5H_4N_4O_3$

nitrogen-containing waste substance, formed from the breakdown of food and body protein.

It is only slightly soluble in water. Uric acid is the normal means by which most land animals that develop in a shell (birds, reptiles, insects, and land gastropods) deposit their waste products. The young are unable to get rid of their excretory products while in the shell and therefore store them in this insoluble form.

Humans and other primates produce some uric acid as well as urea, the normal nitrogenous waste product of mammals, adult amphibians, and many marine fishes. If formed in excess and not excreted, uric acid may be deposited in sharp crystals in the joints and other tissues, causing gout; or it may form stones (calculi) in the kidneys or bladder.

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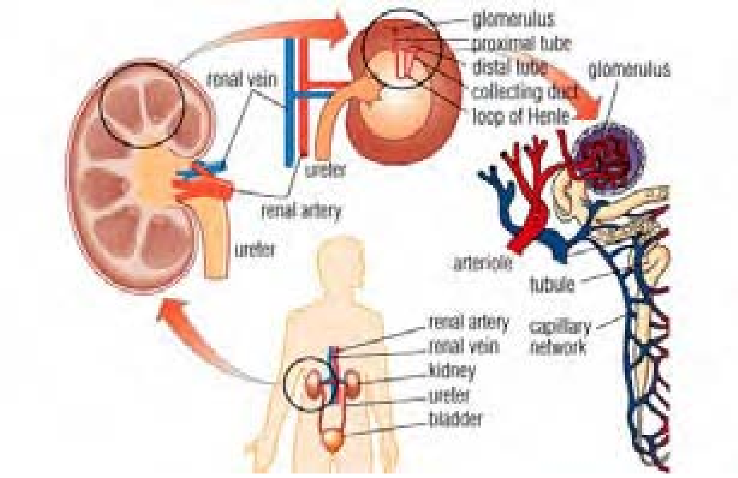
urinary system

system of organs that removes nitrogenous waste products and excess water from the bodies of animals. In vertebrates, it consists of a pair of kidneys, which produce urine; ureters, which drain the kidneys; and (in bony fishes, amphibians, some reptiles, and mammals) a bladder that stores the urine before its discharge. In mammals, the urine is expelled through the urethra; in other vertebrates, the urine drains into a common excretory chamber called a cloaca, and the urine is not discharged separately.

urinary system


glomerulus
proximal tube
distal tube
collecting duct
loop of Henle
glomerulus
renal vein
ureter
renal artery
ureter
arteriole
tubule
renal artery
renal vein
kidney
ureter
bladder
capillary network

(Image © Research Machines plc)

The human urinary system. At the bottom, the complete system in outline; on the left, the arrangement of blood vessels connected to the kidney; at the top right, a detail of the network of vessels within a kidney.

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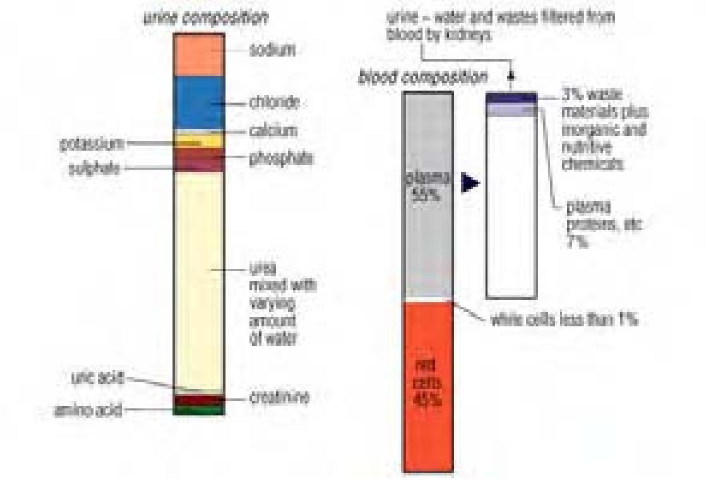
urine

amber-coloured fluid filtered out by the kidneys from the blood. It contains excess water, salts, proteins, waste products in the form of urea, a pigment, and some acid.

The kidneys pass it through two fine tubes (ureters) to the bladder, which may act as a reservoir for up to 0.7 l/1.5 pt at a time. In mammals, it then passes into the urethra, which opens to the outside by a sphincter (constricting muscle) under voluntary control. In reptiles and birds, nitrogenous wastes are discharged as an almost solid substance made mostly of uric acid, rather than urea.

urine



(Image © Research Machines plc)

Urine consists of excess water and waste products that have been filtered from the blood by the kidneys; it is stored in the bladder until it can be expelled from the body via the urethra. Analysing the composition of an individual's urine can reveal a number of medical conditions, such as poorly functioning kidneys, kidney stones, and diabetes.

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urology

medical speciality concerned with diseases of the urinary tract.

Ursa Major

(Latin 'Great Bear')

third-largest constellation in the sky, in the north polar region. Its seven brightest stars make up the familiar shape or asterism of the **Big Dipper** or **Plough**. The second star of the handle of the dipper, called Mizar, has a companion star, Alcor.

Two stars forming the side of the dipper bowl further from the handle act as pointers to the north pole star, Polaris. Dubhe, one of them, is the constellation's brightest star.

Ursa Minor

(Latin 'Little Bear')

small constellation of the northern hemisphere, whose brighter stars form the asterism known in America as 'the Little Dipper'. The bright pole star Polaris lies at the end of the dipper's handle.

Two other bright stars in this group, Beta and Gamma Ursae Minoris, are called 'the Guards' or 'the Guardians of the Pole'. The constellation also contains the orange subgiant Kochab, about 95 light years from Earth.

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urticaria

or nettle rash or hives

irritant skin condition characterized by itching, burning, stinging, and the spontaneous appearance of raised patches of skin. Treatment is usually by antihistamines or steroids taken orally or applied as lotions. Its causes are varied and include allergy and stress.

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user ID

abbreviation for user identification

name or nickname that identifies the user of a computer system or network.

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user interface

in computing, the procedures and methods through which the user operates a program. These might include menus, input forms, error messages, and keyboard procedures. A graphical user interface (GUI or WIMP) is one that makes use of icons (small pictures) and allows the user to make menu selections with a mouse.

US Naval Observatory

US government observatory in Washington, DC, that provides the nation's time service and publishes almanacs for navigators, surveyors, and astronomers. It contains a 66-cm/26-in refracting telescope opened in 1873. A 1.55-m/61-in reflector for measuring positions of celestial objects was opened in 1964 at Flagstaff, Arizona.

UTC

abbreviation for coordinated universal time, an alternative name for universal time coodinated, the standard measurement of time.

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uterus

hollow muscular organ of female mammals, located between the bladder and rectum, and connected to the Fallopian tubes above and the vagina below. The embryo develops within the uterus, and in placental mammals is attached to it after implantation via the placenta and umbilical cord. The lining of the uterus changes during the menstrual cycle to prepare it for pregnancy. In humans and other higher primates, it is a single structure, but in other mammals it is paired.

In fertilization a sperm fuses with an ovum and produces a zygote. The zygote sinks into the lining of the uterus. It then grows a placenta which brings the fetus's blood close to the mother's blood so that the fetus can obtain oxygen and nutrients. The outer wall of the uterus is composed of smooth muscle, capable of powerful contractions (induced by hormones) during childbirth.

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utility program

in computing, a systems program designed to perform a specific task related to the operation of the computer when requested to do so by the computer user. For example, a utility program might be used to complete a screen dump, format a disk, or convert the format of a data file so that it can be accessed by a different applications program.

UV

in physics, abbreviation for **ultraviolet**.

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v

in physics, symbol for velocity.

V

in physics, symbol for volt, the SI unit of emf or potential difference, equal to the potential difference between two points in an electrical circuit when a current of 1 ampere flowing between them dissipates a power of 1 watt.

V

Roman numeral for **five**; in physics, symbol for volt.

---

vaccine

any preparation of modified pathogens (viruses or bacteria) that is introduced into the body, usually either orally or by a hypodermic syringe, to induce the specific antibody reaction that produces immunity against a particular disease.

In 1796 Edward Jenner was the first to inoculate a child successfully with cowpox virus to produce immunity to smallpox. His method, the application of an infective agent to an abraded skin surface, is still used in smallpox inoculation.

Vaccines in Foods

vaccines

Vaccines are proteins that stimulate the immune response of animals, and help protect against infectious diseases caused by viruses and bacteria. More than 75 such diseases can now be prevented in this way and millions of deaths are prevented annually by the use of these products.

oral immunization

Many infectious diseases are spread by contaminated water or food, and enter the body through the membranes of the digestive system. Stimulating the immune system of the cells lining the digestive system best combats such diseases. Most people are familiar with the polio vaccine provided on sugar cubes. This is probably the best example of vaccination provided by mouth (oral immunization) rather than by injection. The most obvious advantage of the oral route is that it does not require the use of sterile needles.

need for new production methods

Like many pharmaceutical products, vaccines are relatively expensive to produce. Recently, it has been suggested that plants may be a useful new production system because large amounts of antigen (the active protein component of the vaccine) could be produced at low cost, using agricultural methods rather than cell culture-based systems that are expensive and complex. This would be particularly valuable for developing countries which often lack capital-intensive infrastructure, and where, for example, the problem of diarrhoeal diseases of children is especially acute.

transgenic plants as a production system

There are two potential methods for producing vaccines in plants. In the first, the DNA fragment encoding the antigen could be introduced directly into the nuclear chromosome of the plant, using any of the methods developed for the production of transgenic plants. The transgenic plants containing the antigen would then be used directly as an oral vaccine, or the antigen could be purified and then consumed. Alternatively, the DNA could be incorporated into a specific virus that only infects plants; this virus could be multiplied within the plant chosen for production. The plant virus particles containing the antigen would then be purified prior to their being used as a vaccine.

Both methods have already been shown to be effective in primary studies, including some conducted on animals. Crops used for animal feed, such as alfalfa, cereals, and legumes are obvious choices for animal vaccines. For humans, plants chosen for production include potato and banana; the latter species may be preferred for tropical countries since it would permit vaccine production in the regions of greatest need. It would also allow inexpensive storage of vaccine material without the need for costly refrigeration facilities.

future prospects

In the next stage of development, the promising results must be confirmed in a wider range of animal and human studies, before such production systems can be approved for widespread use. Remaining challenges include maximizing the level of production of the antigenic protein, stabilizing this protein during post-harvest storage of plant material, and enhancing its immunogenic capacity. In addition, it will be necessary to determine whether 'edible vaccines' should be provided as a specific medical (or veterinary) product or as a routine food source.

Vaccine: The First Vaccination

introduction

Today, during their first few months of life, infants are routinely vaccinated against diphtheria, tetanus, whooping cough, and poliomyelitis. After one year, vaccination against measles, mumps, and rubella is also recommended. Thanks to such preventive medicine and to proper nutrition, the common infectious diseases of childhood have largely disappeared from the developed world; if they do occur, the consequences are not usually serious.

vaccinations

The regular use of vaccination began in 1796 as a result of the pioneering work of Edward Jenner, a British physician (1749-1823). In the 18th century, smallpox was one of the commonest and most deadly diseases. Most people contracted it, and a face completely unscarred by the disease was rare. In 17th-century London, some 10% of all deaths were due to smallpox.

Because the disease was so common, it was well known that an earlier, nonfatal attack of smallpox conferred immunity in any following epidemics. In Eastern countries, people were deliberately exposed to mild forms of the disease. This method was brought back to England in 1721 by Lady Mary Wortley Montagu, wife of the British Ambassador to Turkey. She had her own children 'vaccinated' (the procedure was then called **variolation**), encountering much prejudice as a result.

kill or cure?

In England, an epidemic of smallpox swept Gloucestershire in 1788, and variolation was widely practised. It involved scratching a vein in the arm of a healthy person, and working into it a small of amount of matter from a smallpox pustule taken from a person with a mild attack of the disease. This risky procedure had two major disadvantages. The inoculated subject, unless isolated, was likely to start a fresh smallpox epidemic; and if the dose was too virulent, the resulting disease was fatal.

Edward Jenner had a country medical practice, and was familiar with both human and animal diseases. He noted that milkmaids often caught the disease cowpox, and inquired further. He saw that milking was regularly done by both men and maidservants. The men, after changing the dressings on horses suffering from a disease called 'the grease', went on to milk the cows, thus infecting them at the same time. In due course, the cows became diseased, and in turn the milkmaids who milked them caught cowpox.

Jenner's observations

Jenner wrote: 'Thus the disease makes its progress from the horse to the nipple of the cow, and from the cow to the human subject.' He went on: 'What makes the cowpox virus so extremely singular is that the person who has been thus affected is for ever secure from the infection of the smallpox.' Jenner then describes a great number of instances, in proof of his observations. Here are some of them.

Case I. Joseph Merret, the undergardener to the Earl of Berkeley, had been a farmer's servant in 1770, and sometimes helped with the milking. He also attended the horses. Merret caught cowpox. In April 1795, he was treated during a general inoculation that took place. Jenner found that despite repeatedly inserting variolous matter into Merret's arm, it was impossible to infect him with smallpox. During the whole time his family had smallpox, Merret stayed with them, and remained perfectly healthy. Jenner was at pains to make sure that Merret had at no time previously caught smallpox.

Case II. Sarah Portlock nursed one of her own children who, in 1792, accidentally caught smallpox. She considered herself safe from infection, for as a farmer's servant 27 years previously, she had contracted cowpox. She remained in the same room as her child, and as in the previous case, variolation produced no disease.

Jenner then performed the experiment that was to make him famous, and give medicine vaccination, one of the most powerful weapons against disease.

the first vaccination

Case XVII. On 14 May 1796, Jenner selected a healthy eight-year-old boy and inoculated him with cowpox, taken from a sore in the hand of a dairymaid. He inserted the infected matter in two incisions, each about 25 mm/1 in long. The boy showed only mild symptoms: on the seventh day he complained of a slight headache, became a little chilly and suffered loss of appetite.

Then on 1 July 1796, Jenner inoculated the boy with variolous matter, inserting it in several slight punctures and incisions in both arms. No disease followed. The only symptoms the boy showed were those of someone who had recovered from smallpox, or had previously suffered from cowpox. Several months later, the boy was inoculated again with similar results.

Jenner published his results privately on the advice of Fellows of the Royal Society, who considered that he should not risk his reputation by presenting anything 'so much at variance with established knowledge'. However, in a few years, vaccination was a widespread practice.

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vacuole

in biology, a fluid-filled, membrane-bound cavity inside a cell. It may be a reservoir for fluids that the cell will secrete to the outside, or may be filled with excretory products or essential nutrients that the cell needs to store.

Plant cells usually have a large central vacuole containing call sap (sugar and salts in solution) which serves both as a store of food and as a key factor in storing water and in maintaining turgor. Absorbing more water to make a bigger vacuole adds bulk to the plant. This expansion of cells is very important in plant growth. In amoebae (single-celled animals), vacuoles are the sites of digestion of engulfed food particles. Animal cells may only have small vacuoles, which are usually called vesicles.

---

vacuum

in general, a region completely empty of matter; in physics, any enclosure in which the gas pressure is considerably less than atmospheric pressure (101,325 pascals).

---

vacuum cleaner

cleaning device invented in 1901 by the Scot Hubert Cecil Booth. Having seen an ineffective dust-blowing machine, he reversed the process so that his machine (originally on wheels, and operated from the street by means of tubes running into the house) operated by suction.

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vagina

lower part of the reproductive tract in female mammals, linking the uterus to the exterior. It admits the penis during sexual intercourse, and is the birth canal down which the baby passes during delivery.

---

valence

in chemistry, the measure of an element's ability to combine with other elements, expressed as the number of atoms of hydrogen (or any other standard univalent element) capable of uniting with (or replacing) its atoms. The number of electrons in the outermost shell of the atom dictates the combining ability of an element.

The elements are described as uni-, di-, tri-, and tetravalent when they unite with one, two, three, and four univalent atoms respectively. Some elements have **variable valence**: for example, nitrogen and phosphorus have a valence of both three and five. The valency of oxygen is two: hence the formula for water, H_2O (hydrogen being univalent).

---

valence electron

electron in the outermost shell of an atom. It is the valence electrons that are involved in the formation of ionic and covalent bonds (see molecule). The number of electrons in this outermost shell represents the maximum possible valence for many elements and matches the number of the group that the element occupies in the periodic table of the elements.

---

valerian

any of a group of perennial plants native to the northern hemisphere, with clustered heads of fragrant tubular flowers in red, white, or pink. The root of the common valerian or garden heliotrope *V. officinalis* is used in medicine to relieve wind and to soothe or calm patients. (Genera *Valeriana* and *Centranthus*, family Valerianaceae.)

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validation

in computing, the process of checking input data to ensure that it is complete, accurate, and reasonable. Although it would be impossible to guarantee that only valid data are entered into a computer, a suitable combination of validation checks should ensure that most errors are detected.

Common validation checks include:

character-type check

Each input data item is checked to ensure that it does not contain invalid characters.

For example, an input name might be checked to ensure that it contains only letters of the alphabet, or an input six-figure date might be checked to ensure it contains only numbers.

field-length check

The number of characters in an input field is checked to ensure that the correct number of characters has been entered. For example, a six-figure date field might be checked to ensure that it does contain exactly six digits.

control-total check

The arithmetic total of a specific field from a group of records is calculated – for example, the hours worked by a group of employees might be added together – and then input with the data to which it refers. The program recalculates the control total and compares it with the one entered to ensure that entry errors have not been made.

hash-total check

An otherwise meaningless control total is calculated – for example, by adding together account numbers. Even though the total has no arithmetic meaning, it can still be used to check the validity of the input account numbers.

parity check

Parity bits are added to binary number codes to ensure that each number in a set of data has the same parity (that each binary number has an even number of 1s, for example). The binary numbers can then be checked to ensure that their parity remains the same. This check is often applied to data after they have been transferred from one part of the computer to another; for example, from a disk drive into the immediate-access memory.

check digit

A digit is calculated from the digits of a code number and then added to that number as an extra digit. For example, in the ISBN (International Standard Book Number) 0 631 90057 8, the 8 is a check digit calculated from the book code number 063190057 and then added to it to make the full ISBN. When the full code number is input, the computer recalculates the check digit and compares it with the one entered. If the entered and calculated check digits do not match, the computer reports that an entry error of some kind has been made.

range check

An input numerical data item is checked to ensure that its value falls in a sensible range. For example, an input two-digit day of the month might be checked to ensure that it is in the range 01 to 31.

---

valley

a long, linear depression sloping downwards towards the sea or an inland drainage basin. Types of valleys include the V-shaped valley, U-shaped valley, hanging valley, dry valley, misfit valley, asymmetric valley, and rift valley.

Valley of Ten Thousand Smokes

valley in southwestern Alaska, on the Alaska Peninsula, where in 1912 Mount Katmai erupted in one of the largest volcanic explosions ever known, although without loss of human life since the area was uninhabited. The valley was filled with ash to a depth of 200 m/660 ft. It was dedicated as the Katmai National Monument in 1918. Thousands of fissures on the valley floor continue to emit steam and gases.

Katmai National Park and Preserve

Go to site

Guide to the National Park, which contains the famous Valley of Ten Thousand Smokes, where the 20th century's most dramatic volcanic episode took place.

---

valve

in animals, a structure for controlling the direction of the blood flow. In humans and other vertebrates, the contractions of the beating heart cause the correct blood flow into the arteries because a series of valves prevents back flow. Diseased valves, detected as 'heart murmurs', have decreased efficiency. The tendency for low-pressure venous blood to collect at the base of limbs under the influence of gravity is counteracted by a series of small valves within the veins. It was the existence of these valves that prompted the 17th-century physician William Harvey to suggest that the blood circulated around the body.

---

valve

in technology, a device that controls the flow of a fluid. Inside a valve, a plug moves to widen or close the opening through which the fluid passes.

Common valves include the cone or needle valve, globe valve, and butterfly valve, all named after the shape of the plug. Specialized valves include the one-way valve, which permits fluid flow in one direction only, and the safety valve, which cuts off flow under certain conditions.

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valvular heart disease

damage to the heart valves, leading to either narrowing of the valve orifice when it is open (stenosis) or leaking through the valve when it is closed (regurgitation).

Worldwide, rheumatic fever is the commonest cause of damage to the heart valves, but in industrialized countries it is being replaced by bacterial infection of the valves themselves (infective endocarditis) and ischaemic heart disease as the main causes. Valvular heart disease is diagnosed by hearing heart murmurs with a stethoscope, or by cardiac ultrasound.

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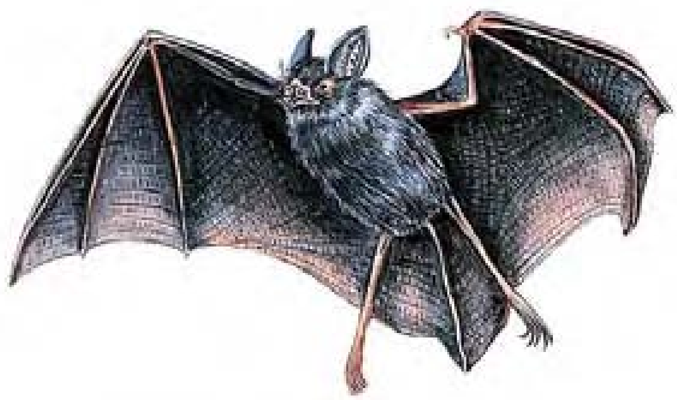
vampire bat

South and Central American bat of the family Desmodontidae, of which there are three species. The **common vampire** *Desmodus rotundus* is found from northern Mexico to central Argentina; its head and body grow to 9 cm/3.5 in. Vampire bats feed on the blood of birds and mammals; they slice a piece of skin from a sleeping animal with their sharp incisor teeth and lap up the flowing blood. They chiefly approach their prey by flying low then crawling and leaping.

Vampire bats feed on all kinds of mammals including horses, cattle, and occasionally humans. The bite is painless and the loss of blood is small (about 1 cubic cm/0.06 cubic in); the victim seldom comes to any harm. Vampire bats are intelligent and among the few mammals to show altruistic behaviour (they adopt orphans and help other bats in need).

The other species are *Diaemus youngi*, the **white-winged vampire**, and *Diphylla ecaudata*, the **hairy-legged vampire**.

vampire bat



(Image © Research Machines plc)

The vampire bat is the only mammal to live as a parasite. It alights a few feet away from its victim and walks forwards on all fours. A small cut is made with its incisor teeth on a hairless part of the victim's body and the bat feeds on the oozing blood. Although the loss of blood is not severe, the bat may transmit serious diseases, such as rabies, to its victim.

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vanadium

chemical symbol V

silver-white, malleable and ductile, metallic element, atomic number 23, relative atomic mass 50.942. It occurs in certain iron, lead, and uranium ores and is widely distributed in small quantities in igneous and sedimentary rocks. It is used to make steel alloys, to which it adds tensile strength.

Spanish mineralogist Andrés del Rio (1764-1849) and Swedish chemist Nils Sefström (1787-1845) discovered vanadium independently, the former in 1801 and the latter in 1831. Del Rio named it 'erythronium', but was persuaded by other chemists that he had not in fact discovered a new element; Sefström gave it its present name, after the Norse goddess of love and beauty, Vanadis (or Freya).

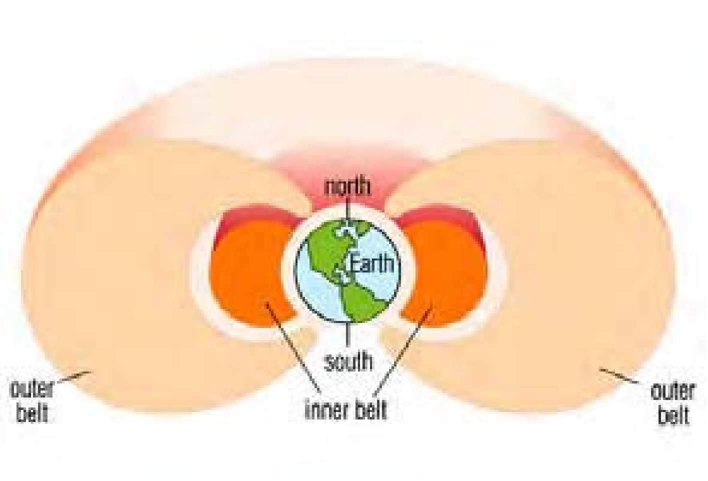
Van Allen, James Alfred (1914-)

US physicist whose instruments aboard the first US satellite Explorer 1 in 1958 led to the discovery of the Van Allen belts, two zones of intense radiation around the Earth. He pioneered high-altitude research with rockets after World War II.

Van Allen radiation belts

two zones of charged particles around the Earth's magnetosphere, discovered in 1958 by US physicist James Van Allen. The atomic particles come from the Earth's upper atmosphere and the solar wind, and are trapped by the Earth's magnetic field. The inner belt lies 1,000-5,000 km/600-3,000 mi above the Equator, and contains protons and electrons. The outer belt lies 15,000-25,000 km/9,000-15,000 mi above the Equator, but is lower around the magnetic poles. It contains mostly electrons from the solar wind.

Van Allen radiation belts



(Image © Research Machines plc)

The Van Allen belts of trapped charged particles are a hazard to spacecraft, affecting on-board electronics and computer systems. Similar belts have been discovered around the planets Mercury, Jupiter, Saturn, Uranus, and Neptune.

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van de Graaff, Robert Jemison (1901-1967)

US physicist who from 1929 developed a high-voltage generator, which in its modern form can produce more than a million volts.

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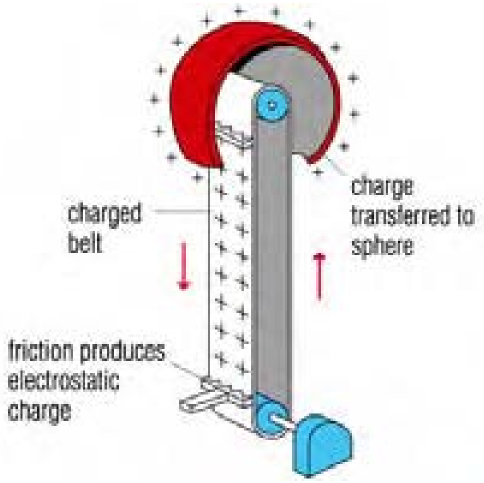
van de Graaff generator

electrostatic generator capable of producing a voltage of over a million volts. It consists of a continuous vertical conveyor belt that carries electrostatic charges (resulting from friction) up to a large hollow sphere supported on an insulated stand. The lower end of the belt is earthed, so that charge accumulates on the sphere. The size of the voltage built up in air depends on the radius of the sphere, but can be increased by enclosing the generator in an inert atmosphere, such as nitrogen.

van de Graaff generator


charge transferred to sphere
charged belt
friction produces electrostatic charge

(Image © Research Machines plc)

US physicist Robert Jemison van de Graaff developed this high-powered generator, which can produce more than a million volts. Experiments involving high-energy charged particles make use of a van de Graaff generator, generally for the initial acceleration of the particles, which are then passed to more powerful accelerators.

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van der Waals' law

modified form of the gas laws that includes corrections for the non-ideal behaviour of real gases (the molecules of ideal gases occupy no space and exert no forces on each other). It is named after Dutch physicist

J D van der Waals (1837-1923).

The equation derived from the law states that:

$(P + a/V^2)(V - b) = RT$

where P, V, and T are the pressure, volume, and temperature (in kelvin) of the gas, respectively; R is the gas constant; and a and b are constants for that particular gas.

Vane, John Robert (1927-)

English pharmacologist who was awarded a Nobel Prize for Physiology or Medicine in 1982 for the discovery of prostaglandins and related biologically active substances. He demonstrated the wide role of prostaglandins in the human body, produced in response to illness and stress. He shared the prize with Sune Bergström and Bengt Samuelsson, both of Sweden.

Vanguard

early series of US Earth-orbiting satellites and their associated rocket launcher. Vanguard 1 was the second US satellite, launched on 17 March 1958 by the three-stage Vanguard rocket. Tracking of its orbit revealed that the Earth is slightly pear-shaped. The series ended in September 1959 with Vanguard 3.

vanilla

any of a group of climbing orchids native to tropical America but cultivated elsewhere, with large, fragrant white or yellow flowers. The dried and fermented fruit, or podlike capsules, of the species *V. planifolia* are the source of the vanilla flavouring used in cookery and baking. (Genus *Vanilla*.)

Annual world production of vanilla pods is estimated at 1,500 tonnes. Vanilla flavouring (**vanillin**) can now be produced artificially from waste sulphite liquor, a by-product of paper pulp-making.

van't Hoff, Jacobus Henricus (1852-1911)

Dutch physical chemist. He explained the 'asymmetric' carbon atom occurring in optically active compounds. His greatest work - the concept of chemical affinity as the maximum work obtainable from a reaction - was shown with measurements of osmotic and gas pressures, and reversible electrical cells. He was the first person to be awarded the Nobel Prize for Chemistry in 1901 for his study of the laws of chemical dynamics and osmotic pressure.

vapour

one of the three states of matter (see also solid and liquid). The molecules in a vapour move randomly and are far apart, the distance between them, and therefore the volume of the vapour, being limited only by the walls of any vessel in which they might be contained. A vapour differs from a gas only in that a vapour can be liquefied by increased pressure, whereas a gas cannot unless its temperature is lowered below its critical temperature; it then becomes a vapour and may be liquefied.

vapour density

density of a gas, expressed as the mass of a given volume of the gas divided by the mass of an equal volume of a reference gas (such as hydrogen or air) at the same temperature and pressure. If the reference gas is hydrogen, it is equal to half the relative molecular weight (mass) of the gas.

vapour pressure

pressure of a vapour given off by (evaporated from) a liquid or solid, caused by atoms or molecules continuously escaping from its surface. In an enclosed space, a maximum value is reached when the number of particles leaving the surface is in equilibrium with those returning to it; this is known as the **saturated vapour pressure** or **equilibrium vapour pressure**.

variable

in computing, a quantity that can take different values. Variables can be used to represent different items of data in the course of a program.

A computer programmer will choose a symbol to represent each variable used in a program. The computer will then automatically assign a memory location to store the current value of each variable, and use the chosen symbol to identify this location.

For example, the letter *P* might be chosen by a programmer to represent the price of an article. The computer would automatically reserve a memory location with the symbolic address *P* to store the price being currently processed.

Different programming languages place different restrictions on the choice of symbols used to represent variables. Some languages only allow a single letter followed, where required, by a single number. Other languages allow a much freer choice, allowing, for example, the use of the full word 'price' to represent the price of an article.

A **global variable** is one that can be accessed by any program instruction; a **local variable** is one that can only be accessed by the instructions within a particular subroutine.

---

variable

in mathematics, a changing quantity (one that can take various values), as opposed to a constant. For example, in the algebraic expression $y = 4x^3 + 2$, the variables are *x* and *y*, whereas 4 and 2 are constants.

A variable may be dependent or independent. Thus if *y* is a function of *x*, written $y = f(x)$, such that $y = 4x^3 + 2$, the domain of the function includes all values of the **independent variable** *x* while the range (or co-domain) of the function is defined by the values of the **dependent variable** *y*.

---

variable star

star whose brightness changes, either regularly or irregularly, over a period ranging from a few hours to months or years. The Cepheid variables regularly expand and contract in size every few days or weeks.

Stars that change in size and brightness at less precise intervals include **long-period variables**, such as the red giant Mira in the constellation Cetus (period about 331 days), and **irregular variables**, such as some red supergiants.
Eruptive variables emit sudden outbursts of light. Some suffer flares on their surfaces, while others, such as a nova, result from transfer of gas between a close pair of stars. A supernova is the explosive death of a star. In an **eclipsing binary**, the variation is due not to any change in the star itself, but to the periodic eclipse of a star by a close companion. The different types of variability are closely related to different stages of stellar evolution.

---

variance

in statistics, the square of the standard deviation, the measure of spread of data. Population variance and sample variance are denoted by σ^2 and s^2, respectively. Variance provides a measure of the dispersion of a set of statistical results about the mean or average value.

---

variation

in biology, a difference between individuals of the same species, found in any sexually reproducing population. Variations may be almost unnoticeable in some cases, obvious in others, and can concern many aspects of the organism. Typically, variations in size, behaviour, biochemistry, or colouring may be found. The cause of the variation is genetic (that is, inherited), environmental, or more usually a combination of the two. Some variation is the result of the environment modifying inherited characteristics. The origins of variation can be traced to the recombination of the genetic material during the formation of the gametes, and, more rarely, to mutation.

An example of inherited variation is blood groups in humans. An extreme example of variation produced by the environment is the loss of a part of the body from injury. An example of variation that involves the environment modifying inherited characteristics is height. The characteristic of being tall or short is inherited, but the availability of food in the environment determines the actual height of the individual.

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varicose veins

or varicosis

condition in which the veins become swollen and twisted. The veins of the legs are most often affected; other vulnerable sites include the rectum (haemorrhoids) and testes.

Some people have an inherited tendency to varicose veins, and the condition often appears in pregnant women, but obstructed blood flow is the direct cause. They may cause a dull ache or may be the site for thrombosis, infection, or ulcers. The affected veins can be injected with a substance that causes them to shrink, or surgery may be needed.

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variegation

description of plant leaves or stems that exhibit patches of different colours. The term is usually applied to plants that show white, cream, or yellow on their leaves, caused by areas of tissue that lack the green pigment chlorophyll. Variegated plants are bred for their decorative value, but they are often considerably weaker than the normal, uniformly green plant. Many will not breed true and require vegetative reproduction.

The term is sometimes applied to abnormal patchy colouring of petals, as in the variegated petals of certain tulips, caused by a virus infection. A mineral deficiency in the soil may also be the cause of variegation.

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variety

in biology, a stable group of organisms within a single species, clearly different from the rest of the species. Such a group would generally be called a variety for plants and a breed for animals. The differences lie in their genetic make-up and could have arisen naturally – through natural selection or as a result of selective breeding by humans. Most varieties have been produced by selective breeding, for example 'Cox's', 'Golden Delicious', and 'Bramley' apple varieties.

In most species there are often genetic differences between individuals that cause them to be distinct. These are not varieties – a variety is a group of individuals. However, not every genetically distinct group can be a variety. There must be a greater degree of variation between varieties than within the varieties for the term to be appropriate. This can be shown by collecting data on the mass, length, and diameter of varieties of tomato, potato, or runner bean, for example.

Selective breeding results in the production of new varieties if enough useful characteristics are brought together in one group. The 'Bramley' apple variety had the characteristics of vigorous growth, disease resistance, large apples, good storage, and soft texture on cooking. This has made it a popular cooking apple in some countries.

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varve

in geology, a pair of thin sedimentary beds, one coarse and one fine, representing a cycle of thaw followed by an interval of freezing, in lakes of glacial regions.

Each couplet thus constitutes the sedimentary record of a year, and by counting varves in glacial lakes a record of absolute time elapsed can be determined. Summer and winter layers often are distinguished also by colour, with lighter layers representing summer deposition, and darker layers being the result of dark clay settling from water while the lake is frozen.

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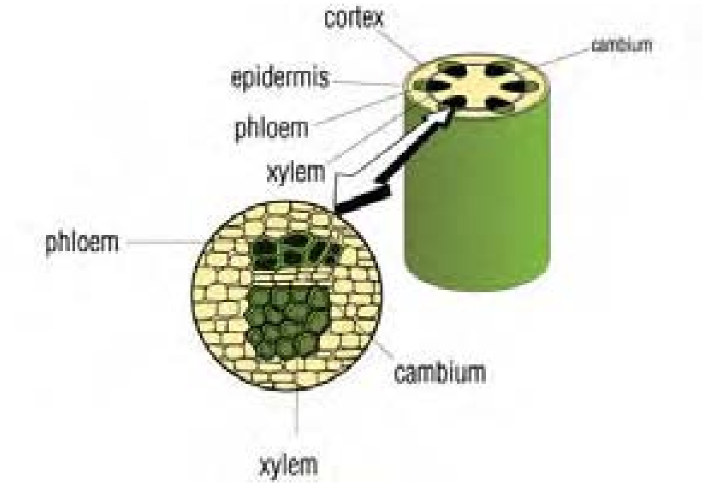
vascular bundle

in botany, strand of primary conducting tissue (a 'vein') in vascular plants, consisting mainly of water-conducting tissues, metaxylem and protoxylem, which together make up the primary xylem, and nutrient-conducting tissue, phloem. It extends from the roots to the stems and leaves. Typically the phloem is situated nearest to the epidermis and the xylem towards the centre of the bundle. In plants exhibiting secondary growth, the xylem and phloem are separated by a thin layer of vascular cambium, which gives rise to new conducting tissues.

vascular bundle



(Image © Research Machines plc)

The fluid-carrying tissue of most plants is normally arranged in units called vascular bundles. The vascular tissue is of two types: xylem and phloem. The xylem carries water up through the plant; the phloem distributes food made in the leaves to all parts of the plant.

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vascular plant

plant containing vascular bundles. Pteridophytes (ferns, horsetails, and club mosses), gymnosperms (conifers and cycads), and angiosperms (flowering plants) are all vascular plants.

vas deferens

in male vertebrates, a tube conducting sperm from the testis to the urethra. The sperm is carried in a fluid secreted by various glands, and can be transported very rapidly when the smooth muscle in the wall of the vas deferens undergoes rhythmic contraction, as in sexual intercourse.

vasectomy

male sterilization; an operation to cut and tie the ducts (see vas deferens) that carry sperm from the testes to the penis. Vasectomy does not affect sexual performance, but the semen produced at ejaculation no longer contains sperm.

Some surgical attempts to reopen the duct have been successful, and some have opened spontaneously, thus making conception possible. Initially there were concerns of lower life expectancy due to increased risks of testicular or prostate cancer. However, a large-scale study in Boston in 1992 found that an increased rate of lung cancer was offset by a reduced rate of cardiovascular disease.

VDT

abbreviation for visual display terminal.

vector graphics

computer graphics that are stored in the computer memory by using geometric formulae. Vector graphics can be transformed (enlarged, rotated, stretched, and so on) without loss of picture resolution. It is also possible to select and transform any of the components of a vector-graphics display because each is separately defined in the computer memory. In these respects vector graphics are superior to raster graphics. Vector graphics are typically used for drawing applications, allowing the user to create and modify technical diagrams such as designs for houses or cars.

Vector and Bitmap Images

Go to site

Learn about the differences between the two major types of 2D graphics: scalable vector graphics and pixel-based bitmap images. Further links cover other useful information, including which format to use when, and the differences between various graphics tools.

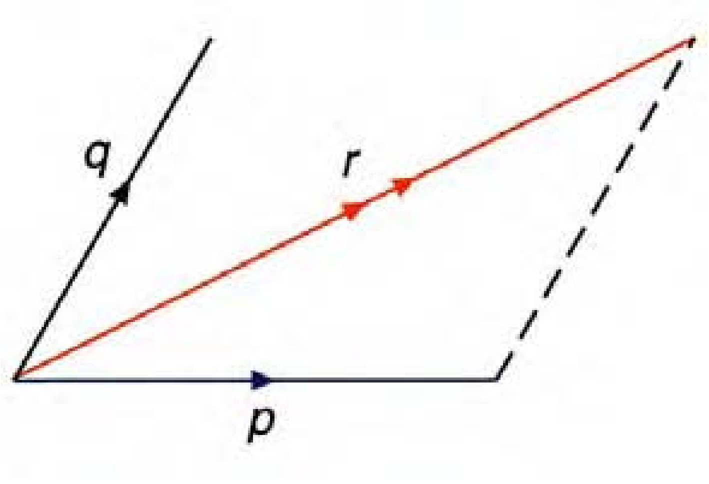
vector quantity

any physical quantity that has both magnitude (size) and direction, such as velocity, acceleration, or force, as distinct from a scalar quantity such as speed, density, or mass, which has magnitude but no direction. A vector is represented either geometrically by an arrow whose length corresponds to its magnitude and points in an appropriate direction, or by two or three numbers representing the magnitude of its components. Vectors can be added graphically by constructing a parallelogram of vectors (such as the parallelogram of forces commonly employed in physics and engineering). This will give a **resultant vector**.

The position vector of a point A(x,y) represents the move from the origin to A, that is a translation. A free vector has magnitude and direction but no fixed position in space.

If two forces p and q are acting on a body at A, then the parallelogram of forces is drawn to determine the resultant force and direction r. p, q, and r are vectors. In technical writing, a vector is denoted by **bold** type, underlined, or overlined.

vector quantity



(Image © Research Machines plc)

A parallelogram of vectors. Vectors can be added graphically using the parallelogram rule. According to the rule, the sum of vectors *p* and *q* is the vector *r* which is the diagonal of the parallelogram with sides *p* and *q*.

Vega

or Alpha Lyrae

brightest star in the constellation Lyra and the fifth-brightest star in the night sky. It is a blue-white star, about 25 light years from the Sun, with a true luminosity 50 times that of the Sun.

In 1983 the Infrared Astronomy Satellite (IRAS) discovered a ring of dust around Vega, possibly a disc from which a planetary system is forming.

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vegetation

plant life of a particular area, such as shrubs, trees, and grasses. The type of vegetation depends on the soil, which may become impoverished by deforestation; climate, especially the amount of moisture available and the possibility of frost, since these factors influence the types of vegetation that can survive; and human activity, such as overgrazing or the destruction of grasslands.

---

vegetative reproduction

type of asexual reproduction in plants that relies not on spores, but on multicellular structures formed by the parent plant. Some of the main types are stolons and runners, gemmae, bulbils, sucker shoots produced from roots (such as in the creeping thistle *Cirsium arvense*), tubers, bulbs, corms, and rhizomes. Vegetative reproduction has long been exploited in horticulture and agriculture, with various methods employed to multiply stocks of plants. See also plant propagation.

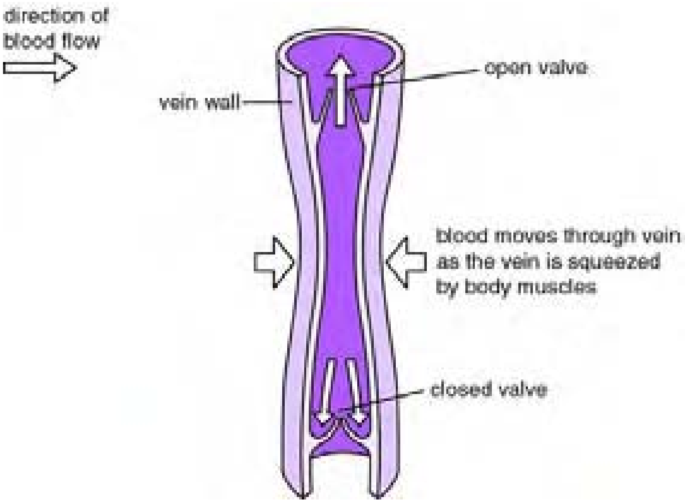
---

vein

vessel that carries blood from the body to the heart in animals with a circulatory system. Veins contain valves that prevent the blood from running back when moving against gravity. They carry blood at low pressure, so their walls are thinner than those of arteries. They always carry deoxygenated blood, with the exception of the pulmonary vein, leading from the lungs to the heart in birds and mammals, which carries newly oxygenated blood.

The term is also used more loosely for any system of channels that strengthens living tissues and supplies them with nutrients - for example, leaf veins (see vascular bundle), and the veins in insects' wings. In leaves they make up the network that can normally be seen, especially from the underside of the leaf. These veins are made up of the two transport tissues of a plant, xylem and phloem.

vein


direction of blood flow
open valve
vein wall
blood moves through vein as the vein is squeezed by body muscles
closed valve

(Image © Research Machines plc)

The structure of a vein, showing how the valves prevent blood from flowing backwards.

Vela

bright constellation of the southern hemisphere near Carina, represented as the sails of a ship. It contains large wisps of gas – called the Gum nebula after its discoverer, the Australian astronomer Colin Gum (1924–1960) – believed to be the remains of one or more supernovae. Vela also contains the second optical pulsar (a pulsar that flashes at a visible wavelength) to be discovered.

Vela was originally regarded as part of Argo. Its four brightest stars are second-magnitude, one of them being Suhail, about 490 light years from Earth.

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veldt

subtropical grassland in South Africa, equivalent to the Pampas of South America.

---

velocity

symbol v

speed of an object in a given direction, or how fast an object changes its position in a given direction. Velocity is a vector quantity, since its direction is important as well as its magnitude (or speed). For example, a car could have a speed of 48 kph/30 mph and a velocity of 48 kph/30 mph northwards. Velocity = change in position/time taken.

The velocity at any instant of a particle travelling in a curved path is in the direction of the tangent to the path at the instant considered. The velocity v of an object travelling in a fixed direction may be calculated by dividing the distance s it has travelled by the time t taken to do so, and may be expressed as: $v = s/t$

---

vena cava

either of the two great veins of the trunk, returning deoxygenated blood to the right atrium of the heart. The **superior vena cava**, beginning where the arches of the two innominate veins join high in the chest, receives blood from the head, neck, chest, and arms; the **inferior vena cava**, arising from the junction of the right and left common iliac veins, receives blood from all parts of the body below the diaphragm.

---

venereal disease

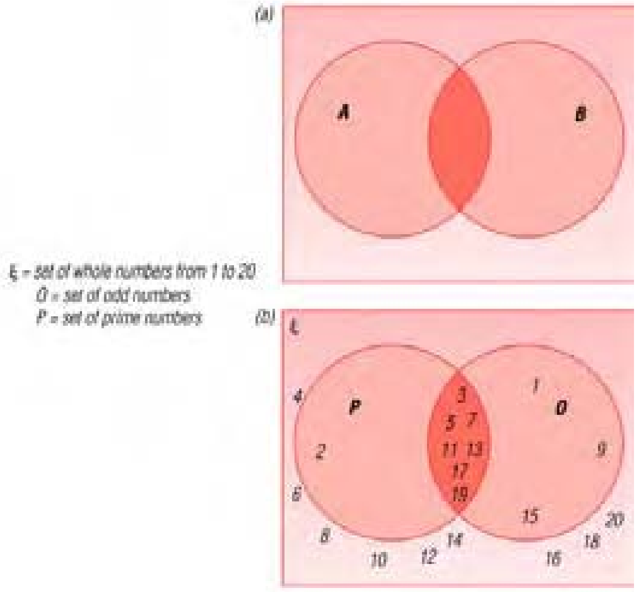
VD

any disease mainly transmitted by sexual contact, although commonly the term is used specifically for gonorrhoea and syphilis, both occurring worldwide, and chancroid ('soft sore') and lymphogranuloma venerum, seen mostly in the tropics. The term **sexually transmitted disease** (STD) is more often used to encompass a growing list of conditions passed on primarily, but not exclusively, by sexual contact.

Venn diagram

in mathematics, a diagram representing a set or sets and the logical relationships between them. The sets are drawn as circles. An area of overlap between two circles (sets) contains elements that are common to both sets, and thus represents a third set. Circles that do not overlap represent sets with no elements in common (disjoint sets). The method is named after the English logician John Venn.

Venn diagram



(Image © Research Machines plc)

Sets and their relationships are often represented by Venn diagrams. The sets are drawn as circles – the area of overlap between the circles shows elements that are common to each set, and thus represent a third set. (Top) A Venn diagram of two intersecting sets and (bottom) a Venn diagram showing the set of whole numbers from 1 to 20 and the subsets P and O of prime and odd numbers, respectively. The intersection of P and O contains all the prime numbers that are also odd.

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ventilation

alternative term for breathing.

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ventral surface

front of an animal. In vertebrates, the side furthest from the backbone; in invertebrates, the side closest to the ground. The positioning of the main nerve pathways on the ventral side is a characteristic of invertebrates.

---

ventricle

in zoology, either of the two lower chambers of the heart that force blood to circulate by contraction of their muscular walls. The term also refers to any of four cavities within the brain in which cerebrospinal fluid is produced.

Ventris, Michael George Francis (1922-1956)

English architect. Deciphering Minoan Linear B, the language of the tablets found at Knossos and Pylos, he showed that it was a very early form of Greek, thus revising existing views on early Greek history.

Venturi tube

device for measuring the rate of fluid flow through a pipe. It consists of a tube with a constriction (narrowing) in the middle of its length. The constriction causes a drop in pressure in the fluid flowing in the pipe. A pressure gauge attached to the constriction measures the pressure drop and this is used to find the rate of fluid flow.

Venturi tubes are also used in the carburettor of a motor car to draw petrol into the engine.

Venus

second planet from the Sun. It can approach Earth to within 38 million km/24 million mi, closer than any other planet. Its mass is 0.82 that of Earth. Venus rotates on its axis more slowly than any other planet, from east to west, the opposite direction to the other planets (except Uranus and Pluto).

mean distance from the Sun

108.2 million km/67.2 million mi

equatorial diameter

12,100 km/7,500 mi

rotation period

243 Earth days

year

225 Earth days

atmosphere

Venus is shrouded by clouds of sulphuric acid droplets that sweep across the planet from east to west every four days. The atmosphere is almost entirely carbon dioxide, with an atmospheric pressure of 90 times that at the surface of the Earth. The gas traps the Sun's heat by the greenhouse effect and raises the planet's surface temperature to 480°C/900°F

surface

consists mainly of silicate rock and may have an interior structure similar to that of Earth: an iron-nickel core, a mantle composed of more mafic rocks (rocks made of one or more ferromagnesian, dark-coloured minerals), and a thin siliceous outer crust. The surface is dotted with deep impact craters. Some of Venus's volcanoes may still be active

satellites

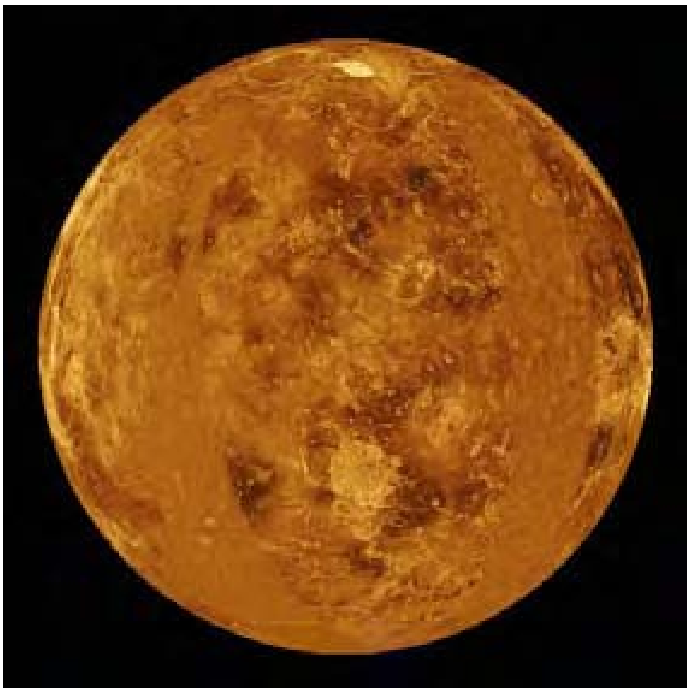
no moons

The first artificial object to hit another planet was the Soviet probe Venera 3, which crashed on Venus on 1 March 1966. Later Venera probes parachuted down through the atmosphere and landed successfully on its surface, analysing surface material and sending back information and pictures. In December 1978, NASA's Pioneer Venus probe went into orbit around the planet and mapped most of its surface by radar, which penetrates clouds. During four years from August 1990 the US space probe Magellan mapped 99% of the planet's surface to a resolution of 100 m/330 ft. The European Space Agency plans a mapping mission called the Venus Express, to begin in 2006 and last about 17 months.

The largest highland area is Aphrodite Terra near the equator, half the size of Africa. The highest mountains are on the northern highland region of Ishtar Terra, where the massif of Maxwell Montes rises to 10,600 m/35,000 ft above the average surface level. The highland areas on Venus were formed by volcanoes.

Venus has an ion-packed tail 45 million km/28 million mi in length that stretches away from the Sun and is caused by the bombardment of the ions in Venus's upper atmosphere by the solar wind. It was first discovered in the late 1970s but it was not until 1997 that the Solar Heliospheric Observatory revealed its immense length.

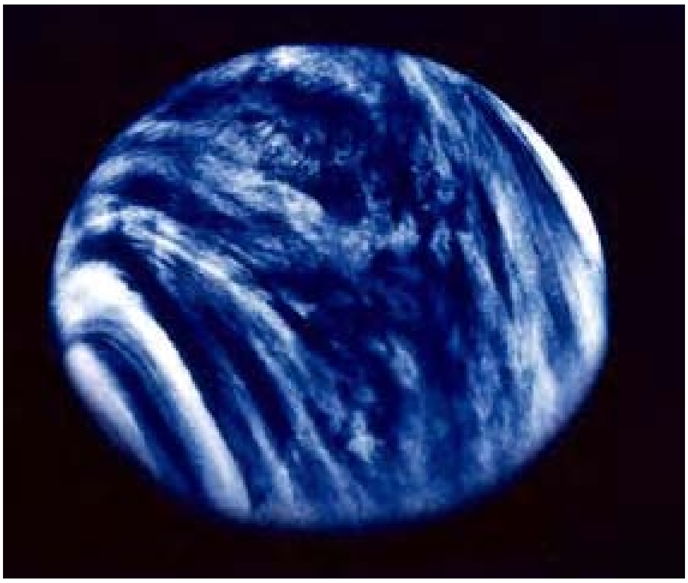
Venus



(Image © NASA)

Global view of Venus compiled from images acquired with the synthetic aperture radar carried by the Magellan spacecraft, with data gaps filled using earlier Pioneer Venus data. The image, centered on 0° longitude, shows the wide variety of exotic landforms discovered on Venus.

Venus



(Image © NASA)

Venus, the planet nearest to Earth, photographed from the Mariner 10 space probe in 1974. When the Sun was cooler Venus may have had oceans and life may have appeared, but as the Sun grew hotter the planet's surface became scorched and covered by dense clouds of carbon dioxide.

Magellan Images

Go to site

Library of images of Venus from NASA's Magellan Project home page. Each image has a full explanation of the subject matter.

Venus Introduction

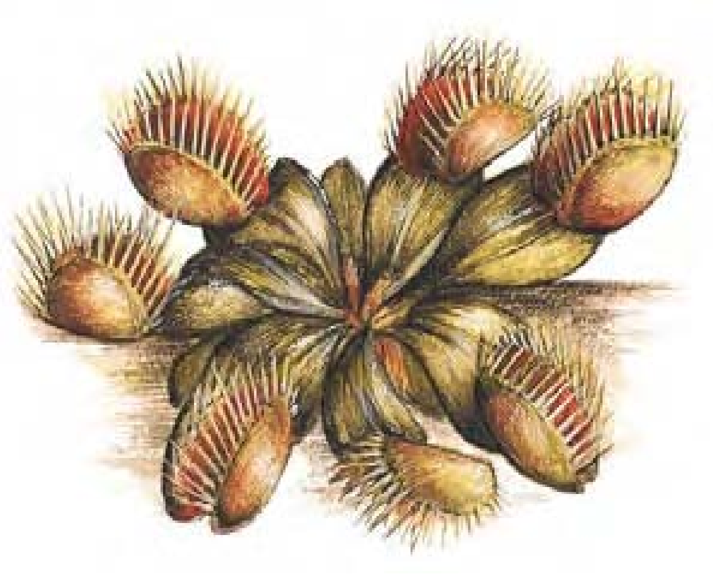
Go to site

All you ever wanted to know about the planet Venus can be found at this site, which includes a table of statistics, photographs of the planet, animations, information about its volcanic features and impact craters, plus a chronology of exploration.

Venus flytrap

insectivorous plant belonging to the sundew family, native to the southeastern USA. Its leaves have two hinged surfaces that rapidly close together to trap any insect which brushes against the sensitive leaf hairs; digestive juices then break down the insect body so that it can be absorbed by the plant. (*Dionaea muscipula*, family Droseraceae.)

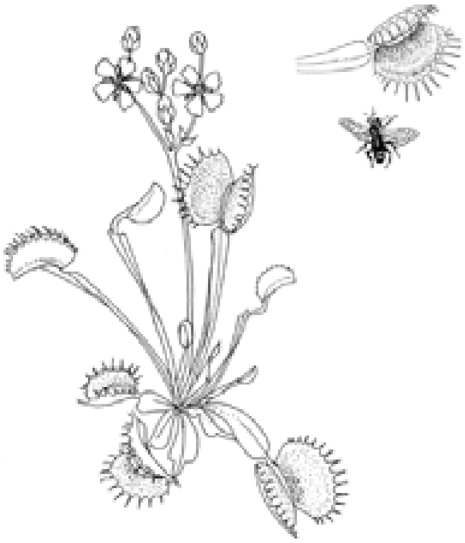
Venus flytrap



(Image © Research Machines plc)

The Venus flytrap is native to the swamp lands of Carolina. Charles Darwin described the plant as 'one of the world's most wonderful plants'. The trap is sprung when insects, attracted by the colour and nectar, touch trigger hairs on the faces of the leaves.

Venus flytrap



(Image © Research Machines plc)

Venus flytrap (*Dionaea muscipula*). The Venus flytrap is a carnivorous plant native to the bogs of the southeastern USA. It is characterized by small white flowers clustered at the end of a stem 20-30 cm/8-12 in high, and distinctive modified leaves. When an insect alights on a leaf, the two halves of the leaf snap shut and then secrete enzymes to digest the insect.

---

verbena

any of a group of plants containing about 100 species, mostly found in the American tropics. The leaves are fragrant and the tubular flowers are arranged in close spikes in colours ranging from white to rose, violet, and purple. The garden verbena is a hybrid annual. (Genus *Verbena*, family Verbenaceae.)

verdigris

green-blue coating of copper ethanoate that forms naturally on copper, bronze, and brass. It is an irritating, poisonous compound made by treating copper with ethanoic acid, and was formerly used in wood preservatives, antifouling compositions, and green paints.

verification

in computing, the process of checking that data being input to a computer have been accurately copied from a source document.

This may be done visually, by checking the original copy of the data against the copy shown on the display screen. A more thorough method is to enter the data twice, using two different keyboard operators, and then to check the two sets of input copies against each other. The checking is normally carried out by the computer itself, any differences between the two copies being reported for correction by one of the keyboard operators. Some operating systems have built-in verification.

vermilion

HgS

red form of mercuric sulphide; a scarlet that occurs naturally as the crystalline mineral cinnabar.

vernal equinox

see equinox.

vernalization

stimulation of flowering by exposure to cold. Certain plants will not flower unless subjected to low temperatures during their development. For example, winter wheat will flower in summer only if planted in the previous autumn. However, by placing partially germinated seeds in low temperatures for several days, the cold requirement can be supplied artificially, allowing the wheat to be sown in the spring.

vernier

device for taking readings on a graduated scale to a fraction of a division. It consists of a short divided scale that carries an index or pointer and is slid along a main scale. It was invented by French engineer Pierre Vernier.

verruca

growth on the skin; see wart.

vertebra

in anatomy, an irregularly shaped bone that forms part of the vertebral column. Children have 33 vertebrae, 5 of which fuse in adults to form the sacrum and 4 to form the coccyx. There are 7 cervical vertebrae in the neck, 12 thoracic vertebrae in the thorax with the ribs attached, and 5 lumbar vertebrae in the lower back.

vertebral column

backbone, giving support to an animal and protecting its spinal cord. It is made up of a series of bones or vertebrae running from the skull to the tail, with a central canal containing the nerve fibres of the spinal cord.

In tetrapods the vertebrae show some specialization with the shape of the bones varying according to position. In the chest region the upper or thoracic vertebrae are shaped to form connections to the ribs. The backbone is only slightly flexible to give adequate rigidity to the animal structure.

vertebrate

any animal with a backbone. The 41,000 species of vertebrates include mammals, birds, reptiles, amphibians, and fishes. They include most of the larger animals, but in terms of numbers of species are only a tiny proportion of the world's animals. The zoological taxonomic group Vertebrata is a subgroup of the phylum Chordata.

In 2003, palaeontologists in Australia reported the discovery of the world's earliest vertebrate. Discovered in the Flingers Ranges of South Australia, the 66-cm/26-in fishlike fossil was dated to at least 560 million years old, around 30 million years older than previously thought for a vertebrate fossil. Prior to this find, a giant fossil conodont (an eel-like organism from the Cambrian period), discovered in South Africa in 1995, was thought to be one of the first vertebrates; conodonts evolved 520 million years ago, pre-dating the earliest fish by about 50 million years.

vertebrate

The amphibian genus *Eleutherodactylus* is the largest vertebrate genus, with more than 500 species.

Major invertebrate and vertebrate groups

Phyla are listed in the order traditionally considered to be from the most primitive to the most advanced.

Taxon[1]	Name	Examples
Invertebrates		
P	Porifera	all sponges
P	Cnidaria	corals, sea anemones, *Hydra*, jellyfishes
P	Ctenophora	sea gooseberries, comb jellies
P	Platyhelminthes	flatworms, flukes, tapeworms
P	Nemertina	nemertine worms, ribbon worms
P	Rotifera	rotifers or wheel animals
P	Nematoda	roundworms
P	Ectoprocta	ectoprocts
P	Mollusca	clams, oysters, snails, slugs, octopuses, squids, cuttlefish
P	Annelida	ringed worms, including lugworms, earthworms, and leeches
P	Arthropoda	(subdivided into classes below)
C	Arachnida	spiders, ticks, scorpions, mites
C	Branchiopoda	water fleas
C	Cirripedia	barnacles
C	Malacostraca	crabs, lobsters, shrimp, woodlice
C	Diplopoda	millipedes
C	Chilopoda	centipedes
C	Insecta	silverfish, dragonflies, mayflies, stoneflies, cockroaches, earwigs, web spinners, termites, booklice, lice, grasshoppers, thrips, lace-wings, scorpion flies, caddis-flies, moths, butterflies, beetles, house flies, fleas, stylopids, ants, bees
P	Echinodermata	sea stars, brittle stars, sea urchins, sand dollars, sea cucumbers
P	Hemichordata	acorn worms, pterobranchs, graptolites
Vertebrates		
Taxon[1]	**Name**	**Examples**
C	Agnatha	(jawless fishes) lampreys, hagfishes
C	Chondricthyes	(cartilaginous fishes) dogfishes, sharks, rays, skates
C	Osteichthyes	(bony fishes) sturgeons, eels, herrings, salmon, carps, catfishes, perches, flatfishes including flounder and halibut
C	Amphibia	caecilians, salamanders, newts, toads, frogs
C	Reptilia	turtles, tortoises, tuatara, lizards, snakes, crocodiles
C	Aves	ostriches, rheas, penguins, divers, pelicans, flamingoes, ducks, falcons, pheasants, cranes, gulls, pigeons, parrots, cuckoos, owls, swifts, kingfishers, sparrows
C	Mammalia	platypus, echidnas, kangaroos, opossums, shrews, bats, rats, anteaters, rabbits, dogs, whales, elephants, manatees, horses, tapirs, camels, pigs, lemurs, monkeys, humans

[1] P represents phylum; C represents class.

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vertex

plural vertices

in geometry, a point shared by three or more sides of a solid figure; the point farthest from a figure's base; or the point of intersection of two sides of a plane figure or the two rays of an angle.

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vertical takeoff and landing craft

VTOL

aircraft that can take off and land vertically. Helicopters, airships, and balloons can do this, as can a few fixed-wing aeroplanes, like the convertiplane.

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vertigo

dizziness; a whirling sensation accompanied by a loss of any feeling of contact with the ground. It may be due to temporary disturbance of the sense of balance (as in spinning for too long on one spot), psychological reasons, disease such as labyrinthitis, or intoxication.

Very Large Array

VLA

largest and most complex single-site radio telescope in the world. It is located on the Plains of San Augustine, 80 km/50 mi west of Socorro, New Mexico. It consists of 27 dish antennae, each 25 m/82 ft in diameter, arranged along three equally spaced arms forming a Y-shaped array. Two of the arms are 21 km/13 mi long, and the third, to the north, is 19 km/11.8 mi long. The dishes are mounted on railway tracks enabling the configuration and size of the array to be altered as required.

Pairs of dishes can also be used as separate interferometers (see interferometry), each dish having its own individual receivers that are remotely controlled, enabling many different frequencies to be studied. There are four standard configurations of antennae ranging from A (the most extended) through B and C to D. In the A configuration the antennae are spread out along the full extent of the arms and the VLA can map small, intense radio sources with high resolution. The smallest configuration, D, uses arms that are just 0.6 km/0.4 mi long for mapping larger sources. Here the resolution is lower, although there is greater sensitivity to fainter, extended fields of radio emission.

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very long-baseline array

VLBA

in astronomy, group of ten 25-m/82-ft radio telescopes spread across North America and Hawaii that operate as a single instrument using the technique of very long-baseline interferometry to obtain high-resolution images. The longest baseline (distance between pairs of telescopes) is about 8,000 km/4,970 mi. The first observation using all ten sites occurred 29 May 1993.The total construction cost was over US$85 million.

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very long-baseline interferometry

VLBI

in radio astronomy, a method of obtaining high-resolution images of astronomical objects by combining simultaneous observations made by two or more radio telescopes thousands of kilometres apart.

Vesalius, Andreas (1514-1564)

Belgian physician who revolutionized anatomy by performing postmortem dissections and making use of illustrations to teach anatomy. Vesalius upset the authority of Galen, and his book - the first real textbook of anatomy - marked the beginning of biology as a science.

Vesalius was taught anatomy in the Galenist tradition. Galen had never dissected a human body - all his accounts of the human anatomy were based on his research of the Barbary ape - although he was regarded as infallible and was venerated until the Renaissance. Vesalius was therefore taught principles of anatomy that had not been questioned for 1,300 years.

Dissatisfied with the instruction he had received, Vesalius resolved to make his own observations. His dissections of the human body (then illegal) enabled him to discover that Galen's system of medicine was based on fundamental anatomical errors. Vesalius disproved the widely held belief that men had one rib less than women. He also believed, contrary to Aristotle's theory of the heart being the centre of the mind and emotion, that the brain and the nervous system were the centre.

Vesalius's book *De humani corporis fabrica/On the Structure of the Human Body* of 1543 employed talented artists to provide the illustrations and is one of the great books of the 16th century. The quality of anatomical depiction introduced a new standard into all illustrated works, especially into medical books, and highlighted the need to introduce scientific method into the study of anatomy. Together with the main work of astronomer Copernicus, published in the same year, *On the Structure of the Human Body* marked the dawn of modern science.

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vestigial organ

in biology, an organ that remains in diminished form after it has ceased to have any significant function in the adult organism. In humans, the appendix is vestigial, having once had a digestive function in our ancestors.

Vesuvio

Italian name for Vesuvius, an active volcano in Campania, Italy.

Vesuvius

Italian Vesuvio

active volcano in Campania, Italy, 15 km/9 mi southeast of Naples, Italy; height 1,277 m/4,190 ft (1969; the height of the main cone changes with each eruption). In AD 79 it destroyed the cities of Pompeii, Herculaneum, and Stabiae. It is the only active volcano on the European mainland.

Vesuvius is a composite volcano at the **convergent plate margin** where the African plate is subducting beneath the Eurasian plate. Its lava is andesite in composition and consequently very viscous, giving rise to explosive eruptions. Vesuvius is comprised of two cones. Monte Somma (1,277 m/4,190 ft), the remnant of a massive wall which once enclosed a huge cone in prehistoric times, is now a semicircular girdle of cliff to the north and east, separated from the main eruptive cone by the valley of Atrio di Cavallo. Layers of lava, scoriae, ashes, and pumice make up the mountain.

The surprising fertility of the volcano's slopes, especially for the cultivation of grapes and production of 'Lacrimae Christi' wine, explains why the environs of Vesuvius remain densely populated in spite of the constant threat of eruption.

eruptions

The eruption on 24 August AD 79 ended a dormant period so long that the volcano had been presumed extinct. This, the earliest recorded eruption, buried Pompeii, Herculaneum, and Stabiae under ashes and mud, and was described by Pliny the Younger. During the eruptions of 472 and 1631 particles of dust are said to have landed in Constantinople (modern Istanbul). Other years of great activity were 1794, 1822, 1855, 1871, 1906, 1929, and 1944. There has been no eruption since 1944.

Vesuvius, Italy

Go to site

Site examining the complex geology of Vesuvius and its famous eruption of AD 79. There are images of the volcano and historical drawings. There is also a link to a local site campaigning for an improved civil defence plan as the volcano prepares once more to explode.

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vetch

any of a group of trailing or climbing plants belonging to the pea family, usually having seed pods and purple, yellow, or white flowers, and including the fodder crop alfalfa (*Medicago sativa*). (Several genera, especially *Vicia*, family Leguminosae.)

VHF

abbreviation for very high frequency

referring to radio waves that have very short wavelengths (10 m-1 m). They are used for interference-free FM transmissions. VHF transmitters have a relatively short range, producing frequencies in the 30-300 MHz band.

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viburnum

any of a group of small trees or shrubs belonging to the honeysuckle family, found in temperate and subtropical regions, including the wayfaring tree, the laurustinus, and the guelder rose of Europe and Asia, and the North American blackhaws and arrowwoods. (Genus *Viburnum*, family Caprifoliaceae.)

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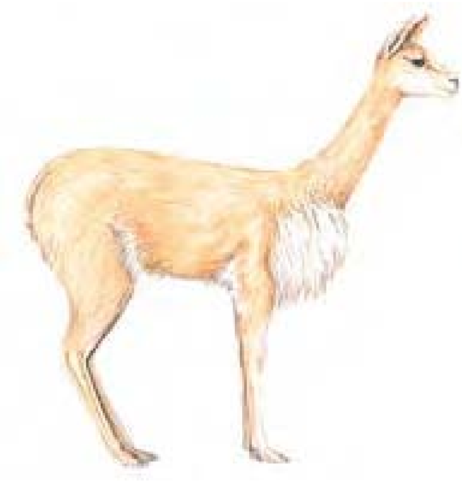
vicuna

ruminant mammal *Lama vicugna* of the camel family that lives in herds on the Andean plateau. It can run at speeds of 50 kph/30 mph. It has good eyesight, fair hearing, and a poor sense of smell. Hunted close to extinction for its meat and soft brown fur, which was used in textile manufacture, the vicuna is now a protected species. Its populations are increasing thanks to strict conservation measures; by 1996 they had reached 100,000-200,000. The vicuna is listed on CITES Appendix 2 (vulnerable).

It is related to the alpaca, the guanaco, and the llama.

vicuna



(Image © Research Machines plc)

The vicuna lives in small herds of 6–12 females with a lone male. The male keeps watch, uttering a shrill whistle at the least sign of danger, and acts to protect the retreating herd.

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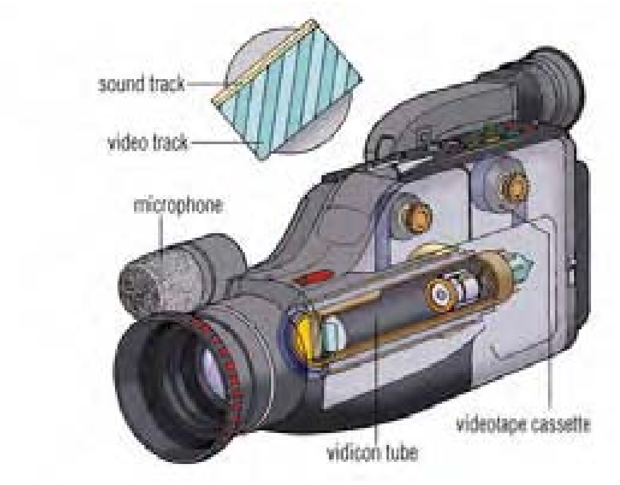
video camera

or camcorder

portable television camera that records moving pictures electronically on magnetic tape. It produces an electrical output signal corresponding to rapid line-by-line scanning of the field of view. The output is recorded on video cassette and is played back on a television screen via a video cassette recorder. From the mid 1990s, these machines began to be replaced by digital versions which store images on memory cards. The images can be downloaded onto computers or transferred to DVDs.

video camera



(Image © Research Machines plc)

The heart of the video camera is the vidicon tube which converts light entering the front lens to an electrical signal. An image is formed on a light-sensitive surface at the front of the tube. The image is then scanned by an electron beam, to give an output signal corresponding to the image brightness. The signal is recorded as a magnetic track traversing the tape diagonally. The sound track, which records the sounds picked up by the microphone, runs along the edge of the tape.

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video cassette recorder

VCR

device for recording pictures and sound on cassettes or spools of magnetic tape. The first commercial VCR was launched 1956 for the television broadcasting industry, but from the late 1970s cheaper models were developed for home use, to record broadcast programs for future viewing and to view rented or owned video cassettes of commercial films. VCRs are giving way to DVD recorders.

Video recording works in the same way as audio tape recording: the picture information is stored as a line of varying magnetism, or track, on a plastic tape covered with magnetic material. The main difficulty – the huge amount of information needed to reproduce a picture – is overcome by arranging the video track diagonally across the tape. During recording, the tape is wrapped around a drum in a spiral fashion. The recording head rotates inside the drum. The combination of the forward motion of the tape and the rotation of the head produces a diagonal track. The audio signal accompanying the video signal is recorded as a separate track along the edge of the tape.

Two video cassette systems were introduced by Japanese firms in the 1970s, but the Betamax standard was first introduced in 1965. The Sony Betamax was considered technically superior, but Matsushita's VHS had larger marketing resources behind it and after some years became the sole system on the market. Super-VHS is an improved version of the VHS system, launched in 1989, with higher picture definition and color quality.

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video disc

term, little used now, referring to a disc with pictures and sounds recorded on it, played back by laser. The DVD is a type of video disc.

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video game

electronic game played on a visual-display screen or, by means of special additional or built-in components, on the screen of a television set. The first commercially sold was a simple bat-and-ball game developed in the USA in 1972.

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videotape recorder

VTR

device for recording on and playing back video cassettes; see video cassette recorder.

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videotex

or videotext

any of various systems in which information (text) is displayed on a television (video) screen. There are two basic systems. In one, information is broadcast using the standard television signals; in the other, information is relayed to the screen from a central data bank via the telephone network. Both systems require the use of a television receiver with decoding device.

Videotex systems under the names of Ceefax and Prestel are a standard addition to television sets in the United Kingdom. No additional box was needed by the viewer: data were transmitted as part of the TV signal. The French videotex system was called Minitel, and required a box that was issued to all users, in order to supersede printed telephone directories (though many additional services were offered via Minitel).

In the United States a number of commercial videotex services were offered from 1982. They used additional hardware and required the use of a phone line; they quickly failed.

Viking

either of two US space probes to the planet Mars, each one consisting of an orbiter and a lander. They were launched on 20 August and 9 September 1975, and transmitted colour pictures and analysed the planet's soil.

Viking 1 carried life-detection laboratories and touched down on 20 July 1976 in the Chryse lowland area. Designed to work for 90 days, the craft operated for 6.5 years, losing contact with Earth in November 1982. No definite signs of life were found. *Viking 2* landed in Utopia on 3 September 1976 and functioned for 3.5 years.

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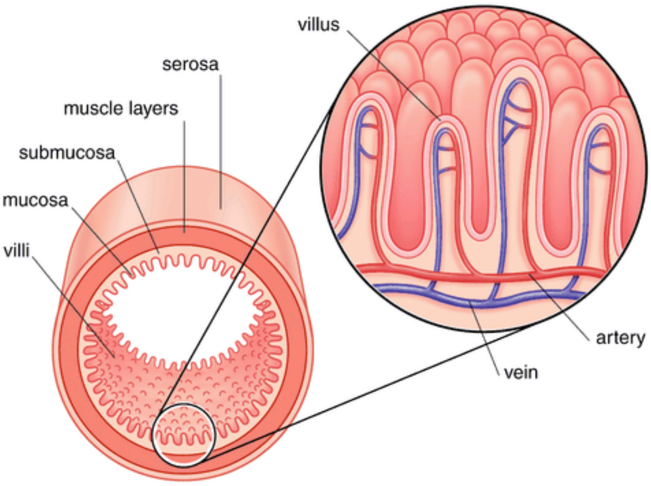
villus

plural villi

small fingerlike projection extending into the interior of the small intestine and increasing the absorptive area of the intestinal wall. Digested nutrients, including sugars and amino acids, pass into the villi and are carried away by the circulating blood.

villus



(Image © Research Machines plc)

Cross section of the small intestine showing the villi and their blood supply. There are hundreds of villi for every square millimetre of the small intestine (itself 5 m/16 ft in length).

vincristine

alkaloid extracted from the blue periwinkle plant *Vinca rosea*. Developed as an anticancer agent, it has revolutionized the treatment of childhood acute leukaemias; it is also included in chemotherapy regimens for some lymphomas (cancers arising in the lymph tissues) and lung and breast cancers. Side effects, such as nerve damage and loss of hair, are severe but usually reversible.

vine

or grapevine

any of a group of climbing woody plants, especially *V. vinifera*, native to Asia Minor and cultivated from antiquity. The fruits (grapes) are eaten or made into wine or other fermented drinks; dried fruits of certain varieties are known as raisins and currants. Many other species of climbing plant are also called vines. (Genus *Vitis*, family Vitaceae.)

violet

plant of the genus *Viola*, family Violaceae, with toothed leaves and mauve, blue, or white flowers, such as the Canada violet *V. canadensis* and primrose violet *V. primulifolia* of North America and the sweet violet *V. odorata* of Europe. The pansy is also a kind of violet.

viper

any front-fanged venomous snake of the family Viperidae. Vipers range in size from 30 cm/1 ft to 3 m/10 ft, and often have diamond or jagged markings. Most give birth to live young.

There are 150 species of viper. The true vipers, subfamily Viperinae, abundant in Africa and southwestern Asia, include the adder*Vipera berus*, the African puff adder *Bitis arietans*, and the horned viper of North Africa *Cerastes cornutus*. The second subfamily Crotalinae includes the mostly New World pit vipers, such as rattlesnakes and copperheads of the Americas, which have a heat-sensitive pit between each eye and nostril.

Virginia creeper

or woodbine

eastern North American climbing vine belonging to the grape family, having tendrils, palmately compound leaves (made up of leaflets arranged like an open hand), green flower clusters, and blue berries eaten by many birds but inedible to humans. (*Parthenocissus quinquefolia*, family Vitaceae.)

Virginia Creeper

Go to site

Description of the plant together with information on its herbal properties, which parts are used, its constituents, and its medicinal action and uses.

Virgo

zodiacal constellation of the northern hemisphere, the second-largest in the sky. It is represented as a maiden holding an ear of wheat, marked by first-magnitude Spica, Virgo's brightest star. The Sun passes through Virgo from late September to the end of October. In astrology, the dates for Virgo are between about 23 August and 22 September (see precession).

Virgo contains the nearest large cluster of galaxies to us, 50 million light years away, consisting of about 3,000 galaxies centred on the giant elliptical galaxy M87. Also in Virgo is the nearest quasar, 3C 273, an estimated 3 billion light years away.

Virtanen, Artturi Ilmari (1895-1973)

Finnish chemist who was awarded the Nobel Prize for Chemistry in 1945 for his discoveries from 1920 in agricultural chemistry. Because green fodder tends to ferment and produce a variety of harmful acids, it cannot be preserved for long. Virtanen prevented the process from starting by acidifying the fodder. In this form it lasted longer and remained nutritious.

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virtual

in computing, without physical existence. Most computers have virtual memory, making their immediate-access memory seem larger than it is. Virtual reality is a computer simulation of a whole physical environment.

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virtual memory

in computing, a technique whereby a portion of the computer backing storage, or external, memory is used as an extension of its immediate-access, or internal, memory. The contents of an area of the immediate-access memory are stored on, say, a hard disk while they are not needed, and brought back into main memory when required.

The process, called **paging** or **segmentation**, is controlled by the computer operating system and is hidden from the programmer, to whom the computer's internal memory appears larger than it really is. The technique can be successfully implemented only if very fast backing store is available, so that 'pages' of memory can be rapidly switched into and out of the immediate-access memory.

---

virtual reality

advanced form of computer simulation, in which a participant has the illusion of being part of an artificial environment. The participant views the environment through two tiny television screens (one for each eye) built into a visor. Sensors detect movements of the participant's head or body, causing the apparent viewing position to change. Gloves (datagloves) fitted with sensors may be worn, which allow the participant seemingly to pick up and move objects in the environment.

The technology is still under development but is expected to have widespread applications; for example, in military and surgical training, architecture, and home entertainment.

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virus

in computing, a piece of software that can replicate and transfer itself from one computer to another, without the user being aware of it. Some viruses are relatively harmless, but others can damage or destroy data. The earliest was the Brain virus, written in Pakistan in 1986.

Viruses are written by anonymous programmers, often maliciously, and are spread on floppy disks, CD-ROMs, and via networks and e-mail attachments. Viruses may be programmed to operate on a particular date. Most viruses hide in the boot sectors of floppy or hard disks or infect program files, but since 1995, there have also been macro viruses that infect Microsoft Word or Excel. The first of these were the Concept virus (infecting Word files) and the Laroux virus (infecting Excel).

Antivirus software can be used to detect and destroy well-known viruses, but new viruses continually appear and these may bypass existing antivirus programs.

In 1999, the Melissa virus caused an estimated US$80 million worth of damage, with LoveBug causing US$7 billion worth and affecting about 45 million computers the following year. In 2003, Slammer caused cash machines to crash and delayed airline flights, while SoBig and Blaster exploited weaknesses in the Windows 2000 and NT operating systems. Most of the latest viruses, such as MyDoom and Netsky in 2004, are actually worms, which replicate themselves over the Internet.

A recent ploy is to use 'social engineering' (such as the pretence of the message having come from a reputable company, or to be reporting a failed attempt to send an e-mail) to trick the recipient into opening the attachment containing the malicious code.

CERT Coordination Center

Go to site

Site tracking and summarizing problems with the Internet, such as virus activity, scans, probes, and attacks. Based at the Carnegie Mellon University in the USA, the CERT Coordination Center studies vulnerabilities in Internet systems, publishes security alerts, and offers advice and training for those looking to improve security on their Web sites. Find out which viruses are active now, and take steps to prevent such viruses from damaging a site.

Dr Solomon's All About Viruses

Go to site

Informative guide to viruses. The pages take the user through what a virus is and what to do if a computer gets one. It differentiates viruses from other programs, such as trojans, bugs, and jokes, and then goes on to detail the different types of virus that exist. It is all presented in clear and straightforward language.

Vmyths.com

Go to site

Avoid falling for computer virus hoaxes by checking suspects at this hysteria-free site. Written and maintained by a former computer security expert, this site provides detailed and up-to-date information about current hoax virus alerts as well as genuine viruses.

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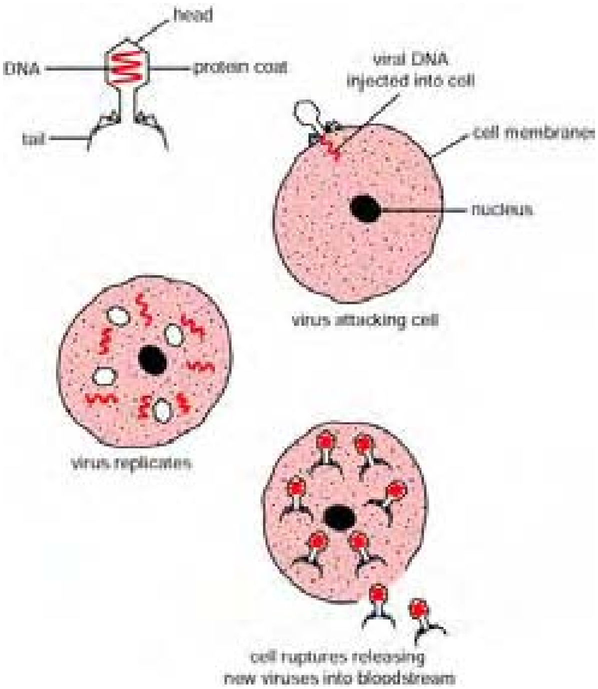
virus

infectious particle consisting of a core of nucleic acid (DNA or RNA) enclosed in a protein shell. They are extremely small and cause disease. They differ from all other forms of life in that they are not cells – they are acellular. They are able to function and reproduce only if they can invade a living cell to use the cell's system to replicate themselves. In the process they may disrupt or alter the host cell's own DNA. They use the cell they invade to make more virus particles that are then released. This usually kills the cell. The healthy human body reacts by producing an antiviral protein, interferon, which prevents the infection spreading to adjacent cells. There are around 5,000 species of virus known to science (1998), although there may be as many as half a million actually in existence.

Examples of diseases in humans caused by viruses are the common cold, chickenpox, influenza, AIDS, herpes, mumps, measles, and rubella. Recent evidence implicates viruses in the development of some forms of cancer (see oncogenes). Antibiotics do not work against viruses. The best protection against diseases caused by viruses is immunization.

Viruses can change by mutation. When they do so, a human body is sometimes unable to fight the new virus very well. This happens regularly with the influenza virus. A small change results in a small influenza epidemic, but a big change results in a pandemic that can kill millions of people worldwide. Many viruses mutate continuously so that the host's body has little chance of developing permanent resistance; others transfer between species, with the new host similarly unable to develop resistance. The viruses that cause AIDS and Lassa fever are both thought to have 'jumped' to humans from other mammalian hosts.

virus


head
DNA
protein coat
tail
viral DNA injected into cell
cell membrane
nucleus
virus attacking cell
virus replicates
cell ruptures releasing new viruses into bloodstream

(Image © Research Machines plc)

How a virus replicates itself to spread infection through the body.

Hidden Killers

Go to site

Viruses are exposed in all their 'villainy' in this sophisticated and dramatic Web site. An excellent and detailed guide to the basic facts on viruses is presented alongside further pages explaining the lethal potential of these micro-organisms and the dangers of their use as weapons.

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viscacha

Argentine Pampas and scrubland-dwelling rodent *Lagostomus maximus* of the chinchilla family. It is up to 70 cm/2.2 ft long with a 20 cm/8 in tail, and weighs 7 kg/15 lb. It is grey and black and has a large head and small ears. Viscachas live in warrens of up to 30 individuals. They are usually nocturnal and feed on grasses, roots, and seeds.

Four species of **Mountain viscachas** genus *Lagidium*, also called Peruvian hares, are smaller and have long ears and tails and are found in rocky places feeding by day on sparse vegetation.

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viscera

general term for the organs contained in the chest and abdominal cavities.

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viscose

yellowish, syrupy solution made by treating cellulose with sodium hydroxide and carbon disulphide or with cuprammonium liquor and sodium hydroxide. The solution is then regenerated as continuous filament (rayon) by forcing it through very small holes and solidifying it (in a process known as spinning). Forcing viscose through a slit instead of small holes produces cellophane.

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viscosity

the resistance of a fluid to flow, caused by its internal friction, which makes it resist flowing past a solid surface or other layers of the fluid. Treacle and other thick, sticky liquids are highly viscous liquids. Water and petrol are runny liquids and have low viscosity.

The term viscosity applies to the motion of an object moving through a fluid as well as the motion of a fluid passing by an object. For the purposes of calculation, many fluids in physics are considered to be perfect, or nonviscous.

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vision

ability or act of seeing. Light that enters the eye is focused by the eye lens, creating a sharp image on the retina. Electrical signals from the retina travel down the optic nerve where they are interpreted by the brain.

In humans, the image of an object created by each of our eyes is slightly different because our eyes are in different positions. The brain combines the two images to give a sense of depth. This is known as **binocular vision**. With one eye closed we lose some of our sense of depth and perspective.

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vision defect

any abnormality of the eye that causes less-than-perfect sight. Common defects are short-sightedness or myopia; long-sightedness or hypermetropia; lack of accommodation or presbyopia; and astigmatism. Other eye defects include color blindness.

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visual display terminal

computer terminal consisting of a keyboard for input data and a screen for displaying output. The oldest and the most popular type of VDT screen is the cathode-ray tube (CRT), which uses essentially the same technology as a television screen. Other types use plasma display technology and liquid-crystal displays.

Screen resolution (the quality of the display) is dependent on the number of pixels used; the smaller the pixel, the higher the resolution. Within the limits of the resolution supported by the screen itself, the display quality can be altered by the user to suit particular applications.

In the same way, the number of **screen colours** supported by a VDT can be selected by the user.

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vitalistic medicine

in alternative medicine, generic term for a range of therapies that base their practice on the theory that disease is engendered by energy deficiency in the organism as a whole or a dynamic dysfunction in the affected part. Such deficiencies or dysfunctions are regarded as antecedent to the biochemical effects in which disease becomes manifest and upon which orthodox medicine focuses. Acupuncture, crystal therapy, homeopathy, magnet therapy, naturopathy, radionics, and Reichian therapy are all basically vitalistic.

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vitamin

any of various chemically-unrelated organic (carbon-containing) compounds that are necessary in small quantities for the normal functioning of the mammalian body. Many act as coenzymes, small molecules that enable enzymes to function effectively. Vitamins must be supplied by the diet because the body generally cannot make them. Deficiency of a vitamin may lead to a metabolic disorder ('deficiency disease'), which can be remedied by sufficient intake of the vitamin. Vitamins are generally classified as **water-soluble** (B and C) or **fat-soluble** (A, D, E, and K).

Vitamin A (retinol) is found in milk, cheese, butter, eggs, liver, kidney, oily fish (such as herring), and cod liver oil. However, the chemical carotene (found in most plants) can be converted to vitamin A in the human body. This vitamin is needed to make a chemical used by rod cells in the retina of the eye that respond in dim light. Shortage of this vitamin results in poor vision, especially at night.

Vitamin D is found in the greatest amounts in fish, but is present in tiny amounts in milk, cheese, butter, eggs, and liver. However, it can be made in the human skin when it is exposed to sunlight and this is sufficient for most people. It is needed to maintain bone in the body. Without the vitamin, bones are weak and can bend (rickets). Young children, pregnant women, and women breastfeeding a baby need much more than most other people. People who are housebound and do not get into the sun may become short of this vitamin.

Most people have balanced diets and so a real need to obtain extra vitamins from tablets is not common. Some vitamins are poisonous in high doses and there have been cases of people dying as a result of taking excessive amounts of vitamin pills.

Chemical names for vitamins

Vitamin	Chemical name
A	retinol
A_2	dehydroretinol
B_1	aneurin(e), thiamine[1]
B_2	riboflavin[1]
B_6	pyridoxine[1]
B_{12}	cyanocobalamin[1]
C	ascorbic acid
D_2	calciferol
D_3	cholecalciferol
E	tocopherol
H	biotin
K_1	phylloquinone
K_2	menaquinone
K_3	menadione
P	bioflavonoid, citrin

[1] Biotin, folic acid, and nicotinamide are also B complex vitamins.

Vitamins

Vitamin	Name	Main dietary sources	Established benefit	Deficiency symptoms
A	retinol	dairy products, egg yolk, liver; also formed in body from β-carotene, a pigment present in some leafy vegetables	aids growth; prevents night blindness and xerophthalmia (a common cause of blindness among children in developing countries); helps keep the skin and mucous membranes resistant to infection	night blindness; rough skin; impaired bone growth
B_1	thiamin	germ and bran of seeds and grains, yeast	essential for carbohydrate metabolism and health of nervous system	beriberi; Korsakov's syndrome
B_2	riboflavin	eggs, liver, milk, poultry, broccoli, mushrooms	involved in energy metabolism; protects skin, mouth, eyes, eyelids, mucous membranes	inflammation of tongue and lips; sores in corners of the mouth

B_6	pyridoxine/pantothenic acid/biotin	meat, poultry, fish, fruits, nuts, whole grains, leafy vegetables, yeast extract	important in the regulation of the central nervous system and in protein metabolism; helps prevent anaemia, skin lesions, nerve damage	dermatitis; neurological problems; kidney stones
B_{12}	cyanocobalamin	liver, meat, fish, eggs, dairy products, soybeans	involved in synthesis of nucleic acids, maintenance of myelin sheath around nerve fibres; efficient use of folic acid	anaemia; neurological disturbance
	folic acid	green leafy vegetables, liver, peanuts; cooking and processing can cause serious losses in food	involved in synthesis of nucleic acids; helps protect against cervical dysplasia (precancerous changes in the cells of the uterine cervix)	megaloblastic anaemia
	nicotinic acid (or niacin)	meat, yeast extract, some cereals; also formed in the body from the amino acid tryptophan	maintains the health of the skin, tongue, and digestive system	pellagra
C	ascorbic acid	citrus fruits, green vegetables, tomatoes, potatoes; losses occur during storage and cooking	prevents scurvy, loss of teeth; fights haemorrhage; important in synthesis of collagen (constituent of connective tissue); aids in resistance to some types of virus and bacterial infections	scurvy
D	calciferol, cholecalciferol	liver, fish oil, dairy products, eggs; also produced when skin is exposed to sunlight	promotes growth and mineralization of bone	rickets in children; osteomalacia in adults
E	tocopherol	vegetable oils, eggs, butter, some cereals, nuts	prevents damage to cell membranes	anaemia
K	phytomenadione, menaquinone	green vegetables, cereals, fruits, meat, dairy products	essential for blood clotting	haemorrhagic problems

Molecular Expressions: The Vitamin Collection

Go to site

Fascinating collection of images showing what all the known vitamins look like when recrystallized and photographed through a microscope. There is also a brief article about vitamins.

Vitamins and Dietary Supplements

Go to site

US-based health site that offers extensive information about the benefits of different vitamins and supplements to your diet.

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vitamin A

another name for retinol.

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vitamin B_1

another name for thiamine.

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vitamin B_6

another name for pyridoxine.

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vitamin B_{12}

another name for cyanocobalamin.

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vitamin B_2

another name for riboflavin.

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vitamin C

another name for ascorbic acid.

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vitamin D

another name for cholecalciferol.

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vitamin E

another name for tocopherol.

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vitamin H

another name for biotin.

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vitamin K

another name for phytomenadione.

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vitreous humour

transparent jellylike substance behind the lens of the vertebrate eye. It gives rigidity to the spherical form of the eye and allows light to pass through to the retina.

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vitriol

former name for any of a number of sulphate salts. Blue, green, and white vitriols are copper, ferrous, and zinc sulphate, respectively.

Oil of vitriol is a former name for sulphuric acid.

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viviparous

in animals, a method of reproduction in which the embryo develops inside the body of the female from which it gains nourishment (in contrast to oviparous and ovoviviparous). Vivipary is best developed in placental mammals, but also occurs in some arthropods, fishes, amphibians, and reptiles that have placentalike structures. In plants, it is the formation of young plantlets or bulbils instead of flowers. The term also describes seeds that germinate prematurely, before falling from the parent plant.

Premature germination is common in mangrove trees, where the seedlings develop sizable spearlike roots before dropping into the swamp below; this prevents their being washed away by the tide.

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vivisection

literally, cutting into a living animal. Used originally to mean experimental surgery or dissection practised on a live subject, the term is often used by antivivisection campaigners to include any experiment on animals, surgical or otherwise.

VLBA

abbreviation for very long-baseline array.

VLF

in physics, abbreviation for **very low frequency**. VLF radio waves have frequencies in the range 3-30 kHz.

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vocal cords

paired folds, ridges, or cords of tissue within a mammal's larynx, and a bird's syrinx. Air expelled from the lungs passes between these folds or membranes and makes them vibrate, producing sounds. Muscles in the larynx change the pitch of the sounds produced, by adjusting the tension of the vocal cords.

vol.

abbreviation for **volume**.

volatile

describing a substance that readily passes from the liquid to the vapour phase. Volatile substances have a high vapour pressure.

volatile memory

in computing, memory that loses its contents when the power supply to the computer is disconnected.

volcanic rock

another name for extrusive rock, igneous rock formed on the Earth's surface.

volcano

crack in the Earth's crust through which hot magma (molten rock) and gases well up. The magma is termed **lava** when it reaches the surface. A volcanic mountain, usually cone-shaped with a crater on top, is formed around the opening, or vent, by the build-up of solidified lava and ash (rock fragments). Most volcanoes occur on plate margins (see plate tectonics), where the movements of plates generate magma or allow it to rise from the mantle beneath. However, a number are found far from plate-margin activity, on hot spots where the Earth's crust is thin, for example in Hawaii. There are two main types of volcano: composite volcanoes and shield volcanoes.

The type of volcanic activity also depends on the age of the volcano. The first stages of an eruption are usually vigorous as the magma forces its way to the surface. As the pressure drops and the vents become established, the main phase of activity begins. Composite volcanoes emit pyroclastic debris, while shield volcanoes produce lava flows. When the pressure from below ceases, due to exhaustion of the magma chamber, activity wanes and is confined to the emission of gases, and in time this also ceases. The volcano then enters a period of quiescence, after which activity may resume after a period of days, years, or even thousands of years. Only when the root zones of a volcano have been exposed by erosion can a volcano be said to be truly extinct.

Many volcanoes are submarine and occur along mid-ocean ridges. The main volcanic regions are around the Pacific rim (Cape Horn to Alaska); the central Andes of Chile (with the world's highest active volcano, Guallatiri, 6,063 m/19,892 ft); North Island, New Zealand; Hawaii; Japan; and Antarctica. There are more than 1,300 potentially active volcanoes on Earth. Volcanism has also helped shape other members of the Solar System, including the Moon, Mars, Venus, and Jupiter's moon Io.

volcano

Mt Pelée volcano in Martinique erupted in 1902. All but one of the port of Saint-Pierre's 30,000 inhabitants were killed by the force of the eruption; the survivor was protected by the thick walls of his jail cell.

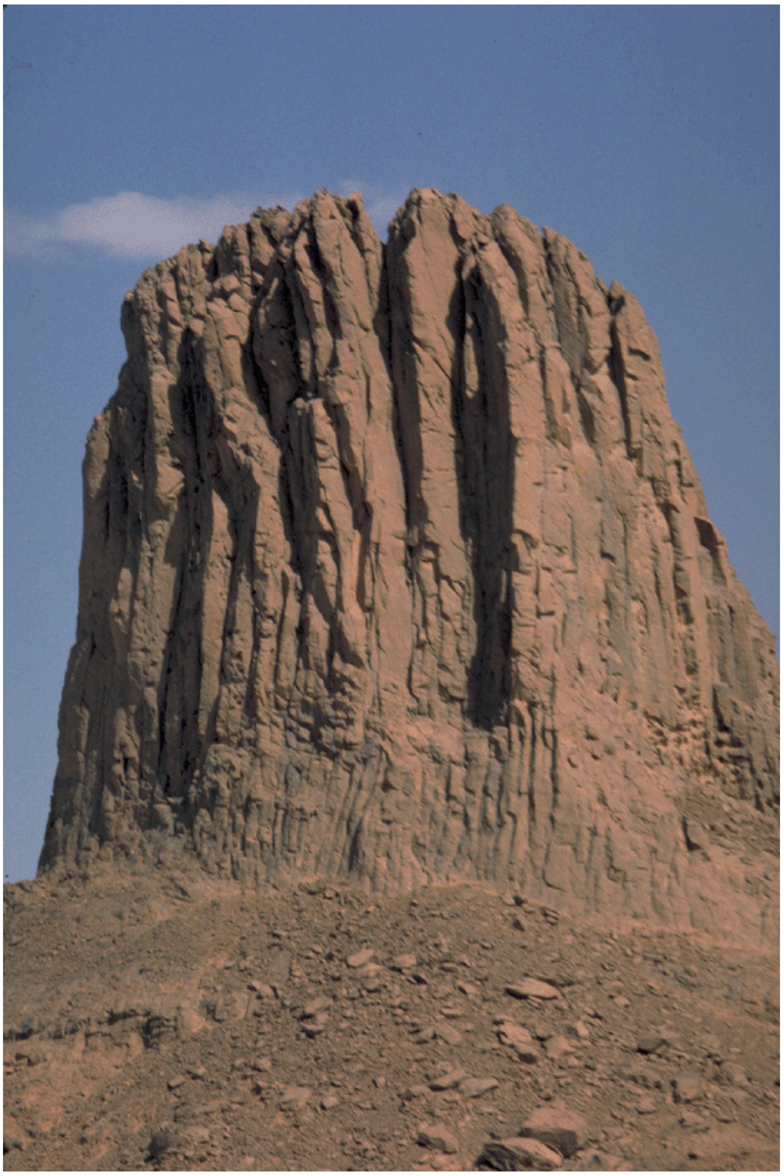
volcano

(Image © Garret Nagle)

The slopes of Helgafell, a volcano on the island of Heimaey, Iceland. Helgafell last erupted in 1973. The eruption created the new Eldfell cone and a 3 km/1.9 mi lava flow. Although the lava slopes have stabilized, the soil remains very hot, and at a depth of 1 m/3.3 ft, the soil and rock hold temperatures up to 300°C/572°

F. In the far distance another volcanic island can be seen.

volcano



(Image © Corel)

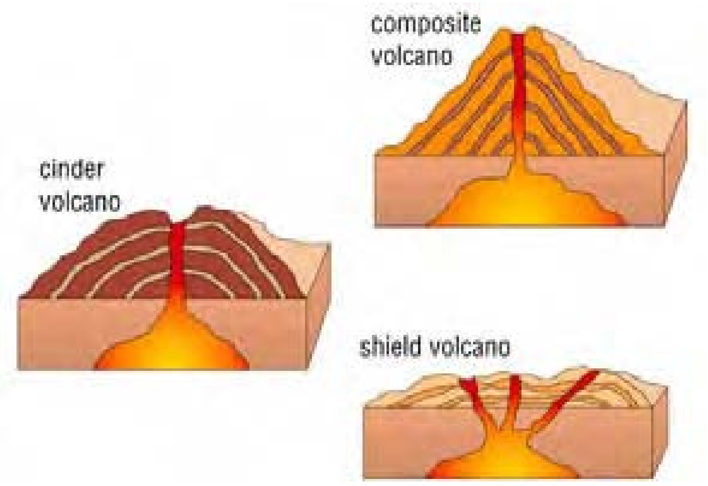
Volcanic plug in Assekrem, Algeria. This outcrop is the remains of a mass of volcanic material which once filled the vent of a volcano. The softer rock surrounding it has eroded away, leaving behind the more resistant 'plug'.

volcano

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

A knife-edge ridge of volcanic rock on the Napali coast of Kauai, one of the westernmost of the Hawaiian islands. Such a ridge may be formed when lava flows along a surface and drops into a crack or crevice, filling it up; the supporting sides eventually erode away, leaving only the shape of the original fissure.

volcano



(Image © Research Machines plc)

There are two main types of volcano, but three distinctive cone shapes. Composite volcanoes emit a stiff, rapidly solidifying lava which forms high, steep-sided cones. Volcanoes that regularly throw out ash build up flatter domes known as cinder cones. The lava from a shield volcano is not ejected violently, flowing over the crater rim forming a broad low profile.

Major volcanic eruptions in the 20th century

Volcano	Location	Year	Estimated number of deaths
Santa María	Guatemala	1902	1,000
Pelée	Martinique	1902	28,000
Taal	Philippines	1911	1,400
Kelut	Java, Indonesia	1919	5,500
Vulcan	Papua New Guinea	1937	500
Lamington	Papua New Guinea	1951	3,000
St Helens	USA	1980	57
El Chichon	Mexico	1982	1,880
Nevado del Ruiz	Colombia	1985	23,000
Lake Nyos	Cameroon	1986	1,700
Pinatubo	Luzon, Philippines	1991	639
Unzen	Japan	1991	39
Mayon	Philippines	1993	70
Loki[1]	Iceland	1996	0
Soufriere	Montserrat	1997	23
Merapi	Java, Indonesia	1998	38

[1] The eruption caused severe flooding, and melted enough ice to create a huge sub-glacial lake.

Dinosaur Extinction - The Volcano-Greenhouse Theory

Go to site

One theory about the reason why the dinosaurs became extinct in such a short space of time. As well as arguing the case well, this site also offers some links to related dinosaur sites.

MTU Volcanoes Page

Go to site

Provided by Michigan Technological University, this site includes a world map of volcanic activity with information on recent eruptions, the latest research in remote sensing of volcanoes, and many spectacular photographs.

Volcanoes

Go to site

Dramatic site that opens with a picture of an erupting volcano and asks whether volcanic catastrophes - which threaten millions of people in an increasingly densely populated world - can be predicted. With the help of video clips and interactive tasks, the well-written text goes on to answer important questions about volcanic activity: how volcanoes form and what the forces are that cause solid rock to melt and burst through the surface of the Earth.

VolcanoWorld

Go to site

Comprehensive site on volcanoes, with details of the most recent eruptions, currently active volcanoes, a glossary, images and video clips, and even a list of extraterrestrial volcanoes. If you cannot find out what you want to know, you can 'Ask a volcanologist'.

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vole

any of various rodents of the family Cricetidae, subfamily Microtinae, distributed over Europe, Asia, and North America, and related to hamsters and lemmings. They are characterized by stout bodies and short tails. They have brown or grey fur, and blunt noses, and some species reach a length of 30 cm/12 in. They feed on grasses, seeds, aquatic plants, and insects. Many show remarkable fluctuations in numbers over 3-4 year cycles.

The most common genus is *Microtus*, which includes 45 species distributed across North America and Eurasia.

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volt

symbol V

SI unit of electromotive force or electric potential (see potential, electric). A small battery usually has a potential of one or two volts; the domestic electricity supply in the USA is 110 volts. A high-tension transmission line may carry up to 765,000 volts.

The absolute volt is defined as the potential difference necessary to produce a current of one ampere through an electric circuit with a resistance of one ohm. It can also be defined as the potential difference that requires one joule of work to move a positive charge of one coulomb from the lower to the higher potential. It is named after the Italian scientist Alessandro Volta.

Volta, Alessandro Giuseppe Antonio Anastasio (1745-1827)

Count Volta

Italian physicist who invented the first electric cell (the voltaic pile, in 1800), the electrophorus (an early electrostatic generator, in 1775), and an electroscope.

studies of gas and vapour

In 1776 Volta discovered methane by examining marsh gas found in Lago Maggiore. He then made the first accurate estimate of the proportion of oxygen in the air by exploding air with hydrogen to remove the oxygen. In about 1795, Volta recognized that the vapour pressure of a liquid is independent of the pressure of the atmosphere and depends only on temperature.

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voltage amplifier

electronic device that increases an input signal in the form of a voltage or potential difference, delivering an output signal that is larger than the input by a specified ratio.

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voltaic cell

another name for an electric cell.

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voltmeter

instrument for measuring the potential difference (voltage) between two points in a circuit. It should not be confused with an ammeter, which measures current. A voltmeter has a high internal resistance (so that it passes only a small current), and is connected in parallel with the component across which potential difference is to be measured - that is, the current divides and passes through both the voltmeter and the component at the same time.

A common type of voltmeter is constructed from a sensitive current-detecting moving-coil galvanometer placed in series with a high-value resistor (multiplier). To measure an AC (alternating current) voltage, the circuit must usually include a rectifier; however, a moving-iron instrument can be used to measure alternating voltages without the need for such a device.

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volume

in geometry, the space occupied by a three-dimensional (3D) solid object. A prism such as a cube, cuboid, or a cylinder has a volume equal to the area of the base multiplied by the height. For a pyramid or cone, the volume is equal to one-third of the area of the base multiplied by the perpendicular height. The volume of a sphere is equal to $4/3 \times \pi r^3$, where r is the radius. Volumes of irregular solids may be calculated by the technique of integration.

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volumetric analysis

chemical procedure used for determining the concentration of a solution. A known volume of a solution of unknown concentration is reacted with a known volume of a solution of known concentration (standard). The standard solution is delivered from a burette so the volume added is known. This technique is known as titration. Often an indicator is used to show when the correct proportions have reacted. This procedure is used for acid-base, redox, and certain other reactions involving solutions.

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von Braun, Wernher Magnus Maximilian (1912-1977)

German rocket engineer responsible for Germany's rocket development programme in World War II (V1 and V2), who later worked for the space agency NASA in the USA. He also invented the Saturn rocket (Saturn V) that sent the *Apollo* project spacecraft to the Moon in 1969.

During the 1940s he was technical director of the research team at Peenemünde on the Baltic coast that produced the V1 (flying bomb) and supersonic V2 rockets. In the 1950s von Braun was part of the team that produced rockets for US satellites (the first, Explorer 1, was launched early 1958) and early space flights by astronauts.

Wernher Von Braun

Go to site

Biographical sketch of German rocket engineer Wernher von Braun. These pages document his early years, his life in Germany, his escape to the West, and his work at the Marshall Space Flight Center. There are photographs and links to several other pages with biographical information.

Von Neumann, John (or Johann) (1903-1957)

Hungarian-born US scientist and mathematician, a pioneer of computer design. He invented his 'rings of operators' (called **Von Neumann algebras**) in the late 1930s, and also contributed to set theory, game theory, quantum mechanics, cybernetics (with his theory of self-reproducing automata, called **Von Neumann machines**), and the development of the atomic and hydrogen bombs.

He designed and supervised the construction of the first computer able to use a flexible stored program (named EDVAC) at the Institute for Advanced Study at Princeton 1940-1952. This work laid the foundations for the design of all subsequent programmable computers.

Voskhod

(Russian 'ascent')

either of two Soviet spacecraft launched in October 1964 and March 1965. *Voskhod* was modified from the single-seat *Vostok*, and was the first spacecraft capable of carrying two or three cosmonauts. During *Voskhod 2* 's flight in 1965, Aleksi Leonov made the first space walk.

Vostok

(Russian 'east')

first Soviet spacecraft, used 1961-63. *Vostok* was a metal sphere 2.3 m/7.5 ft in diameter, capable of carrying one cosmonaut. It made flights lasting up to five days. *Vostok 1* carried the first person into space, Yuri Gagarin.

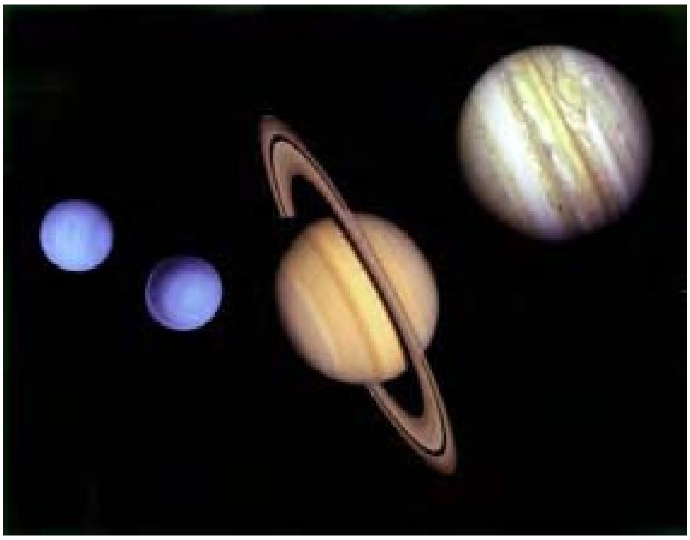
Voyager

either of two US space probes. Voyager 1, launched on 5 September 1977, passed the planet Jupiter in March 1979, and reached Saturn in November 1980. Voyager 2 was launched earlier, on 20 August 1977, on a slower trajectory that took it past Jupiter in July 1979, Saturn in August 1981, Uranus in January 1986, and Neptune in August 1989. Like the Pioneer probes, the Voyagers are now far beyond the orbit of Pluto.

Their tasks include helping scientists to locate the heliopause, the boundary at which the influence of the Sun gives way to the forces exerted by other stars. Voyager 1 is expected to reach this point between 2013 and 2015, Voyager 2 some five years later.

Both Voyagers carry coded recordings called 'Sounds of Earth', intended to enlighten any other civilizations that might find them.

Voyager



(Image © NASA)

Photo montage of the gas giants from the Voyager 'grand tour'. Bottom to top, with increasing distance from the inner Solar System, are Jupiter, Saturn, Uranus, and Neptune.

Vries, Hugo (Marie) de (1848-1935)

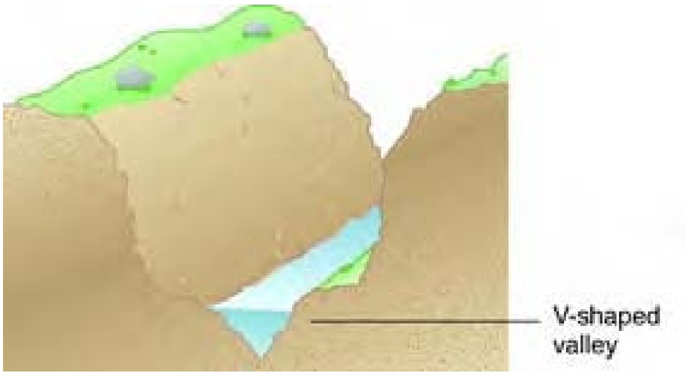
Dutch botanist who conducted important research on osmosis in plant cells and was a pioneer in the study of plant evolution. His work led to the rediscovery of Austrian biologist Gregor Mendel's laws and the discovery of spontaneously occurring mutations.

V-shaped valley

river valley with a V-shaped cross-section. Such valleys are usually found near the source of a river, where the steeper gradient means that there is a great deal of corrasion (grinding away by rock particles) along the stream bed, and erosion cuts downwards more than it does sideways. However, a V-shaped valley may also be formed in the lower course of a river when its powers of downward erosion become renewed by a fall in sea level, a rise in land level, or the capture of another river.

The angle of the V-shaped cross-section depends on the rate of uplift of rock, the type of rock, the erosive ability of the river, the type of climate, and the stage of the river.

V-shaped valley



(Image © Research Machines plc)

Cross section of a V-shaped valley. V-shaped valleys are formed through erosion by water.

VSTOL

abbreviation for vertical/short takeoff and landing

aircraft capable of taking off and landing either vertically or using a very short length of runway (see STOL). Vertical takeoff requires a vector-control system that permits the thrust of the aircraft engine to be changed from horizontal to vertical for takeoff and back again to horizontal to permit forward flight. An alternative VSTOL technology developed in the USA involves tilting the wings of the aircraft from vertical to horizontal and along with them the aircraft propellers, thus changing from vertical lift to horizontal thrust.

The first VSTOL was US Convair XFY-1 in 1954. The British Harrier fighter bomber is the most successful VSTOL aircraft. It is now manufactured under licence in the USA and provides integral air support for the US Marines. In addition to the UK's Royal Air Force and Royal Navy, the Indian, Spanish, and Italian navies are equipped with the Harrier. It was used in the 1982 Falklands conflict and the 1991 Gulf War.

vulcanization

technique for hardening rubber by heating and chemically combining it with sulphur. The process also makes the rubber stronger and more elastic. If the sulphur content is increased to as much as 30%, the product is the inelastic solid known as ebonite. More expensive alternatives to sulphur, such as selenium and tellurium, are used to vulcanize rubber for specialized products such as vehicle tyres. The process was discovered by US inventor Charles Goodyear in 1839 and patented in 1844.

Accelerators can be added to speed the vulcanization process, which takes from a few minutes for small objects to an hour or more for vehicle tyres. Moulded objects are often shaped and vulcanized simultaneously in heated moulds; other objects may be vulcanized in hot water, hot air, or steam.

Vulpecula

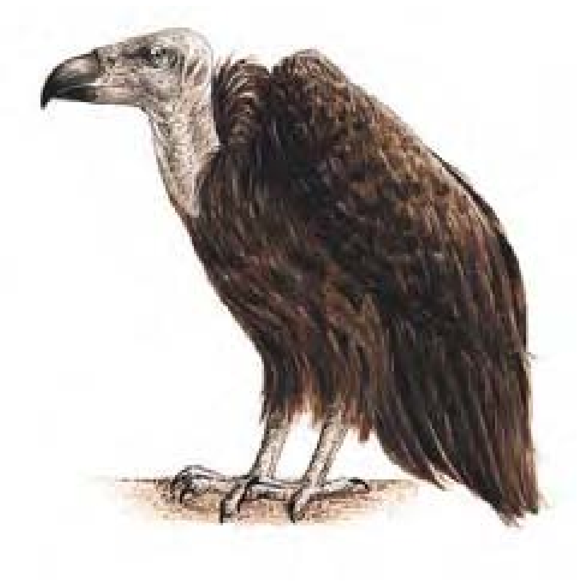
small constellation in the northern hemisphere just south of Cygnus, represented as a fox. It contains a major planetary nebula, the Dumbbell, and the first pulsar (pulsating radio source) to be discovered.

vulture

any of various carrion-eating birds of prey in the order Falconiformes, with naked heads and necks, strong hooked bills, and keen senses of sight and smell. Vultures are up to 1 m/3.3 ft long, with wingspans of up to 3.7 m/12 ft. The plumage is usually dark, and the head brightly coloured.

The vulture's eyes are adapted to give an overall view with a magnifying area in the centre, enabling it to locate possible food sources and see the exact site in detail.

vulture



(Image © Research Machines plc)

There are 15 species in Africa, Asia, and Europe, with a further seven species in America. Most have dark plumage, bare head and neck, strongly curved beak, and powerful talons.

W

in physics, symbol for watt, the SI unit of power, equal to a power output of 1 joule per second. Multiple units include the kilowatt (kW, 1,000 watts) and megawatt (MW, 1,000,000 watts).

W

abbreviation for **west**; in physics, symbol for watt.

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wadi

in arid regions of the Middle East, a steep-sided valley containing an intermittent stream that flows in the wet season.

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wagtail

slim, narrow-billed bird of the genus *Motacilla*, in the family Motacillidae, order Passeriformes, about 18 cm/7 in long, with a characteristic flicking movement of the tail. There are about 30 species, found mostly in Eurasia and Africa.

Waksman, Selman Abraham (1888-1973)

Ukrainian-born US biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1952 for his discovery of streptomycin, the first antibiotic effective against tuberculosis. He coined the word 'antibiotic' for bacteria-killing chemicals derived from micro-organisms.

Wald, George (1906-1997)

US biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1967 for work on the physiology and chemistry of vision. He discovered the role played in night vision by the retinal pigment rhodopsin, and later identified the three primary-colour pigments.

Waldsterben

(German 'forest death')

tree decline related to air pollution, common throughout the industrialized world. It appears to be caused by a mixture of pollutants; the precise chemical mix varies between locations, but it includes acid rain, ozone, sulphur dioxide, and nitrogen oxides.

Waldsterben was first noticed in the Black Forest of Germany during the late 1970s, and is spreading to many countries in the developing world, such as China.

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wallaby

any of various small and medium-sized members of the kangaroo family.

Wallace line

imaginary line running down the Lombok Strait in Southeast Asia, between the island of Bali and the islands of Lombok and Sulawesi. It was identified by English naturalist Alfred Russel Wallace as separating the South Asian (Oriental) and Australian biogeographical regions, each of which has its own distinctive animals.

Subsequently, others have placed the boundary between these two regions at different points in the Malay archipelago, owing to overlapping migration patterns.

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wallflower

European perennial cottage garden plant with fragrant spikes of red, orange, yellow, brown, or purple flowers in spring. (Genus *Cheiranthus cheiri*, family Cruciferae.)

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wall pressure

in plants, the mechanical pressure exerted by the cell contents against the cell wall. The rigidity (turgor) of a plant often depends on the level of wall pressure found in the cells of the stem. Wall pressure falls if the plant cell loses water.

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walnut

genus *Juglans* of trees of the family Juglandaceae, closely related to hickories. Walnuts have pinnately compound leaves and nuts enclosed in a thick leathery husk. Six species, including the black walnut *J. nigra* and the butternut *J. cinerea*, are native to the USA. About 15 other species occur in South America and Eurasia. The English walnut *J. regia*, originally from southeastern Europe and Asia, is cultivated widely for its nut crop.

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walrus

Arctic marine carnivorous mammal *Odobenus rosmarus* of the same family (Otaridae) as the eared seals. It can reach 4 m/13 ft in length, and weigh up to 1,400 kg/3,000 lb. It has webbed flippers, a bristly moustache, and large tusks. It is gregarious except at breeding time and feeds mainly on molluscs. It has been hunted for its ivory tusks, hide, and blubber; the Alaskan walrus is close to extinction.

Walruses feed continuously for days at a time, after which they rest for several days. They need to eat 2,000-6,000 shellfish a day to remain healthy. Walruses feed on fish, shellfish, and other sea invertebrates such as crabs and squid, but they will also hunt and kill seals. Their lifespan is around 40 years, with females reaching sexual maturity at about six years, and males between seven and ten years. The gestation period is 15 months and females give birth to a single calf every third year. Calves are weaned at two years.

Walrus

Go to site

Illustrated guide to the walrus including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

Wang, An (1920-1990)

Chinese-born US engineer, founder in 1951 of Wang Laboratories, one of the world's largest computer companies in the 1970s. In 1948 he invented the computer memory core, the most common device used for storing computer data before the invention of the integrated circuit (chip).

WAP

acronym for Wireless Application Protocol

initiative started in the 1990s by Unwired Planet and mobile phone manufacturers Motorola, Nokia, and Ericsson to develop a standard for delivering Web-like applications on mobile phones and other wireless devices. In theory WAP phones can be used for e-mail and messaging, reading Web pages, shopping, booking tickets, and making other financial transactions, as well as for phone calls. WAP as been superseded to some extent by 3G (third generation) mobile phone technology.

The WAP protocol has many similarities to Internet technologies. For instance, the Wireless Markup Language (WML) used to create WAP pages is very similar to HTML, which is used to create Web pages. Similarly, the WMLScript is based on JavaScript. Both WML and WMLScript are adapted and designed for a wireless environment, to address issues such as limited bandwidth and limited processing power in the mobile phone.

WAP Forum

Go to site

Official home of the Wireless Application Protocol (WAP) Forum, an industry association comprising 90% of all organizations involved in WAP technology development, and a leading source of information about WAP and telephony. If you want to know more about WAP technology, there is a useful 'Frequently Asked Questions' section, details of the Forum's work, and a news and events area.

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wapiti

alternate name for elk.

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warble fly

large, brownish, hairy flies, with mouthparts that are reduced or vestigial. The larva is a large maggot covered with spines. They cause myiasis (invasion of the tissues by fly larvae) in animals.

In agriculture, warble flies are pests, causing damage to livestock, where their presence can retard growth, reduce milk and meat yield, and render hides worthless.

The larvae of *Oestrus ovis* normally invade the nasal cavities of sheep and goats, and those of *Hypoderma* are skin parasites of cattle and other animals, causing 'ulcers' in the skin, a condition called warbles. In humans *Oestrus* invasion is rare, except for shepherds and goatherds, and the larva is more often noticed attempting to penetrate the eye than the nasal cavities. *Hypoderma* attempts to follow its normal pattern, migrating from the site of the bite to the shoulders or neck.

classification

Warble flies are in family Oestridae, order Diptera, class Insecta, phylum Arthropoda.

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warbler

any of two families of songbirds, order Passeriformes. The Old World warblers are in the family Sylviidae, while the New World warblers are members of the Parulidae.

American or wood warblers (family Parulidae) are small, insect-eating birds, often brightly coloured, such as the yellow warbler, prothonatory warbler, and dozens of others. This group is sometimes placed in the same family (Emberizidae) as sparrows and orioles. Old World warblers (family Sylviidae) are typically slim and dull-plumaged above, lighter below, insectivorous, and fruit-eating, overwhelmingly represented in Eurasia and Africa. These are sometimes considered a subgroup of the same family (Muscicapidae) that includes thrushes.

Warburg, Otto Heinrich (1883-1970)

German biochemist who was awarded a Nobel Prize for Physiology or Medicine in 1931 for the discovery of respiratory enzymes that enable cells to process oxygen. In 1923 he devised a manometer (pressure gauge) sensitive enough to measure oxygen uptake of respiring tissue. By measuring the rate at which cells absorb oxygen under differing conditions, he was able to show that enzymes called cytochromes enable cells to process oxygen.

Later he discovered the mechanism of the conversion of light energy to chemical energy that occurs in photosynthesis. He also demonstrated that cancerous cells absorb less oxygen than normal cells.

---

warfarin

poison that induces fatal internal bleeding in rats; neutralized with sodium hydroxide, it is used in medicine as an anticoagulant in the treatment of thrombosis: it prevents blood clotting by inhibiting the action of vitamin K. It can be taken orally and begins to act several days after the initial dose.

Warfarin is a crystalline powder, $C_{19}H_{16}O_4$. Heparin may be given in treatment at the same time and discontinued when warfarin takes effect. It is often given as a preventive measure, to reduce the risk of thrombosis or embolism after major surgery.

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warning coloration

in biology, an alternative term for aposematic coloration.

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wart

protuberance composed of a local overgrowth of skin. The common wart (*Verruca vulgaris*) is due to a virus infection. It usually disappears spontaneously within two years, but can be treated with peeling applications, burning away (cautery), freezing (cryosurgery), or laser treatment.

Childhood Infections - Warts

Go to site

Useful information about warts. There is a detailed, illustrated description of the infection, its symptoms, and its duration. There are also notes on how warts can be treated both at home and professionally, and what to do should the symptoms occur.

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wart hog

African wild pig*Phacochoerus aethiopicus*, which has a large head with a bristly mane, fleshy pads beneath the eyes, and four large tusks. It has short legs and can grow to 80 cm/2.5 ft at the shoulder.

Wart hog

Go to site

Illustrated guide to the wart hog including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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washing soda

chemical name sodium carbonate decahydrate; $Na_2CO_3.10H_2O$

substance added to washing water to 'soften'hard water. The calcium and magnesium ions in hard water react with the carbonate ions from the sodium carbonate and a precipitate of calcium carbonate results.

$Na_2CO_{3(aq)} + CaSO_{4(aq)} \rightarrow CaCO_{3(s)} + Na_2SO_{4(aq)}$

Washington Convention

alternative name for CITES, the international agreement that regulates trade in endangered species.

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wasp

any of several families of winged stinging insects of the order Hymenoptera, characterized by a thin stalk between the thorax and the abdomen. Wasps can be social or solitary. Among social wasps, the queens devote themselves to egg laying, the fertilized eggs producing female workers; the males come from unfertilized eggs and have no sting. The larvae are fed on insects, but the mature wasps feed mainly on fruit and sugar. In winter, the fertilized queens hibernate, but the other wasps die.

wasp

Wasps use tools. After laying her eggs, the female sand wasp sometimes uses a small pebble to smooth sand over the entrance to her nest to seal it.

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waste

materials that are no longer needed and are discarded. Examples are household waste, industrial waste (which often contains toxic chemicals), medical waste (which may contain organisms that cause disease), and nuclear waste (which is radioactive). By recycling, some materials in waste can be reclaimed for further use. In 1990 the industrialized nations generated 2 billion tonnes of waste. In the USA, 40 tonnes of solid waste are generated annually per person, roughly twice as much as in Europe or Japan.

There has been a tendency to increase the amount of waste generated per person in industrialized countries, particularly through the growth in packaging and disposable products, creating a 'throwaway society'.

Environment: EU Focus on Waste Management

Go to site

Details of European Union policy on waste management made available in a downloadable Adobe Acrobat document. There is information on waste-related EU events, strategy documents, scientific reports, and access to other areas of the EU Environment Commission.

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waste disposal

or waste management

depositing of waste. Modern methods of waste disposal are commonly referred to as waste management as they are increasingly using methods such as recycling that allows waste to be re-used and not simply disposed of. Methods of waste disposal vary according to the materials in the waste, and include incineration, burial at designated sites (landfill sites), dumping at sea, and reclaiming and recycling. Organic waste can be treated and reused as fertilizer (see sewage disposal). Nuclear waste and toxic waste are usually buried or dumped at sea, although this does not negate the danger (it simply removes it from the immediate vicinity of human habitation). Some types of nuclear waste are reprocessed to remove useful fissile components before being sent to long-term containment.

environmental pollution

Waste disposal is an ever-growing problem. Environmental groups, as well as government initiatives, campaign for more recycling, encouraging changes in lifestyle so that less waste is produced and also disposed of more safely and efficiently.

Although incineration cuts down on landfill and can produce heat as a useful by-product it is still a wasteful method of disposal in comparison with recycling. For example, recycling a plastic bottle saves twice as much energy as is obtained by burning it.

European Commission: Environment

Go to site

Huge collection of materials documenting the activities and concerns of the EU Environment Commission. A plain but well-organized Web site, it has its own search engine to help locate items of interest.

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watch

portable timepiece. In the early 20th century increasing miniaturization, mass production, and convenience led to the watch moving from the pocket to the wrist. Watches were also subsequently made waterproof, antimagnetic, self-winding, and shock-resistant. In 1957 the electric watch was developed, and in the 1970s came the digital watch, which dispensed with all moving parts.

history

Miniature sundials were the earliest portable timepieces. The first true watches, miniature clocks worn at the waist, were developed in the 15th century. Mechanical watches with analogue dials (hands) were based on the invention by Peter Henlein (1480–1542) of the mainspring as the energy source. By 1675 the invention of the balance spring allowed watches to be made small enough to move from waist to pocket. By the 18th century pocket-watches were relatively accurate, and by the 20th century wristwatches were introduced. In the 1950s battery-run electromagnetic watches were developed; in the 1960s electronic watches were marketed, which used the piezoelectric oscillations of a quartz crystal to mark time and an electronic circuit to drive the hands. In the 1970s quartz watches without moving parts were developed – the solid-state watch with a liquid crystal display of digits. Some included a tiny calculator and such functions as date, alarm, stopwatch, and reminder beeps.

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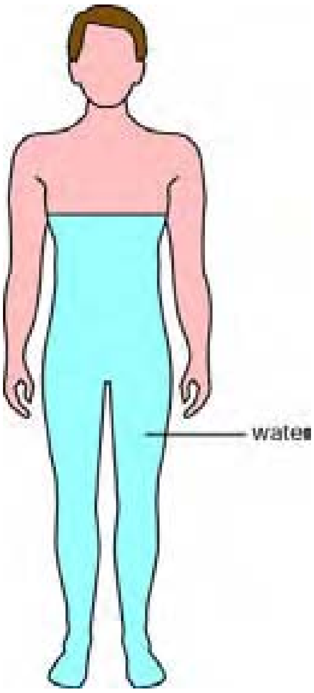
water

chemical compound of hydrogen and oxygen elements – H_2O. It can exist as a solid (ice), liquid (water), or gas (water vapour). Water is the most common compound on Earth and vital to all living organisms. It covers 70% of the Earth's surface, and provides a habitat for large numbers of aquatic organisms. It is the largest constituent of all living organisms – the human body consists of about 65% water. It is found in all cells and many chemicals involved in processes such as respiration and photosynthesis need to be in solution in water in order to react. Pure water is a colourless, odourless, tasteless liquid which freezes at 0°C/32°F, and boils at 100°C/212°F. Natural water in the environment is never pure and always contains a variety of dissolved substances. Some 97% of the Earth's water is in the oceans; a further 2% is in the form of snow or ice, leaving only 1% available as freshwater for plants and animals. The recycling and circulation of water through the biosphere is termed the **water cycle**, or 'hydrological cycle'; regulation of the water balance in organisms is termed osmoregulation. Water becomes more dense when it cools but reaches maximum density at 4°C/39°F. When cooled below this temperature the cooler water floats on the surface, as does ice formed from it. Animals and plants can survive under the ice.

The recycling and circulation of water on Earth is called the water cycle. Water occurs on the Earth's surface as standing water in oceans and lakes, as running water in rivers and streams, as rain, and as water vapour in the atmosphere. Together these sources comprise the hydrosphere which is in a constant state of flux – water vapour condenses as it cools to form clouds, droplets of water in the clouds merge to form raindrops that fall to earth (precipitation), and after flowing through rivers and streams into lakes and oceans water is returned to the atmosphere by evaporation; and so the cycle continues. Since the hydrological cycle is a closed system, the amount of water in the Earth's hydrosphere is constant. The cycle is powered by solar radiation which provides the energy to maintain the flow through the processes of evaporation, transpiration, precipitation, and run-off.

water



(Image © Research Machines plc)

Approximately two-thirds of the human body is made up of water.

Clean Water - Life Depends on It

Go to site

Extensive investigation into the quality of the planet's water (or the lack of it) and the risks that technological advances have brought about. The site includes definitions of the major notions related to these issues, sections on the self-cleansing of water, a fact sheet about water quality and the risks to human health as a result of water pollution, a detailed presentation of water quality pollutants, and guidelines delineating the optimal behaviour towards water and the aquatic environments.

Physical Properties of Water and Ice

Go to site

Well-designed guide to the molecular properties of water in its various states. Click on the introduction for a clear outline of the concepts, then take a look at the various molecular models and select which is water and which is ice. This graphics-rich site is part of a much larger resource for science students.

Water

Go to site

'The aqueous environment influences all of the chemistry that takes place in it', according to this Molecule of the Month page from Bristol University, UK, which takes a challenging look at the chemistry of water. One of the most exciting aspects considered is the discovery of the 'hot life' found in thermal vents on the open floor.

---

water beetle

aquatic beetle with an oval, flattened, streamlined shape. The head is sunk into the thorax and the hindlegs are flattened into flippers for swimming; there is a wide variation in size within the species; they are usually dark or black in colour and the entire body has a resplendent sheen. Both the adults and larvae are entirely aquatic, and are common in still, fresh waters such as ponds and lakes.

classification

Water beetles are in family Dytiscidae, order Coleoptera, class Insecta, phylum Arthropoda.

Both adults and larvae are carnivorous. The larvae have a particularly fierce appearance with sickle-shaped mandibles, or jaws. These mandibles have holes at their tips through which the larva secretes digestive enzymes when it catches its prey. So to a great extent digestion is external, the body fluids of its victim being sucked up via the holes and the channels in the mandibles. The pupal stage is terrestrial, being spent under the soil. There are some 4,000 species within this family.

The adult beetles return to the water surface periodically to replenish their supply of air, which is trapped under their wing cases.

---

water boatman

any water bug of the family Corixidae that feeds on plant debris and algae. It has a flattened body 1.5 cm/0.6 in long, with oarlike legs.

The name is sometimes also used for the backswimmers, genus *Notonecta*, which are superficially similar, but which can fly and which belong to a different family (Notonectidae) of bugs.

---

water-borne disease

disease associated with poor water supply. In developing world countries four-fifths of all illness is caused by water-borne diseases, with diarrhoea being the leading cause of childhood death. Malaria, carried by mosquitoes that are dependent on stagnant water for breeding, affects 400 million people every year and kills 5 million. Polluted water is also a problem in industrialized nations, where industrial dumping of chemical, hazardous, and radioactive wastes causes a range of medical conditions from headache to cancer.

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waterbuck

any of several African antelopes of the genus *Kobus* which usually inhabit swampy tracts and reedbeds. They vary in size from about 1.8m/6 ft to 2.1 m/7.25 ft long, are up to 1.4 m/4.5 ft tall at the shoulder, and have long brown fur. The large curved horns, normally carried only by the males, have corrugated surfaces. Some species have white patches on the buttocks. Lechwe, kor, and defassa are alternative names for some of the species.

---

water bug

any of a number of aquatic bugs where all stages of the life cycle (adult, larval, and egg) occur in the water;

the eggs are usually attached to the stems or leaves of water plants. In contrast to the land bugs, which have quite distinctly noticeable antennae, the antennae of water bugs are hidden. In general, water bugs are also less brightly coloured; they are usually varying shades of black or brown, and tend to inhabit the bottom strata of ponds, lakes, and streams. They may or may not have wings.

classification

Water bugs belong to the suborder Heteroptera, order Hemiptera, class Insecta, phylum Arthropoda.

The largest water bugs, giant waterbugs, belong to the family Belostomatidae. They found in Australia, India, China, and South America. They are over 10 cm/4 in long, and prey on insects, tadpoles, and small fish.

---

watercress

perennial aquatic plant found in Europe and Asia and cultivated for its pungent leaves which are used in salads. (Genus *Nasturtium officinale*, family Cruciferae.)

Watercress

Go to site

Detailed information relating to this plant. It contains an informative description of the plant and its habitat. There are also notes on the constituents and possible medicinal uses of watercress.

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water cycle

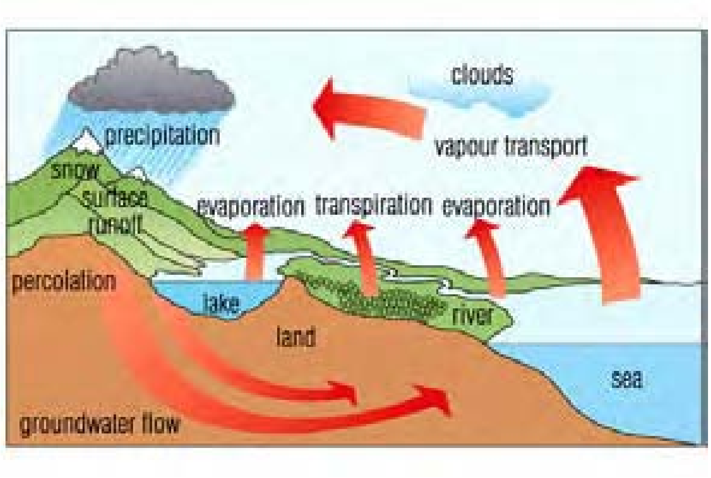
or hydrological cycle

natural circulation of water through the upper part of the Earth. It is a complex system involving a number of physical and chemical processes (such as evaporation, precipitation, and infiltration) and stores (such as rivers, oceans, and soil).

Water is lost from the Earth's surface to the atmosphere by evaporation caused by the Sun's heat on the surface of lakes, rivers, and oceans, and through the transpiration of plants. This atmospheric water is carried by the air moving across the Earth, and **condenses** as the air cools to form clouds, which in turn deposit moisture on the land and sea as precipitation. The water that collects on land flows to the ocean overland – as streams, rivers, and glaciers – or through the soil (infiltration) and rock (groundwater). The boundary that marks the upper limit of groundwater is called the water table.

The oceans, which cover around 70% of the Earth's surface, are the source of most of the moisture in the atmosphere.

water cycle



(Image © Research Machines plc)

About one-third of the solar energy reaching the Earth is used in evaporating water. About 380,000 cubic km/95,000 cubic mi is evaporated each year. The entire contents of the oceans would take about one million years to pass through the water cycle.

Hydrologic Cycle

Go to site

Easy-to-understand, well-illustrated guide to the water cycle. The site is part of an online meteorology guide provided by the University of Illinois and includes useful diagrams to aid understanding.

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waterfall

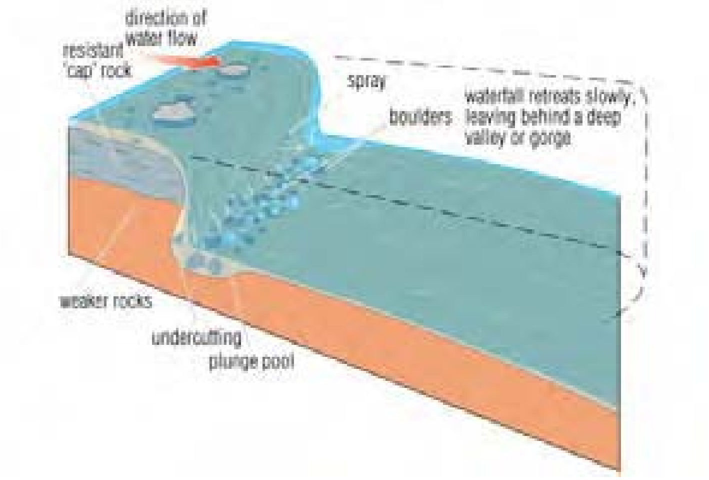
cascade of water in a river or stream. It occurs when a river flows over a bed of rock that resists erosion; weaker rocks downstream are worn away, creating a steep, vertical drop and a plunge pool into which the water falls. Over time, continuing erosion causes the waterfall to retreat upstream forming a deep valley, or gorge. Good examples of waterfalls include Victoria Falls (Zimbabwe/Zambia), Niagara Falls (USA/Canada), and Angel Falls (Venezuela).

waterfall

(Image © Research Machines plc)

Cumberland Falls, Kentucky. The Cumberland, a branch of the Ohio River, rises in Kentucky, winds southwest into Tennessee, and then turns north and back into Kentucky. The horseshoe shape of the falls gives it the nickname 'the Niagara of the South.'

waterfall


direction of water flow
resistant 'cap' rock
spray
boulders
waterfall retreats slowly, leaving behind a deep valley or gorge
weaker rocks
undercutting
plunge pool

(Image © Research Machines plc)

When water flows over hard rock and soft rock, the soft rocks erode creating waterfalls. As the erosion processes continue, the falls move backwards, in the opposite direction of the water

Highest waterfalls in the world

Waterfall	Location	Total drop	
		m	ft
Angel Falls	Venezuela	979	3,212
Yosemite Falls	USA	739	2,425
Mardalsfossen-South	Norway	655	2,149
Tugela Falls	South Africa	614	2,014
Cuquenan	Venezuela	610	2,000
Sutherland	New Zealand	580	1,903
Ribbon Fall, Yosemite	USA	491	1,612
Great Karamang River Falls	Guyana	488	1,600
Mardalsfossen-North	Norway	468	1,535
Della Falls	Canada	440	1,443
Gavarnie Falls	France	422	1,385
Skjeggedal	Norway	420	1,378

Glass Falls	Brazil	404	1,325
Krimml	Austria	400	1,312
Trummelbach Falls	Switzerland	400	1,312
Takkakaw Falls	Canada	366	1,200
Silver Strand Falls, Yosemite	USA	357	1,170
Wallaman Falls	Australia	346	1,137
Wollomombi	Australia	335	1,100
Cusiana River Falls	Colombia	300	984
Giessbach	Switzerland	300	984
Skykkjedalsfossen	Norway	300	984
Staubbach	Switzerland	300	984

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water flea

any aquatic crustacean in the order Cladocera, of which there are over 400 species. The commonest species is *Daphnia pulex*, used in the pet trade to feed tropical fish.

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waterfowl

any water bird, but especially any member of the family Anatidae, which consists of ducks, geese, and swans.

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water gas

fuel gas consisting of a mixture of carbon monoxide and hydrogen, made by passing steam over red-hot coke. The gas was once the chief source of hydrogen for chemical syntheses such as the Haber process for making ammonia, but has been largely superseded in this and other reactions by hydrogen obtained from natural gas.

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water glass

common name for sodium metasilicate (Na_2SiO_3). It is a colourless, jellylike substance that dissolves readily in water to give a solution used for preserving eggs and fireproofing porous materials such as cloth, paper, and wood. It is also used as an adhesive for paper and cardboard and in the manufacture of soap and silica gel, a substance that absorbs moisture.

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water hyacinth

tropical aquatic plant belonging to the pickerelweed family. In one growing season 25 plants can produce 2 million new plants. It is liable to choke waterways, removing nutrients from the water and blocking out the sunlight, but it can be used to purify sewage-polluted water as well as in making methane gas, compost, concentrated protein, paper, and baskets. Originating in South America, it now grows in more than 50 countries. (Genus *Eichhornia crassipes*, family Pontederiaceae.)

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water lily

any of a group of aquatic plants belonging to the water lily family. The fleshy roots are embedded in mud and the large round leaves float on the surface of the water. The cup-shaped flowers may be white, pink, yellow, or blue. (Genera *Nymphaea* and *Nuphar*, family Nymphaeaceae.)

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water meadow

irrigated meadow. By flooding the land for part of each year, increased yields of hay are obtained. Water meadows were common in Italy, Switzerland, and England (from 1523) but have now largely disappeared.

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water measurer

slender long-legged wingless bug found on the water surface or on vegetation skirting the water. They are carnivorous, feeding on animals such as water fleas. They walk slowly and gracefully on the water surface using their long legs, their bodies held above the surface film.

classification

The water measurers belong to family Hydrometridae, order Hemiptera, class Insecta, phylum Arthropoda.

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watermelon

large melon belonging to the gourd family, native to tropical Africa, with a dark green rind and reddish juicy flesh studded with a large number of black seeds. It is widely cultivated in subtropical regions. (Genus *Citrullus vulgaris*, family Cucurbitaceae.)

water mill

machine that harnesses the energy in flowing water to produce mechanical power, typically for milling (grinding) grain. Water from a stream is directed against the paddles of a water wheel to make it turn. Simple gearing transfers this motion to the millstones. The modern equivalent of the water wheel is the water turbine, used in hydroelectric power plants.

Although early step wheels were used in ancient China and Egypt, and parts of the Middle East, the familiar vertical water wheel came into widespread use in Roman times. There were two types: **undershot**, in which the wheel simply dipped into the stream, and the more powerful **overshot**, in which the water was directed at the top of the wheel. The Domesday Book records over 7,000 water mills in Britain. Water wheels remained a prime source of mechanical power until the development of a reliable steam engine in the 1700s. Water power was used not only for milling but also for metalworking, crushing and grinding operations, and driving machines in the early factories. Steam power and the water wheel were combined to form paddlewheel steamboats in the 18th century.

water of crystallization

water chemically bonded to a salt in its crystalline state. For example, in copper(II) sulphate, there are five moles of water per mole of copper sulphate: hence its formula is $CuSO_4.5H_2O$. This water is responsible for the colour and shape of the crystalline form. When the crystals are heated gently, the water is driven off as steam and a white powder of the anhydrous salt is formed.

$$CuSO_4.5H_2O_{(s)} \rightarrow CuSO_{4\,(s)} + 5H_2O_{(g)}$$

water pollution

any addition to fresh or seawater that interferes with biological processes or causes a health or environmental hazard. Common pollutants include nitrates, pesticides, and sewage (resulting from poor sewage disposal methods), although a huge range of industrial contaminants, such as chemical by-products and residues created in the manufacture of various goods, also enter water – legally, accidentally, and through illegal dumping.

In December 2002, United Nations secretary general Kofi Annan launched the International Year of Fresh Water 2003. By the end of 2003, the UN estimated that around 1 billion people worldwide did not have access to safe drinking water and that two-thirds of the world's population would live under 'water stress' conditions by 2025 if trends were not changed.

Surfers Against Sewage

Go to site

Web site of a pressure group claiming to represent not only surfers but the 20 million people who use the UK coastline every year. The site contains a medical database of over 800 cases of illness alleged to be the result of the raw sewage that washes around British beaches. A 'clickable' map allows you to check out your nearest beach for cleanliness.

water scorpion

water bug in which the first pair of legs are modified into prehensile organs for grasping prey. They are carnivorous and feed on smaller insects. The prey is held securely between their first pair of legs while the water scorpion sucks up its body fluids.

classification

Water scorpion are in family Nepidae, order Hemiptera, class Insecta, phylum Arthropoda.

Another characteristic feature of these bugs is their respiratory tube. While the bug remains at the bottom of the water, the respiratory tube reaches up to the surface, thus renewing its supply of air. The respiratory tube itself has quite a complex structure. It is made up of two grooved canals locked together by minute hairs or bristles, which give it the appearance of a single tube. At the base of the tube there are two respiratory spiracles or 'air-diffusing holes'. This respiratory tube is often wrongly believed to be a stinging organ, hence the name of water scorpion.

water softener

any substance or unit that removes the hardness from water. Hardness is caused by the presence of calcium and magnesium ions, which combine with soap to form an insoluble scum, prevent lathering, and cause deposits to build up in pipes and cookware (kettle fur). A water softener replaces these ions with sodium ions, which are fully soluble and cause no scum.

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waterspout

funnel-shaped column of water and cloud that is drawn from the surface of the sea or a lake by a tornado.

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water strider

any of various insect-eating aquatic bugs of the family Gerridae that use their long legs to skate along the water surface without breaking through.

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water supply

distribution of water for domestic, municipal, or industrial consumption. Water supply in sparsely populated regions usually comes from underground water rising to the surface in natural springs, supplemented by pumps and wells. Urban sources are deep artesian wells, rivers, and reservoirs, usually formed from enlarged lakes or dammed and flooded valleys, from which water is conveyed by pipes, conduits, and aqueducts to filter beds. As water seeps through layers of shingle, gravel, and sand, harmful organisms are removed and the water is then distributed by pumping or gravitation through mains and pipes.

water treatment

Often other substances are added to the water, such as chlorine and fluoride; aluminium sulphate, a clarifying agent, is the most widely used chemical in water treatment. In towns, domestic and municipal (road washing, sewage) needs account for about 135 l/30 gal per head each day. In coastal desert areas, such as the Arabian peninsula, desalination plants remove salt from sea water. The Earth's waters, both fresh and saline, have been polluted by industrial and domestic chemicals, some of which are toxic and others radioactive (see water pollution).

drought

A period of prolonged dry weather can disrupt water supply and lead to drought. The area of the world subject to serious droughts, such as the Sahara, is increasing because of destruction of forests, overgrazing, and poor agricultural practices.

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water table

upper level of groundwater (water collected underground in porous rocks). Water that is above the water table will drain downwards; a spring forms where the water table meets the surface of the ground. The water table rises and falls in response to rainfall and the rate at which water is extracted, for example for irrigation and industry.

In many irrigated areas the water table is falling due to the extraction of water. Below northern China, for example, the water table is sinking at a rate of 1 m/3 ft a year. Regions with a high water table and dense industrialization have problems with pollution of the water table. In the USA, New Jersey, Florida, and Louisiana have water tables that are contaminated by both industrial wastes and saline seepage from the ocean.

Watson, James Dewey (1928-)

US biologist who was awarded a Nobel Prize for Physiology or Medicine in 1962 for the discovery of the double-helical structure of DNA and determining the significance of this structure in the replication and transfer of genetic information. He shared the prize with his co-worker Francis Crick.

Crick and Watson published their work on the proposed structure of DNA in 1953, and explained how genetic information could be coded.

Dr James D Watson Profile

Go to site

Description of the life and works of the discoverer of the structure of the DNA molecule, James Watson. Watson won the Nobel prize for his most famous discovery (made with Francis Crick) in 1962. The Web site contains not only a profile and biographical information, but also holds a lengthy interview with Watson from 1991 accompanied by a large number of photographs, video sequences, and audio clips.

Watson, John Broadus (1878-1958)

US psychologist, founder of behaviourism. He rejected introspection (observation by an individual of his or her own mental processes) and regarded psychology as the study of observable behaviour, within the scientific tradition.

Classics In The History Of Psychology - Psychology As The Behaviourist Views It

Go to site

Full transcript of John B Watson's 1913 paper *Psychology As The Behaviourist Views It*. This is Watson's most famous publication, and probably did more than anything else to turn psychology into a mainstream science and away from its introspective origins.

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watt

symbol W

SI unit of power (the rate of expenditure or transformation of energy from one form to another) defined as one joule per second. A light bulb, for example, may use 40, 60, 100, or 150 watts of power; an electric heater will use several kilowatts (thousands of watts). The watt is named after the Scottish engineer James Watt.

The absolute watt is defined as the power used when one joule of work is done in one second. In electrical terms, the flow of one ampere of current through a conductor whose ends are at a potential difference of one volt uses one watt of power (watts = volts × amperes).

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wattle

any of certain species of acacia in Australia, where their fluffy golden flowers are the national emblem. The leathery leaves are adapted to drought conditions and avoid loss of water through transpiration by turning their edges to the direct rays of the sun. Wattles are used for tanning leather and in fencing.

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wave

in the oceans, a ridge or swell formed by wind or other causes. The power of a wave is determined by the strength of the wind and the distance of open water over which the wind blows (the fetch). Waves are the main agents of coastal erosion and deposition: sweeping away or building up beaches, creating spits and berms, and wearing down cliffs by their hydraulic action and by the corrosion of the sand and shingle that they carry. A tsunami (misleadingly called a 'tidal wave') is formed after a submarine earthquake.

As a wave approaches the shore it is forced to break as a result of friction with the seabed. When it breaks on a beach, water and sediment are carried up the beach as **swash**; the water then drains back as **backwash**.

A **constructive wave** causes a net deposition of material on the shore because its swash is stronger than its backwash. Such waves tend be low and have crests that spill over gradually as they break. The backwash of a **destructive wave** is stronger than its swash, and therefore causes a net removal of material from the shore. Destructive waves are usually tall and have peaked crests that plunge downwards as they break, trapping air as they do so.

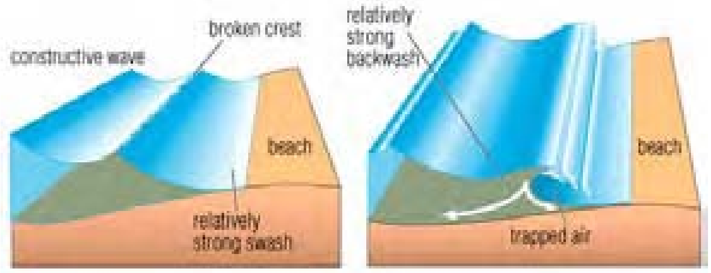
If waves strike a beach at an angle the beach material is gradually moved along the shore (longshore drift), causing deposition of material in some areas and erosion in others.

Atmospheric instability caused by the greenhouse effect and global warming appears to be increasing the severity of Atlantic storms and the heights of the ocean waves. Waves in the South Atlantic are shrinking - they are on average half a metre smaller than in the mid-1980s - and those in the northeast Atlantic have doubled in size over the last 40 years. As the height of waves affects the supply of marine food, this could affect fish stocks, and there are also implications for shipping and oil and gas rigs in the North Atlantic, which will need to be strengthened if they are to avoid damage.

Freak or 'episodic' waves form under particular weather conditions at certain times of the year, travelling long distances across the Atlantic, Indian, and Pacific oceans. They are considered responsible for the sudden unexplained disappearance of many ships.

Freak waves become extremely dangerous when they reach the shallow waters of the continental shelves at 100 fathoms (180 m/600 ft), especially when they meet currents: for example, the Agulhas Current to the east of South Africa, and the Gulf Stream in the North Atlantic. A wave height of 34 m/112 ft has been recorded.

wave



(Image © Research Machines plc)

The low, gentle crests of a constructive wave, with the energy of the wave flowing up the beach in a strong swash and depositing material, contrasts with the high, steep-crested, more forceful motions of destructive waves which crash in at an angle to the beach directing all their energy into plunging waves which tear up the sand and shingle and carry it out with the strong backwash.

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wave

in physics, oscillation that is propagated from a source. Mechanical waves require a medium through which to travel. Electromagnetic waves do not; they can travel through a vacuum. Waves carry energy but they do not transfer matter. The medium (for example the Earth, for seismic waves) is not permanently displaced by the passage of a wave. The model of waves as a pattern is used to help understand the properties of light and sound. Experiments conducted in a ripple tank with water waves can explain how waves slow down as water becomes shallower, how waves change direction when travelling through another medium, and how waves are reflected from different surfaces. See also standing wave.

types of wave

There are various ways of classifying wave types. One of these is based on the way the wave travels. In a transverse wave, the displacement of the medium is perpendicular to the direction in which the wave travels. An example of this type of wave is a mechanical wave projected along a tight string. The string moves at right angles to the wave motion. Electromagnetic waves are another example of transverse waves. The directions of the electric and magnetic fields are perpendicular to the wave motion. In a longitudinal wave the disturbance takes place parallel to the wave motion. A longitudinal wave consists of a series of compressions and rarefactions (states of maximum and minimum density and pressure, respectively). Such waves are always mechanical in nature and thus require a medium through which to travel. Sound waves are an example of longitudinal waves. Waves that result from a stone being dropped into water appear as a series of circles. These are called circular waves and can be generated in a ripple tank for study. Waves on water that appear as a series of parallel lines are called plane waves.

characteristics of waves

All waves have a wavelength. This is measured as the distance between successive crests (or successive troughs) of the wave. It is given the Greek symbol λ. The frequency of a wave is the number of vibrations per second. It is expressed in hertz, symbol Hz (1 Hz = 1 cycle per second). The reciprocal of this is the wave period. This is the time taken for one complete cycle of the wave oscillation. The speed of the wave is measured by multiplying wave frequency by the wavelength.

properties of waves

When a wave moves from one medium to another (for example a light wave moving from air to glass) it moves with a different speed in the second medium. This change in speed causes it to change direction. This property is called refraction. The angle of refraction depends on whether the wave is speeding up or slowing down as it changes medium. Reflection occurs whenever a wave hits a barrier. The wave is sent back, or reflected, into the medium. The angle of incidence (the angle between the ray and a perpendicular line drawn to the surface) is equal to the angle of reflection (the angle between the reflected ray and a perpendicular to the surface). See also total internal reflection. An echo is the repetition of a sound wave by reflection from a surface. All waves spread slightly as they travel. This is called diffraction and it occurs chiefly when a wave interacts with a solid object. The degree of diffraction depends on the relationship between the wavelength and the size of the object (or gap through which the wave travels). If the two are similar in size, diffraction occurs and the wave can be seen to spread out. Large objects cast shadows because the difference between their size and the wavelength is so large that light waves are not diffracted around the object. A dark shadow results. When two or more waves meet at a point, they interact and combine to produce a resultant wave of larger or smaller amplitude (depending on whether the combining waves are in or out of phase with each other). This is called interference. Transverse waves can exhibit polarization. If the oscillations of the wave take place in many different directions (all at right angles to the directions of the wave) the wave is unpolarized. If the oscillations occur in one plane only, the wave is polarized. Light, which consists of transverse waves, can be polarized.

Making Waves

Go to site

Easy-to-follow site created by students at a US high school. The topics covered include 'Sound', 'Microwave', 'Light and lasers', and 'Gamma rays'.

Physics Department: Waves

Go to site

Examination of the properties of waves. The site includes an introduction to waves, an explanation of transverse and longitudinal waves, plus reflection and interference. The site makes good use of diagrams and Java applets to explain the physics behind waves.

Wavelength

Go to site

General explanation of the basics behind waves. The information is offered in a series of lessons, which cover the nature, properties, and behaviour of waves, and also looks at standing waves.

Waves

Go to site

Animations demonstrating different types of wave behaviour. There are a series of Java applets demonstrating moving, stationary, and circular waves, plus reflection, refraction, and diffraction. This is a very simple but effective site.

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wave-cut platform

gently sloping rock surface found at the foot of a coastal cliff. Covered by water at high tide but exposed at low tide, it represents the last remnant of an eroded headland (see coastal erosion). Wave-cut platforms have a gentle gradient (usually less than 1°) and can be up to about 1 km/0.6 mi in length. Over time, wave-cut platforms are lengthened and protect the cliffs behind them.

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waveguide

hollow metallic tube, either empty or containing a dielectric, used to guide a high-frequency electromagnetic wave (microwave) travelling within it. The wave is reflected from the internal surfaces of the guide. Waveguides are extensively used in radar systems.

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wavelength

distance between successive crests or troughs of a wave. The wavelength of a light wave determines its colour; red light has a wavelength of about 700 nanometres, for example. The complete range of wavelengths of electromagnetic waves is called the electromagnetic spectrum.

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wave power

power obtained by harnessing the energy of water waves. Various schemes have been advanced since 1973 when oil prices rose dramatically and an energy shortage threatened. In 1974, the British engineer Stephen Salter developed the 'duck' - a floating boom, the segments of which nod up and down with the waves. The nodding motion can be used to drive pumps and spin generators. Another device, developed in Japan, uses an oscillating water column to harness wave power. A major technological breakthrough will be required if wave power is ever to contribute significantly to the world's energy needs, although several ideas have reached prototype stage.

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wax

solid fatty substance of animal, vegetable, or mineral origin.

Waxes are composed variously of esters, fatty acids, free alcohols, and solid hydrocarbons.

Mineral waxes are obtained from petroleum and vary in hardness from the soft petroleum jelly (or petrolatum) used in ointments to the hard paraffin wax employed for making candles and waxed paper for drinks cartons.

Animal waxes include beeswax, the wool wax lanolin, and spermaceti from sperm-whale oil; they are used mainly in cosmetics, ointments, and polishes. Another animal wax is tallow, a form of suet obtained from cattle and sheep's fat, once widely used to make candles and soap. Sealing wax is made from lac or shellac, a resinous substance obtained from secretions of scale insects.

Vegetable waxes, which usually occur as a waterproof coating on plants that grow in hot, arid regions, include carnauba wax (from the leaves of the carnauba palm) and candelilla wax, both of which are components of hard polishes such as car waxes.

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waxbill

any of a group of small, mainly African, seed-eating birds in the family Estrildidae, order Passeriformes, which also includes the grass finches of Australia. Waxbills grow to 15 cm/6 in long, are brown and grey with yellow, red, or brown markings, and have waxy-looking red or pink beaks.

They sometimes raise the young of whydahs, who lay their eggs in waxbill nests.

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waxwing

any of several fruit-eating birds of the family Bombycillidae, order Passeriformes. They are found in the northern hemisphere. The Bohemian waxwing *Bombycilla garrulus* of North America and Eurasia is about 18 cm/7 in long, and is greyish-brown above with a reddish-chestnut crest, black streak at the eye, and variegated wings. It undertakes mass migrations in some years.

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wayfaring tree

European shrub belonging to the honeysuckle family, with clusters of fragrant white flowers, found on limy soils; it is naturalized in the northeastern USA. (Genus *Viburnum lantana*, family Caprifoliaceae.)

Wb

in physics, symbol for weber, the SI unit of magnetic flux, equal to the flux that (linking a circuit of one turn) produces an emf (electromotive force) of 1 volt when the flux is reduced at a constant rate to zero in 1 second.

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weak acid

acid that only partially ionizes in aqueous solution (see dissociation). Weak acids include ethanoic acid and carbonic acid. The pH of such acids lies between pH 3 and pH 6.

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weak base

base that only partially ionizes in aqueous solution (see dissociation); for example, ammonia. The pH of such bases lies between pH 8 and pH 10.

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weak nuclear force

or weak interaction

one of the four fundamental forces of nature, the other three being the gravitational force or gravity, the electromagnetic force, and the strong nuclear force. It causes radioactive beta decay and other subatomic reactions. The particles that carry the weak force are called weakons (or intermediate vector bosons) and comprise the positively and negatively charged W particles and the neutral Z particle.

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weakon

or intermediate vector boson

member of a group of elementary particles, see intermediate vector boson.

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weapon

any implement used for attack and defence, from simple clubs, spears, and bows and arrows in prehistoric times to machine guns and nuclear bombs in modern times. A revolution in warfare came with the invention of gunpowder and the development of cannons and shoulder-held guns. Many other weapons now exist, such as grenades, shells, torpedoes, rockets, and guided missiles. The ultimate in explosive weapons are the atomic (fission) and hydrogen (fusion) bombs. They release the enormous energy produced when atoms split or fuse together. There are also chemical and bacteriological weapons, which release poisons or disease.

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weasel

any of various small, short-legged, lithe carnivorous mammals with bushy tails, especially the genus *Mustela*, found worldwide except Australia. They feed mainly on small rodents although some, like the mink *M. vison*, hunt aquatic prey. Most are 12-25 cm/5-10 in long, excluding the tail.

Included in this group are the North American long-tailed weasel, the northern hemisphere ermine or stoat, the Eurasian polecat, and the endangered North American black-footed ferret. In cold regions the coat colour of several species changes to white during the winter.

Black-footed ferrets were so close to extinction in 1987 that the entire wild population was taken into captivity. The captive population has grown from 18 then to 350 in 1998. Some have also been released back into the wild, where the population stands at between 50 and 60.

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weather

variation of atmospheric conditions at any one place over a short period of time. Such conditions include humidity, precipitation, temperature, cloud cover, visibility, and wind. Weather differs from climate in that the latter is a composite of the average weather conditions of a locality or region over a long period of time (at least 30 years). Meteorology is the study of short-term weather patterns and data within a particular area; climatology is the study of weather over longer timescales on a zonal or global basis. Weather forecasts are based on current meterological data, and predict likely weather for a particular area.

weather

The
ENEMY
is listening

(Image © National Oceanic and Atmospheric Administration/Department of Commerce)

During World War II it was essential for the Royal Air Force to have the most accurate meteorological - and specifically high-altitude - information possible, before the pilots took off on their dangerous missions. It was one of many jobs that were entrusted to women during wartime. Precedents were set for the involvement of women in a wide variety of industries, including meteorology and weather forecasting, in the following years.

weather prediction: pressure

A weather prediction:

When smoke descends, good weather ends
(low pressure forces smoke down)

weather prediction: rain

A weather prediction:

Rain before seven, fine before eleven

weather prediction: rain and dew

A weather prediction:

When grass is dry in morning light, look for rain before the night. When the dew is on the grass, rain will never come to pass

weather prediction: red sky

A traditional rhyme to predict the weather:

Red sky at night, shepherds delight, red sky in the morning, shepherds warning
In other words if the sky is red in the evening, the next day will be fine, but if it is red in the morning, expect bad weather

weather prediction: storms

A weather prediction:

Sound travelling far and wide, a stormy day this doth betide
(in fair weather, sound waves travel upward and outward in the atmosphere and dissipate there; on humid, cloudy days, they are sent back to earth)

weather system

A formula for finding the centre of a weather system (applies in the northern hemisphere only; reverse for the southern hemisphere):

When the wind is at your back, the low is on your left

Dan's Wild Wild Weather Page

Go to site

Introduction to the weather for kids. It has pages dealing with everything from climate to lightning, from satellite forecasting to precipitation - all explained in a lively style with plenty of pictures.

Weather: What Forces Affect Our Weather?

Go to site

User-friendly, US-based site exploring aspects of climate including 'The water cycle', 'Powerful storms', and 'Our changing climate'. The site includes 'hands-on' activities such as 'Try your hand at tornado chasing'.

---

weather forecast

prediction for changes in the weather. The forecast is based on several different types of information from several sources. Weather stations are situated around the world, on land, in the air (on aircraft and air balloons), and in the sea (on ships, buoys, and oilrigs). Forecasters also use satellite photographs which show cloud patterns, and information from the Meteorological Office, such as a synoptic chart which shows atmospheric pressure and changes in air masses (known as a weather front). The information is used to predict the weather over a 24-hour period, and to suggest likely changes over a period of three or four days.

Forecasts may be short-range (covering a period of one or two days), medium-range (five to seven days), or long-range (a month or so). Weather observations are made on an hourly basis at meteorological recording stations - there are more than 3,500 of these around the world. More than 140 nations participate in the exchange of weather data through the World Weather Watch programme, which is sponsored by the World Meteorological Organization (WMO), and information is distributed among the member nations by means of a worldwide communications network. Incoming data is collated at weather centres in individual countries and plotted on weather maps, or charts. The weather map uses internationally standardized symbols to indicate barometric pressure, cloud cover, wind speed and direction, precipitation, and other details reported by each recording station at a specific time. Points of equal atmospheric pressure are joined by lines called isobars and from these the position and movement of weather fronts and centres of high and low pressure can be extrapolated. The charts are normally compiled on a three-hourly or six-hourly basis - the main synoptic hours are midnight, 0600, 1200 and 1800 - and predictions for future weather are drawn up on the basis of comparisons between current charts and previous charts. Additional data received from weather balloons and satellites help to complete and corroborate the picture obtained from the weather map.

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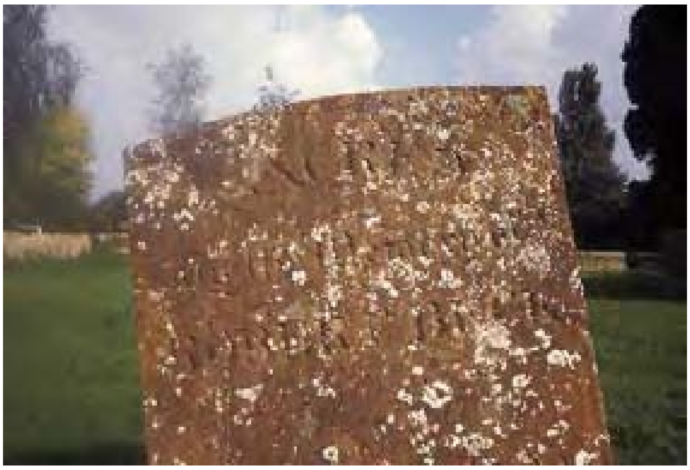
weathering

process by which exposed rocks are broken down on the spot (in situ) by the action of rain, frost, wind, and other elements of the weather. It differs from erosion in that no movement or transportion of the broken-down material takes place. Two types of weathering are recognized: physical (or mechanical) weathering and chemical weathering. They usually occur together, and are an important part of the development of landforms.

weathering



(Image © Garret Nagle)

A weathered gravestone at Cassington, Oxfordshire, England. Gravestones are excellent laboratories for geographers. The date on the grave gives us a good idea how long the rock has been exposed to the forces of nature. The gravestone has been subjected to biological weathering (the growth of lichens, ivy and other plants). In the UK, west-facing stones are usually more weathered than east-facing stones, because winds from the west are warmer and moister, whereas east winds are typically colder and drier. Rock type is also important: igneous and metamorphic rocks, such as granite and marble, weather more slowly than sedimentary rocks, such as limestone.

weathering

(Image © Garret Nagle)

This rock face in the Dolomite mountains of northern Italy has been subjected to extensive weathering. Unlike mountains in other parts of the Alps, the various peaks are not linked by smooth and winding crests, but instead stand apart and isolated.

Physical Weathering

Go to site

After a quick definition of weathering and erosion the main body of this page deals with physical weathering. The types of physical weathering covered are 'Pressure release', 'Exfoliation', 'Frost shattering', 'Crystallization', and 'Biological weathering'. The locations in which the different types of weathering take place are covered, and links are provided to other types of weathering.

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weaver

any small bird of the family Ploceidae, order Passeriformes; they are mostly about 15 cm/6 in long. The majority of weavers are African, a few Asian. The males use grasses to weave elaborate globular nests in bushes and trees. The nests are entered from beneath, and the male hangs from it calling and flapping his wings to attract a female. Their bodies are somewhat elongated and the tails long, and the prominent conical bill is very powerful. They eat insects and may eat cultivated grain. Males are often more brightly coloured than females.

Many kinds are polygamous, so build several nests, and some species build large communal nests with many chambers. One species, the red-billed African quelea *Quelea quelea*, lives and breeds in flocks numbering many thousands of individuals; the flocks migrate to follow food sources. Their destructive power can equal that of locusts.

Web browser

in computing, client software that allows access to the World Wide Web. See browser.

---

weber

symbol Wb

SI unit of magnetic flux (the magnetic field strength multiplied by the area through which the field passes). It is named after German chemist Wilhelm Weber. One weber equals 10^8 maxwells.

A change of flux at a uniform rate of one weber per second in an electrical coil with one turn produces an electromotive force of one volt in the coil.

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wedge

block of triangular cross-section that can be used as a simple machine. An axe is a wedge: it splits wood by redirecting the energy of the downward blow sideways, where it exerts the force needed to split the wood.

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weedkiller

or herbicide

chemical that kills some or all plants. Selective herbicides are effective with cereal crops because they kill all broad-leaved plants without affecting grasslike leaves. Those that kill all plants include sodium chlorate and paraquat; see also Agent Orange. The widespread use of weedkillers in agriculture has led to an increase in crop yield but also to pollution of soil and water supplies and killing of birds and small animals, as well as creating a health hazard for humans.

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weever fish

any of a family (Trachinidae) of marine bony fishes of the perch family, especially the genus *Trachinus*, with poison glands on the dorsal fin and gill cover that can give a painful sting. It grows up to 5 cm/2 in long, has eyes near the top of the head, and lives on sandy seabeds.

---

weevil

any of a superfamily (Curculionoidea) of beetles, usually less than 6 mm/0.25 in in length, and with a head prolonged into a downward beak, which is used for boring into plant stems and trees for feeding.

The larvae are usually white and the adults green, black, or brown. There are approximately 570 species of weevil in Britain and 40,000 known species worldwide. The grain weevil *Sitophilus granarius* is a serious pest of stored grain and the boll weevil *Anthonomus grandis* damages cotton crops.

Wegener, Alfred Lothar (1880-1930)

German meteorologist and geophysicist whose theory of continental drift, expounded in *Origin of Continents and Oceans* in 1915, was originally known as 'Wegener's hypothesis'. His ideas can now be explained in terms of plate tectonics, the idea that the Earth's crust consists of a number of plates, all moving with respect to one another.

---

weight

force exerted on an object by gravity. The weight of an object depends on its mass - the amount of material in it - and the strength of the Earth's gravitational pull (the acceleration due to gravity), which decreases with height. Consequently, an object weighs less at the top of a mountain than at sea level. On the surface of the Moon, an object has only one-sixth of its weight on Earth (although its mass is unchanged), because the Moon's surface gravity is one-sixth that of the Earth's.

---

weightlessness

apparent loss in weight of a body in free fall. Astronauts in an orbiting spacecraft do not feel any weight because they are falling freely in the Earth's gravitational field (not because they are beyond the influence of Earth's gravity). The same phenomenon can be experienced in a falling lift or in an aircraft imitating the path of a freely falling object.

weightlessness

(Image © NASA)

Astronaut Janice Voss experiencing weightlessness aboard a DC-9 aircraft. Parabolic trajectories are flown by aircraft such as this and the notorious KC-135 'vomit comet', to produce weightless conditions for experimental and training purposes.

Weil's disease

or leptospirosis

infectious disease of animals that is occasionally transmitted to human beings, usually by contact with water contaminated with rat urine. It is characterized by acute fever, and infection may spread to the brain, liver, kidneys, and heart. It has a 10% mortality rate.

The usual form occurring in humans is caused by a spiral-shaped bacterium (spirochete) that is a common parasite of rats. The condition responds poorly to antibiotics.

---

weir

low wall built across a river to raise the water level.

Weismann, August Friedrich Leopold (1834-1914)

German biologist, one of the founders of genetics. He postulated that every living organism contains a special hereditary substance, the 'germ plasm', and in 1892 he proposed that changes to the body do not in turn cause an alteration of the genetic material.

This 'central dogma' of biology remains of vital importance to biologists supporting the Darwinian theory of evolution. If the genetic material can be altered only by chance mutation and recombination, then the Lamarckian view that acquired bodily changes can subsequently be inherited becomes obsolete.

---

welding

joining pieces of metal (or non-metal) at faces rendered plastic or liquid by heat or pressure (or both). The principal processes today are gas and arc welding, in which the heat from a gas flame or an electric arc melts the faces to be joined. Additional 'filler metal' is usually added to the joint.

Forge (or hammer) welding, employed by blacksmiths since early times, was the only method available until the late 19th century. Resistance welding is another electric method in which the weld is formed by a combination of pressure and resistance heating from an electric current. Recent developments include electric-slag, electron-beam, high-energy laser, and the still experimental radio-wave energy-beam welding processes.

welding

(Image © Research Machines plc)

Shielded metal arc welding, or stick welding, is one of the most commonly used welding processes. The metal to be joined is heated by means of an electric arc created between the welding tool's coated electrode and the metal.

Welsh corgi

breed of dog with a foxlike head and pricked ears, originally bred for cattle herding. The coat is dense, with several varieties of colouring. Corgis are about 30 cm/12 in at the shoulder, and weigh up to 12 kg/27 lb.

There are two types of corgi, the Pembrokeshire and the Cardiganshire. The Pembrokeshire has a finely textured coat, yellowish or reddish brown, or sometimes black and tan, and has almost no tail. The Cardiganshire corgi has a short, rough coat, usually red and white, and a long furry tail. Their small size is an advantage because cattle are unable to bend low enough to gore them.

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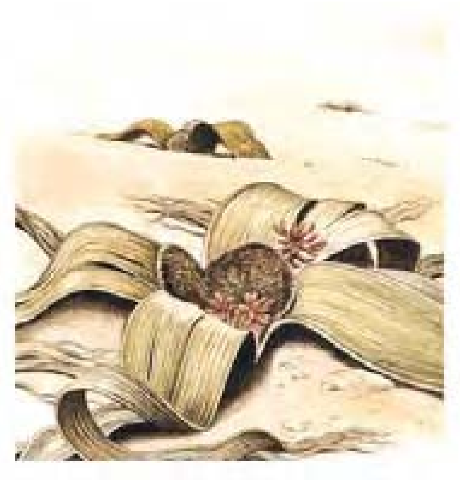
welwitschia

woody plant found in the deserts of southwestern Africa. It has a long, water-absorbent taproot and can live for up to 100 years. (Genus *Welwitschia mirabilis*, order Gnetales.)

welwitschia



(Image © Research Machines plc)

This rare plant is found only in the coastal deserts of Namibia and Angola. It is a gymnosperm like conifers and cycads but it is quite different from them. It uses its very long taproot to absorb the slightest moisture from deep below the ground, and may live for several hundred years.

Werner, Abraham Gottlob (1749-1817)

German geologist, one of the first to classify minerals systematically. He also developed the later discarded theory of neptunism – that the Earth was initially covered by water, with every mineral in suspension; as the water receded, layers of rocks 'crystallized'.

Werner, Alfred (1866-1919)

French-born Swiss chemist. He was awarded the Nobel Prize for Chemistry in 1913 for his work on valency theory, which gave rise to the concept of coordinate bonds and coordination compounds.

Werner demonstrated that different three-dimensional arrangements of atoms in inorganic compounds gives rise to optical isomerism (the rotation of polarized light in opposite directions by molecules that contain the same atoms but are mirror images of each other).

Werner's syndrome

in medicine, a rare genetic disorder characterized by premature ageing. In their late twenties sufferers show signs of advanced ageing, with greying hair, wrinkles, and cataracts. They develop cancer, heart disease, and other medical problems usually associated with the elderly, and do not usually survive beyond 50. Werner's gene, located 1996, codes for the enzyme helicase that is involved in the unwinding of DNA before division. The syndrome results from two defective copies of this gene.

westerlies

prevailing winds from the west that occur in both hemispheres between latitudes of about 35° and 60°. Unlike the trade winds, they are very variable and produce stormy weather.

The westerlies blow mainly from the southwest in the northern hemisphere and the northwest in the southern hemisphere, bringing moist weather to the west coast of the landmasses in these latitudes.

Westinghouse, George (1846-1914)

US inventor and founder of the Westinghouse Corporation in 1886. He patented a powerful air brake for trains in 1869, which allowed trains to run more safely with greater loads at higher speeds. In the 1880s he turned his attention to the generation of electricity. Unlike Thomas Edison, Westinghouse introduced alternating current (AC) into his power stations.

Weston, Edward (1886-1958)

US photographer. A founding member of the 'f/64' group (after the smallest lens opening), a school of photography advocating sharp definition. He is noted for the technical mastery, composition, and clarity in his California landscapes, clouds, gourds, cacti, and nude studies.

weta

flightless insect *Deinacrida rugosa*, 8.5 cm/3.5 in long, resembling a large grasshopper, found on offshore islands of New Zealand.

wetland

permanently wet land area or habitat. Wetlands include areas of marsh, fen, bog, flood plain, and shallow coastal areas. Wetlands are extremely fertile. They provide warm, sheltered waters for fisheries, lush vegetation for grazing livestock, and an abundance of wildlife. Estuaries and seaweed beds are more than 16 times as productive as the open ocean.

The term is often more specifically applied to a naturally flooding area that is managed for agriculture or wildlife. A water meadow, where a river is expected to flood grazing land at least once a year thereby replenishing the soil, is a traditional example.

wetted perimeter

length of that part of a river's cross-section that is in contact with the water. The wetted perimeter is used to calculate a river's hydraulic radius, a measure of its channel efficiency.

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whale

any marine mammal of the order Cetacea. The only mammals to have adapted to living entirely in water, they have front limbs modified into flippers and no externally visible traces of hind limbs. They have horizontal tail flukes. When they surface to breathe, the hot air they breathe out condenses to form a 'spout' through the blowhole (single or double nostrils) in the top of the head. Whales are intelligent and have a complex communication system, known as 'songs'. They occur in all seas of the world.

The order is divided into two groups: the toothed whales (Odontoceti) and the baleen whales (Mysticeti). Toothed whales are predators, feeding on fish and squid. They include dolphins and porpoises, along with large forms such as sperm whales. The largest whales are the baleen whales, with plates of modified mucous membrane called baleen (whalebone) in the mouth; these strain the food, mainly microscopic plankton, from the water. Baleen whales include the finback and right whales, and the blue whale, the largest animal that has ever lived, of length up to 30 m/100 ft.

Whales have been hunted for hundreds of years (see whaling); today they are close to extinction. Of the 11 great whale species, 7 were listed as either endangered or vulnerable in 1996. Whale-watching, as an economic alternative to whaling, generated US$121 million worldwide in 1994.

whale

The song of the blue whale is extraordinarily precise: it consists of one note every 128 seconds. A note may be missed in which the whale pauses and then makes its next note after 256 seconds. The sound carries hundreds of kilometres.

whale: barnacles

Most of the great whales have barnacles living on them. The grey whale is the most heavily encrusted, mainly around its head and along its back. About 100,000 lice live among the barnacles on each whale.

whale: bone density

The densest bone ever found is in the skull of Blaineville's beaked whale *Mesoplodon densirostris*; it has a density of 2.7 g/0.1 oz per cm^3, about 50% denser than the average mammalian bone.

whale: diving

The beluga (white whale) can dive to depths of 600 m/1,969 ft and stay down for up to 18 minutes.

whale: feeding

A full-grown humpback whale must consume a tonne of krill each day. This provides it with the daily equivalent of more than one million calories.

whale: skull

A whale's skull is made up of 30 bones (compared with 22 in the human skull).

Classification of Whales

Go to site

Description of the two suborders of cetaceans: the baleen whales or *Mysticeti* and the toothed whales or *Odontoceti*. A chart shows the main differences between the two suborders.

Whales - Endangered Species

Go to site

Home page of the endangered species of whales in both the North Atlantic and North Pacific regions. Further pages describe the biology, distribution, and threat to each of the endangered species in turn.

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whaling

the hunting of whales. Whales have been killed by humans since at least the middle ages. There were hundreds of thousands of whales at the beginning of the 20th century, but the invention of the harpoon in 1870, and improvements in ships and mechanization, have led to the near-extinction of several species of whale. Commercial whaling was largely discontinued in 1986, although Norway and Japan have continued commercial whaling.

Traditional whaling areas include the coasts of Greenland and Newfoundland, but the Antarctic, in the summer months, supplies the bulk of the catch.

Practically the whole of the animal can be utilized in one form or another: whales are killed for whale oil (made from the thick layer of fat under the skin, called 'blubber'), which is used as a lubricant, or for making soap, candles, and margarine; for the large reserve of oil in the head of the sperm whale, used in the leather industry; and for **ambergris**, a waxlike substance from the intestines of the sperm whale, used in making perfumes. Whalebone was used by corset manufacturers and in the brush trade; there are now synthetic substitutes for all these products. Whales have also been killed for use in pet food manufacture in the USA and Europe, and as a food in Japan. The flesh and ground bones are used as soil fertilizers.

Whaling

whaling in crisis

The 30-year debate about commercial killing of whales, a group of intelligent marine mammals, flared up again with Norway's resumption of the killing of minke whales (*Balaenoptera acutorostrata*) for meat in 1993.

Commercial killing of whales, for meat, blubber, whalebone (the baleen filters used by many whales to filter plankton from the water), sperm whale oil, and so on, has devastated many populations. The blue whale (*Balaenoptera musculus*) is the largest animal ever to have lived on earth, weighing in at the equivalent of 30 elephants, or 1,600 people, and measuring up to 30 m/100 ft. A favourite of the whaling fleets, its population was reduced from an original 250,000 (estimated) to under 3,000 before it was protected in 1967. Its long-term survival remains uncertain.

the IWC ban

Whale hunting is controlled, in theory, by the International Whaling Commission (IWC) set up in 1946 and now with delegates from 38 countries. In 1982, in response to rising worries about the decline in whale populations, concern about the suffering of whales during the hunt, and an increasing domination of the IWC by nonwhaling nations, the commission voted to ban commercial whaling indefinitely from 1986. (Some 'subsistence' whaling continues by isolated populations, such as the Alaskan Inuit and Siberian Aleut people, Faroese, and Greenlanders.) The 1982 vote was regarded as a major victory for the environmental lobby and was hailed as the end of whaling.

However, the minority of whaling nations continued to lobby for the hunt to resume. In 1991, Iceland resigned from the IWC in protest at the continuing moratorium. In 1993, Japan and Norway both lobbied to be allowed to resume hunting minke whales, citing evidence that populations had increased. Arguments in favour of whaling ranged from the need for remote fishing communities to find employment, claims that minke whales were reducing stocks of cod, and even suggestions that increases in minke whale numbers were inhibiting the recovery of other whale populations.

Norway ignores the ban

In the event, the IWC voted to maintain the ban. However, Norway decided to ignore the ruling which, like many international agreements, has no legal standing outside the agreement between members, and accordingly started commercial whaling again. The decision also caused discord within the environmental movement, with some smaller organizations accusing the more established bodies of taking too soft a line. Greenpeace activists have been arrested for attempting to block the hunt.

Meanwhile, whales have some extra protection but also face new threats. The establishment of the Southern Ocean Whale Sanctuary by the IWC effectively provides long-term protection against pelagic whaling to nearly all the whales of the southern hemisphere. But new threats come from marine pollution, especially organochlorines such as PCBs, declining stocks of prey species, and climate change.

The main economic benefits from whales today come from those allowed to live peacefully. Millions of people around the world pay to watch whales in places where they pass close to shore on their migrations. In 1994, whale-watching worldwide generated $121 million.

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wheat

cereal plant derived from the wild *Triticum*, a grass native to the Middle East. It is the chief cereal used in breadmaking and is widely cultivated in temperate climates suited to its growth. Wheat is killed by frost, and damp makes the grains soft, so warm, dry regions produce the most valuable grain.

The main wheat-producing areas of the world are the Ukraine, the prairie states of the USA, the Punjab in India, the Prairie Provinces of Canada, parts of France, Poland, southern Germany, Italy, Argentina, and southeastern Australia. Flour is milled from the nutritious tissue surrounding the embryonic plant in the grain (the endosperm); the coatings of the grain produce bran. Semolina is also prepared from wheat; it is a by-product from the manufacture of fine flour.

wheat harvest

(Image © Corel)

Grain harvesting in Canada. The majority of Canada's wheat is grown on the prairies of Saskatchewan, Manitoba, and Alberta.

wheatear

small (15 cm/6 in long) migratory bird *Oenanthe oenanthe* of the family Muscicapidae, order Passeriformes (which includes thrushes). Wheatears are found throughout the Old World and also breed in far northern parts of North America. The plumage is light grey above and white below with a buff tinge on the breast, a black face-patch, and black and white wings and tail. In flight a white patch on the lower back and tail is conspicuous. The wheatear's food consists chiefly of insects.

Wheeler, (Robert Eric) Mortimer (1890-1976)

English archaeologist. After a number of distinguished excavations in Britain, he was director general of archaeology in India 1944-48, and later adviser to the government of Pakistan. He excavated sites of the forgotten Indus Valley civilization, which flourished in the later 3rd millennium, and helped to popularize archaeology by appearances on television, even on entertainment programmes such as *Animal, Vegetable or Mineral*.

Wheeler adhered to the rules for stratigraphic excavation set down by the English archaeologist Augustus Pitt-Rivers, despite the sometimes less than scientific methodology pursued by his contemporaries.

Two major cities were excavated in the Indus Valley, Mohenjo Daro and Harappa, revealing a society that was advanced enough to produce ceremonial and state architecture and a complex water, drainage, and waste-disposal system. Other excavations were carried out at Charsada and Taxila in northwestern India, and at Arikamedu (the Roman-Indian trading post of Poduca) in southern India after identifying Roman pottery in the government museum.

Among Wheeler's many excavation reports and books are *Maiden Castle, Dorset* 1943 and *The Indus Civilization* 1968.

whelk

any of various families of large marine snails with a thick spiral shell, especially the family Buccinidae. Whelks are scavengers, and also eat other shellfish. The largest grow to 40 cm/16 in long. Tropical species, such as the conches, can be very colourful.

whey

watery by-product of the cheesemaking process, which is drained off after the milk has been heated and rennet (a curdling agent) added to induce its coagulation.

In Scandinavia, especially Norway, whey is turned into cheese, *mysost* and (from goat's whey) *gjetost*. The flavour of whey cheese is sweet from added brown sugar and is an acquired taste.

whimbrel

wading bird *Numenius phaeopus*, order Charadriiformes, with a medium-sized down-curved bill, streaked brown plumage, and striped head. About 40 cm/1.3 ft long, it breeds in the Arctic, and winters in Africa, southern North America, South America, and South Asia. It is related to the curlew.

whiplash injury

damage to the neck vertebrae and their attachments caused by a sudden backward jerk of the head and neck. It is most often seen in vehicle occupants as a result of the rapid deceleration experienced in a crash.

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whippet

breed of dog resembling a small greyhound. It grows to 56 cm/22 in at the shoulder, and 9 kg/20 lb in weight.

Whippets: Born to Run

Go to site

Everything you always wanted to know about whippets: their relationship to greyhounds, their agility and speed (including QuickTime movie) and how to rear, care, and race them, together with many links to related sites.

Whipple, Fred Lawrence (1906-2004)

US astronomer whose hypothesis in 1949 that the nucleus of a comet is like a dirty snowball was confirmed in 1986 by space-probe studies of Halley's Comet.

Whipple, George Hoyt (1878-1976)

US physiologist who was awarded the Nobel Prize for Physiology or Medicine in 1934 for work on the treatment of pernicious anaemia by increasing the amount of liver in the diet. His research interest concerned the formation of haemoglobin in the blood. He showed that anaemic dogs, kept under restricted diets, responded well to a liver regime, and that their haemoglobin quickly regenerated. This work led to a cure for pernicious anaemia. He shared the prize with George Minot and William Murphy.

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whippoorwill

North American nightjar*Caprimulgus vociferus*, order Caprimulgiformes, so called from its cry during the nights of its breeding season. It is about 25 cm/10 in long, mottled tawny brown in colour, with a white collar on the throat, and long, stiff bristles at the base of the bill.

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whip snake

or coachwhip

any of the various species of nonpoisonous slender-bodied tree-dwelling snakes of the New World genus *Masticophis*, family Colubridae. They are closely allied to members of the genus *Coluber* of southwestern North America, Eurasia, Australasia, and North Africa, some of which are called whip snakes in the Old World, but racers in North America.

Whip snakes grow to about 1.5 m/5 ft in length, move very quickly, and are partially tree-dwelling. They feed on rodents, small birds, lizards, sucker frogs, and insects. All lay eggs.

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whirligig beetle

aquatic steel-black beetle with an oval, flattened body. The second and third pairs of legs are exceptionally short and broad, and are used for paddling in the water. About 400 species have been recorded.

classification

The whirligig beetle is in the family Gyrinidae, order Coleoptera, class Insecta, phylum Arthropoda.

Whirligig beetles are usually found in groups whirling around on the water surface. When disturbed they dart into the water. Both adults and larvae are carnivorous, feeding on small insects that fall onto the water. The adults have well developed wings and are capable of flying from one pond to the next.

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whirling disease

parasitic disease of trout. The parasite *Myxobolus cerebralis* spends part of its life cycle in tubifex worms, before moving to trout where it consumes the cartilage causing eventual death. Infected fish start to swim in circles after their spines have been destroyed, hence the name.

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whirlwind

rapidly rotating column of air, often synonymous with a tornado. On a smaller scale it produces the dust-devils seen in deserts.

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whitebait

any of the fry (young) of various silvery fishes, especially herring. It is also the name for a Pacific smelt *Osmerus mordax*.

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whitebeam

tree native to southern Europe, usually found growing on chalk or limestone. It can reach 20 m/60 ft in height. It takes its name from the dense coat of short white hairs on the underside of the leaves. (Genus *Sorbus aria*, family Rosaceae.)

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white blood cell

part of the body's immune system; see leukocyte.

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white dwarf

small, hot star, the last stage in the life of a star such as the Sun. White dwarfs make up 10% of the stars in the Galaxy; most have a mass 60% of that of the Sun, but only 1% of the Sun's diameter, similar in size to the Earth. Most have surface temperatures of 8,000°C/14,400°F or more, hotter than the Sun. However, being so small, their overall luminosities may be less than 1% of that of the Sun. The Milky Way contains an estimated 50 billion white dwarfs.

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whitefish

any of various freshwater fishes, genera *Coregonus* and *Prosopium*, of the salmon family, found in lakes and rivers of North America and Eurasia. They include the **whitefish** *C. clupeaformis* and **cisco** *C. artedi*.

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whitefly

tiny four-winged insect related to aphids and scale insects. The adults barely exceed a length of 3 mm/0.12 in; their wings are dusted with a powdery white wax which they secrete. In temperate countries they may be found in glasshouses, where they are pests of plants, such as cucumber and tomato. They are widely distributed in the tropics, where they attack citrus trees. They injure the plant by feeding on the sap and excreting honeydew, which encourages sooty black mould to grow.

classification

Whiteflies are in family Aleyrodidae, order Hemiptera, class Insecta, phylum Arthropoda.

development

In general the eggs are laid on the undersurface of leaves in a characteristic circular or arch-shape, and are attached to the leaves by means of a stalk. Each female lays about 100 eggs that hatch into first-instar larvae, which are oval-shaped, have antennae, walking legs, and feed actively by means of their stylets and proboscis. The mobile first-instar larva moults into a rather immobile second-instar larva, which is similar in shape, but has much shorter legs and antennae; third and fourth instars follow; the fourth feeds initially, but then stops and secretes a case around itself which bears waxy filaments. The case splits along a characteristic T-shaped line of suture (dorsally) and the adult whitefly emerges.

Whitehead, Alfred North (1861-1947)

English philosopher and mathematician. In his 'theory of organism', he attempted a synthesis of metaphysics and science. His works include *Principia Mathematica* (1910-13) (with Bertrand Russell), *The Concept of Nature* (1920), and *Adventures of Ideas* (1933).

Whitehead's research in mathematics involved a highly original attempt - incorporating the principles of logic - to create an extension of ordinary algebra to universal algebra (*A Treatise of Universal Algebra* (1898)), and a meticulous re-examination of the relativity theory of Albert Einstein.

Whitehead, Alfred North

Go to site

Good summary of the life and legacy of the English mathematician and logician. His influence in mathematics, metaphysics, and the philosophy of science is examined. There is a full list of his publications and a good bibliography.

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whiteout

'fog' of grains of dry snow caused by strong winds in temperatures of between -18°C/0°F and -1°C/30°F. The uniform whiteness of the ground and air causes disorientation in humans.

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white spirit

colourless liquid derived from petrol; it is used as a solvent and in paints and varnishes.

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whitethroat

any of several Old World warblers of the genus *Sylvia* in the family Muscicapidae, order Passeriformes. They are found in scrub, hedges, and wood clearings of Eurasia in summer, migrating to Africa in winter. They are about 14 cm/5.5 in long.

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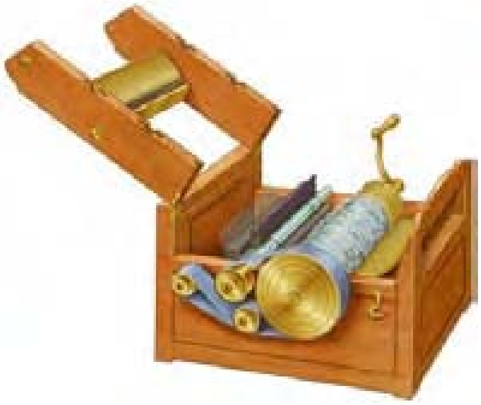
whiting

any of various edible marine bony fishes, especially the silver hake and various kingfishes, genus *Menticirrhus*.

Whitney, Eli (1765-1825)

US inventor who in 1794 patented the cotton gin, a device for separating cotton fibre from its seeds. Also a manufacturer of firearms, he created a standardization system that was the precursor of the assembly line.

cotton gin



(Image © Research Machines plc)

The cotton gin, devised by US inventor Eli Whitney, separates the cotton fibres from the seed bolls (pods).

Whittle, Frank (1907-1996)

English engineer. He patented the basic design for the turbojet engine in 1930. In the Royal Air Force he worked on jet propulsion 1937-46. In May 1941 the Gloster E 28/39 aircraft first flew with the Whittle jet engine. Both the German (first operational jet planes) and the US jet aircraft were built using his principles. He was knighted in 1948.

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whooping cough

or pertussis

acute infectious disease, seen mainly in children, caused by colonization of the air passages by the bacterium *Bordetella pertussis*. There may be catarrh, mild fever, and loss of appetite, but the main symptom is violent coughing, associated with the sharp intake of breath that is the characteristic 'whoop', and often followed by vomiting and severe nose bleeds. The cough may persist for weeks.

Although debilitating, the disease is seldom serious in older children, but infants are at risk both from the illness itself and from susceptibility to other conditions, such as pneumonia. Immunization lessens the incidence and severity of the disease: the whole cell (or 'killed') vaccine has been replaced by an acellular version, which is made up from the bacteria *Bordetella pertussis*, and has fewer side effects than its predecessor.

According to World Health Organization (WHO) figures, there are 20-40 million cases each year, leading to up to 400,000 deaths, of which 90% occurred in developing countries (2003).

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whortleberry

a form of bilberry.

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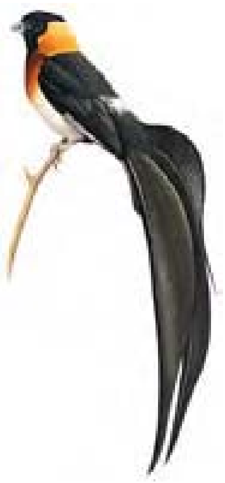
whydah

any of various African birds of the genus *Vidua*, order Passeriformes, of the weaver family. They lay their eggs in the nests of waxbills, which rear the young. Young birds resemble young waxbills, but the adults do not resemble adult waxbills. Males have long tail feathers used in courtship displays.

whydah



(Image © Research Machines plc)

During the breeding season the male paradise whydah has elongated black tail feathers 28 cm/11 in long. The paradise whydah lives in dry bush country in central Africa.

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wide-angle lens

photographic lens of shorter focal length than normal, taking in a wider angle of view.

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wide area network

WAN

in computing, a network that connects computers distributed over a wide geographical area. 'Dumb' terminals and microcomputers act as workstations, which connect to remote systems via a local host computer.

Wiener, Norbert (1894-1964)

US mathematician, credited with the establishment of the science of cybernetics in his book *Cybernetics* (1948). In mathematics, he laid the foundation of the study of stochastic processes (those dependent on random events), particularly Brownian motion.

Wiener, Norbert

Go to site

Part of an archive containing the biographies of the world's greatest mathematicians, this site is devoted to the life and contributions of Norbert Wiener. In addition to biographical information, you will find a list of references about Wiener and links to other essays in the archive that reference him. The text of this essay includes hypertext links to the essays of those mathematicians and thinkers who influenced Wiener. There is also an image of him, which can be enlarged, and a map of his birthplace.

Wien's displacement law

in physics, a law of radiation stating that the wavelength carrying the maximum energy is inversely proportional to the absolute temperature of a black body: the hotter a body is, the shorter the wavelength. It has the form $\lambda_{max}T$ = constant, where λ_{max} is the wavelength of maximum intensity and T is the temperature. The law is named after German physicist Wilhelm Wien.

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wigeon

either of two species of dabbling duck of genus *Anas*, order Anseriformes. The **American wigeon** *A. americana*, about 48 cm/19 in long, is found along both coasts in winter and breeds inland. Males have a white-capped head and a green eye stripe.

Wilczek, Frank (1951-)

US physicist. With US physicists David Gross and Hugh Politzer he shared the Nobel prize in Physics in 2004 for his contribution to the theoretical explanation of how the strong nuclear force holds quark subatomic particles together.

Wilczek and fellow Nobel laureates, Gross and Politzer, all worked on the same problem, trying to derive a theory to explain the properties of the strong force, also called the colour interaction, one of the four fundamental forces that apply to nature in the microscopic world, according the standard model of particle physics. It was known that the strong interaction held together subatomic articles known as quarks, the building blocks of protons and neutrons, in the nucleus of an atom, but it was not understood why quarks could not be found as discrete particles except in very high energy situations. The standard model could not account for this behaviour. Wilczek and the others discovered that the force between quarks increased with distance, keeping them together the further apart the quarks were, exactly explaining the behaviour seen in particle physics experiments. The discovery was published in two scientific papers in 1971 and formed the basis of the theory of colour interaction known as quantum chromodynamics (QCD). This work allowed the standard model theory to be completed.

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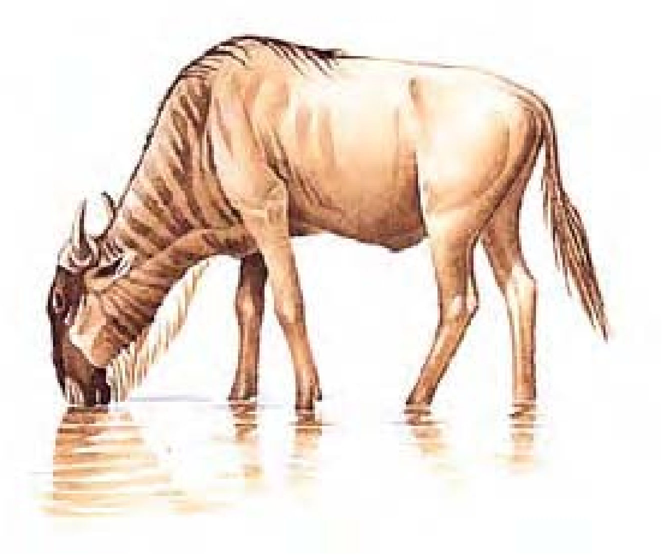
wildebeest

or gnu

either of two species of African antelope, with a cowlike face, a beard and mane, and heavy curved horns in both sexes. The body is up to 1.3 m/4.2 ft high at the shoulder and slopes away to the hindquarters. (Genus *Connochaetes*.)

The **brindled wildebeest** *C. taurinus* is silver-grey with a dark face, mane, and tail tuft, and is found from Kenya southwards. Vast herds move together on migration. The **white-tailed wildebeest** *C. gnou* of South Africa almost became extinct, but was saved by breeding on farms.

wildebeest



(Image © Research Machines plc)

The brindled wildebeest *Connochaetes taurinus*. The animal is one of the larger members of the antelope family.

wildebeest

(Image © Corel)

The gnu (or wildebeest) lives mainly on the African grassland plains.

wilderness

area of uninhabited land that has never been disturbed by humans, usually located some distance from towns and cities. According to estimates by US group Conservation International, 52% (90 million sq km/35 million sq mi) of the Earth's total land area was still undisturbed in 1994.

Wilderness Society: Protecting America's Wilderness

Go to site

Frequently updated site with news of the Wilderness Society's events and campaigns. Attractive pages present the work of the Wilderness Society's regional offices and include detailed information on wildfires and forest management.

Wilding, Dorothy (1893-1976)

English society photographer, considered the most successful portraitist during the 1920s, 1930s, and 1940s in the UK. She popularized the profile portrait as well as innovative, stylized settings. She enjoyed a long-standing close relationship with the royal family and is perhaps best known for her definitive portrait of Queen Elizabeth II, used on postage stamps during the 1950s and 1960s.

She worked in studios in both London, England, and in New York, New York, USA.

wildlife trade

international trade in live plants and animals, and in wildlife products such as skins, horns, shells, and feathers. The trade has made some species virtually extinct, and whole ecosystems (for example, coral reefs) are threatened. Wildlife trade is to some extent regulated by CITES (Convention on International Trade in Endangered Species).

Species almost eradicated by trade in their products include many of the largest whales, crocodiles, marine turtles, and some wild cats. Until recently, some 2 million snake skins were exported from India every year. Populations of black rhino and African elephant have collapsed because of hunting for their horns and tusks (ivory), and poaching remains a problem in cases where trade is prohibited.

wild type

in genetics, the naturally occurring gene for a particular character that is typical of most individuals of a given species, as distinct from a new allele of this gene that arises by mutation.

Wilkins, Maurice Hugh Frederick (1916-2004)

New Zealand-born British molecular biologist who was awarded the Nobel Prize for Physiology or Medicine in 1962 with Francis Crick and James Watson for the discovery of the double-helical structure of DNA and of the significance of this structure in the replication and transfer of genetic information.

Wilkins began his career as a physicist working on luminescence and phosphorescence, radar, and the separation of uranium isotopes, and worked in the USA during World War II on the development of the atomic bomb. After the war he turned his attention from nuclear physics to molecular biology, and studied the genetic effects of ultrasonic waves, nucleic acids, and viruses by using ultraviolet light.

will-o'-the-wisp

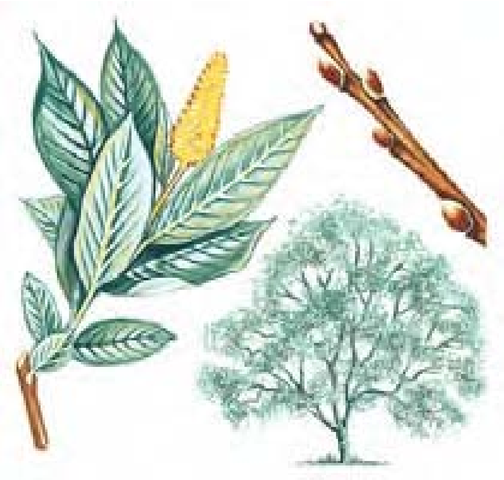
light sometimes seen over marshy ground, believed to be burning gas containing methane from decaying organic matter.

An Australian scientist put forward the hypothesis in 1995 that the phenomenon may be caused by barn owls, which sometimes develop a ghostly glow due to a light-emitting honey fungus that they pick up from rotting trees.

willow

any of a group of trees or shrubs containing over 350 species, found mostly in the northern hemisphere, flourishing in damp places. The leaves are often lance-shaped, and the male and female catkins are borne on separate trees. (Genus *Salix*, family Salicaceae.)

willow



(Image © Research Machines plc)

The willow tree is deciduous with simple leaves and small erect catkins. Willows are found throughout the world, except Australasia.

willowherb

plant of the genus *Epilobium*, a perennial weed. Fireweed *E. angustifolium* is common in woods and waste places, especially after forest fires in areas bordering the Arctic. It grows to 4 ft/1.2 m with long terminal racemes of red or purplish flowers.

willow warbler

bird *Phylloscopus trochilus*, family Muscicapidae, order Passeriformes. It is about 11 cm/4 in long, similar in appearance to the chiffchaff, but with a distinctive song. It is found in woods and shrubberies, and migrates from northern Eurasia to Africa.

willy-willy

Australian Aboriginal term for a cyclonic whirlwind.

Wilms's tumour

or nephroblastoma

one of the rare cancers of infancy, arising in the kidneys. Often the only symptom is abdominal swelling. Treatment is by removal of the affected kidney (nephrectomy), followed by radiotherapy and cytotoxic drugs.

Wilson, Edward Osborne (1929-)

US zoologist whose books have stimulated interest in biogeography, the study of the distribution of species, and sociobiology, the evolution of behaviour. He is a world authority on ants.

wilting

loss of rigidity (turgor) in plants, caused by a decreasing wall pressure within the cells making up the supportive tissues. Wilting is most obvious in plants that have little or no wood.

WIMP

acronym for Windows, icons, menus, pointing device

in computing, another name for graphical user interface (GUI).

Winchester drive

in computing, an old-fashioned term for hard disk.

wind

lateral movement of the Earth's atmosphere from high-pressure areas (anticyclones) to low-pressure areas (depressions). Its speed is measured using an anemometer or by studying its effects on, for example, trees by using the Beaufort scale. Although modified by features such as land and water, there is a basic worldwide system of trade winds, westerlies, and polar easterlies.

A belt of low pressure (the doldrums) lies along the Equator. The trade winds blow towards this from the horse latitudes (areas of high pressure at about 30° north and south of the Equator), blowing from the northeast in the northern hemisphere, and from the southeast in the southern hemisphere. The westerlies (also from the horse latitudes) blow north of the Equator from the southwest, and south of the Equator from the northwest.

Cold winds blow outwards from high-pressure areas at the poles. More local effects result from landmasses heating and cooling faster than the adjacent sea, producing onshore winds in the daytime and offshore winds at night.

The monsoon is a seasonal wind of southern Asia, blowing from the southwest in summer and bringing the rain on which crops depend. It blows from the northeast in winter.

Famous warm winds include the **chinook** of the eastern Rocky Mountains, North America; the **föhn** of Europe's Alpine valleys; the **sirocco** (Italy)/**khamsin** (Egypt)/**sharav** (Israel) - spring winds that bring warm air from the Sahara and Arabian deserts across the Mediterranean; and the **Santa Ana**, a periodic warm wind from the inland deserts that strikes the California coast.

The dry northerly **bise** (Switzerland) and the **mistral** (which strikes the Mediterranean area of France) are unpleasantly cold winds.

The fastest wind speed ever measured on Earth, 512 kph/318 mph, occurred on 3 May 1999 in a tornado that struck the suburbs of Oklahoma City, Oklahoma, USA.

Global Wind Patterns

Go to site

Definition and explanation of the different types of wind patterns present around the world. Basic terms are defined in bold, such as trade winds, doldrums, prevailing westerlies, and polar easterlies. An activity is also included, which enables the user to see visually the world's wind patterns.

wind-chill factor

or wind-chill index

estimate of how much colder it feels when a wind is blowing. It is arrived at by combining the actual temperature and wind speed and is given as a different temperature.

Wind chill can be calculated in Celsius using the formula: wind chill = $0.045(5. \times \sqrt{V} + 10.45 - 0.28V)(T - 33) + 33$ where V is in the wind speed in kilometres per hour and T is the temperature in degrees Celsius; and in Fahrenheit: wind chill = $0.0817(3.71 \times \sqrt{V} + 5.81 - 0.25V)(T - 91.4) + 91.4$ where V is in the wind speed in miles per hour and T is the temperature in degrees Fahrenheit.

wind farm

array of windmills or wind turbines used for generating electrical power. The world's largest wind farm at Altamont Pass, California, USA, consists of 6,000 wind turbines generating 1 TWh of electricity per year. Wind farms supply about 1.5% of California's electricity needs. To produce 1,200 megawatts of electricity (an output comparable with that of a nuclear power station), a wind farm would need to occupy around 370 sq km/140 sq mi.

Denmark built the world's first offshore wind farm, off Vindeby on Lolland Island in the North Sea.

National Wind Technology Centre

Go to site

Source of information on the importance of tapping wind power and how to do it. This US Department of Energy site has reports on the latest research. For children there is a wind energy quiz and details of educational materials. There is information about a number of authorities generating energy from wind power in various parts of world.

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windmill

mill with sails or vanes that, by the action of wind upon them, drive machinery for grinding corn or pumping water, for example. Wind turbines, designed to use wind power on a large scale, usually have a propeller-type rotor mounted on a tall shell tower. The turbine drives a generator for producing electricity.

Windmills were used in the East in ancient times, and in Europe they were first used in Germany and the Netherlands in the 12th century. The main types of traditional windmill are the **post mill**, which is turned around a post when the direction of the wind changes, and the **tower mill**, which has a revolving turret on top. It usually has a device (fantail) that keeps the sails pointing into the wind. In the USA windmills were used by the colonists and later a light type, with steel sails supported on a long steel girder shaft, was introduced for use on farms.

windmill control arms

(Image © Corel)

Control arms of a tower windmill. The turret at the top of the windmill revolves so that the sails can be pointed into the prevailing wind. The sails turn a mill for grinding corn or pumping water.

windmill, Skagen

(Image © Corel)

An old tower windmill in Skagen, at the northernmost tip of the Danish mainland. The tower windmill was first used in Europe in the 14th century, for grinding grain and pumping water for irrigation.

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window

in computing, a rectangular area on the screen of a graphical user interface. A window is used to display data and can be manipulated in various ways by the computer user.

Windows

in computing, originally Microsoft's graphical user interface (GUI) for IBM personal computers and clones running MS-DOS. Windows has since developed into a family of operating systems that run on a wide variety of computers, from pen-operated palmtop personal digital assistants (PDAs) to large, multiprocessor computers in corporate data centres.

Windows XP Home edition is designed for homes and offices and retains maximum compatibility with programs written for the MS-DOS operating system and earlier versions of Windows.
Windows XP Professional edition is designed for business use, especially on workstations and server computers, where it is seen as a rival to Unix and Novell NetWare.
Windows CE is a small, modular operating system that supports a subset of the Windows applications programming interface. It is used in PDAs (where it is known as Pocket PC), Windows-Based Terminals (WBTs), and consumer electronics products such as games consoles, DVD players, and television set-top boxes for Internet use. Windows XP Home is limited to Intel and x86-compatible processors but both XP Professional and CE run on a variety of chips from different manufacturers.

Windows XP, called by the company the most important Microsoft product since Windows 95, was released in 2001, promising improved ability to deal with digital multimedia. In 2002, Microsoft released a version of Windows XP to run on the new tablet PC, with advanced handwriting and speech recognition capabilities.

Windows95 Annoyances

Go to site

Forum for intermediate to advanced users of Windows 95 who seek answers to annoying questions or have helpful tips they wish to share with others. Troubleshooting techniques, lost files, screen problems, bugs, and other topics are thoroughly discussed in this site. The tips date back to 1996, so not all of the concerns are up-to-date. However, there is still ample valid and important information for Windows 95 users.

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windpipe

in medicine, another name for the trachea.

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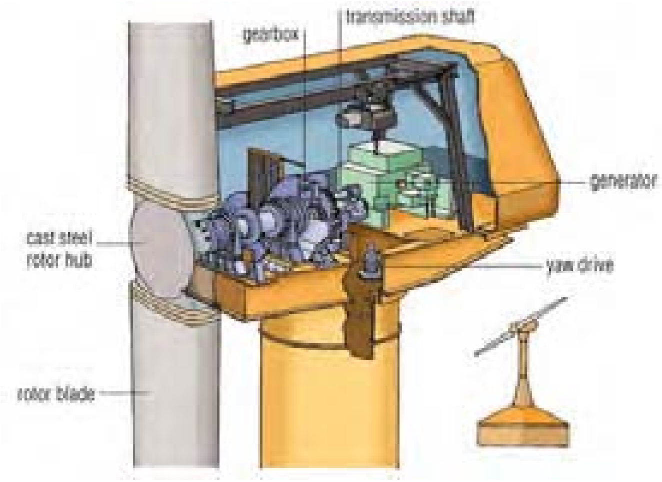
wind power

power produced from the harnessing of wind energy. The wind has long been used as a source of energy: sailing ships and windmills are ancient inventions. After the energy crisis of the 1970s wind turbines began to be used to produce electricity on a large scale.

wind power



(Image © Research Machines plc)

The wind turbine is the modern counterpart of the windmill. The rotor blades are huge - up to 100 m/330 ft across - in order to extract as much energy as possible from the wind. Inside the turbine head, gears are used to increase the speed of the turning shaft so that the electricity generation is as efficient as possible.

British Wind Energy Association

Go to site

Promoting the use of wind power as a clean, sustainable source of energy, this site includes a list of wind farms throughout the UK, as well as a detailed selection of fact sheets about related issues.

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wind turbine

windmill of advanced aerodynamic design connected to a generator producing electrical energy and used in wind-power installations. Wind is a form of renewable energy that is used to turn the turbine blades of the windmill. Wind turbines can be either large propeller-type rotors mounted on a tall tower, or flexible metal strips fixed to a vertical axle at top and bottom.

wind turbine

(Image © Research Machines plc)

Wind turbines at the Delabole Wind Farm, in Cornwall, the first wind farm in the United Kingdom. Its ten turbines have a total generating capacity of 4 megawatts. There are now six wind farms in the county of Cornwall, with a combined total output of more than 31 megawatts of electricity, enough to meet the annual needs of 19,500 homes.

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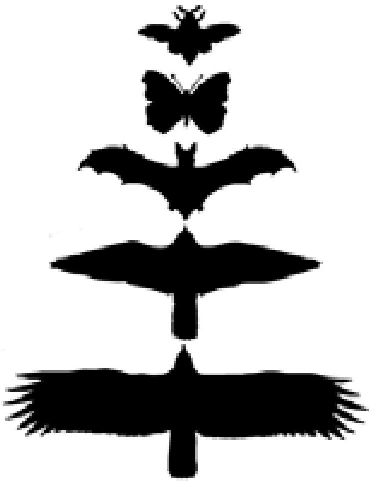
wing

in biology, the modified forelimb of birds and bats, or the membranous outgrowths of the exoskeleton of insects, which give the power of flight. Birds and bats have two wings. Bird wings have feathers attached to the fused digits ('fingers') and forearm bones, while bat wings consist of skin stretched between the digits. Most insects have four wings, which are strengthened by wing veins.

The wings of butterflies and moths are covered with scales. The hind pair of a fly's wings are modified to form two knoblike balancing organs (halteres).

wing



(Image © Research Machines plc)

Birds can fly because of the specialized shape of their wings: a rounded leading edge, flattened underneath and round on top. This aerofoil shape produces lift in the same way that an aircraft wing does. The outline of the wing is related to the speed of flight. Fast birds of prey have a streamlined shape. Larger birds, such as the eagle, have large wings with separated tip feathers which reduce drag and allow slow flight. Insect wings are not aerofoils. They push downwards to produce lift, in the same way that oars are used to push through water.

wintergreen

any of a group of plants belonging to the heath family, especially the species *G. procumbens* of northeastern North America, which creeps underground and sends up tiny shoots. Oil of wintergreen, used in treating rheumatism, is extracted from its leaves. Wintergreen is also the name for various plants belonging to the wintergreen family Pyrolaceae, including the green pipsissewa *C. maculata* of northern North America, Europe, and Asia. (Genus *Gaultheria*, family Ericaceae; also genera *Pyrola*, *Chimaphila*, *Orthilia*, and *Moneses*, family Pyrolaceae.)

wire

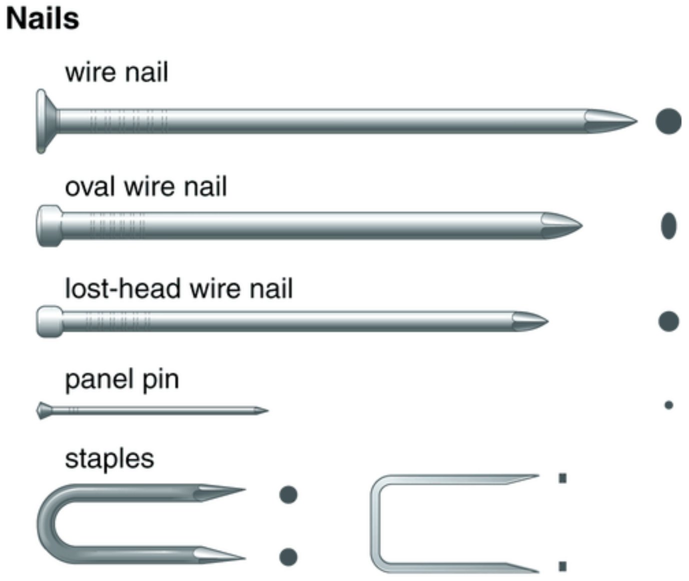
thread of metal, made by drawing a rod through progressively smaller-diameter dies. Fine-gauge wire is used for electrical power transmission; heavier-gauge wire is used to make load-bearing cables.

Gold, silver, and bronze wire has been found in the ruins of Troy and in ancient Egyptian tombs. From early times to the 14th century, wire was made by hammering metal into sheets, cutting thin strips, and making the strips round by hammering them. The Romans made wire by hammering heated metal rods.

Wire drawing was introduced in Germany in the 14th century. In this process, a metal rod is pulled (drawn) through a small hole in a mould (die). Wire drawing mills, powered by water, were at work in Germany in the 15th century; now all wire is drawn by machine. Metal rods are pulled through a series of progressively smaller tungsten carbide dies to produce large-diameter wire, and through diamond dies for very fine wire. The die is funnel-shaped, with one opening smaller than the diameter of the rod. The rod, which is pointed at one end, is coated with a lubricant to allow it to slip through the die. Pincers pull the rod through until it can be wound round a drum. The drum then rotates, drawing the wire through the die and winding it into a coil.

There are many kinds of wire for different uses: galvanized wire (coated with zinc), which does not rust; barbed wire and wire mesh for fencing; and wire cable, made by weaving thin wires into ropes. Needles, pins, nails, and rivets are made from wire.

wire



(Image © Research Machines plc)

Nails, pins, and staples are made of wire and are a quick way of joining materials together.

wireless

original name for a radio receiver. In early experiments with transmission by radio waves, notably by Italian inventor Guglielmo Marconi in Britain, signals were sent in Morse code, as in telegraphy. Radio, unlike the telegraph, used no wires for transmission, and the means of communication was termed 'wireless telegraphy'. The term has returned to describe technologies that enable devices to communicate by radio or infrared - for example, Wireless LAN.

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wireless LAN

WLAN

type of local area network that allows wireless-enabled laptop computers and personal digital assistants to connect to the Internet. 'Hot spots' for wireless access are being increasingly established in public areas such as Internet cafes, airport lounges, hotel lobbies, shopping malls, and exhibition halls.

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wireworm

larva of some species of click beetle. Wireworms are considered agricultural pests as they attack the seeds of many crops.

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wisent

another name for the European bison.

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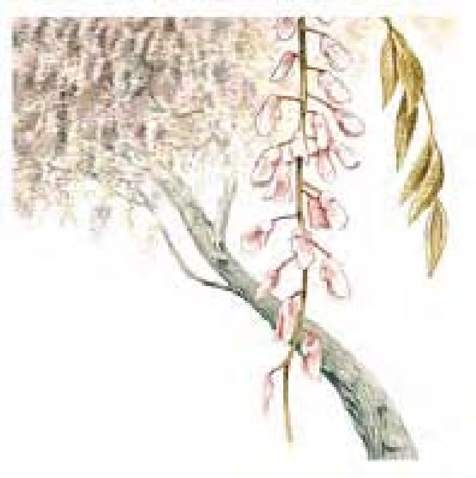
wisteria

any of a group of climbing leguminous shrubs (see legume), including *W. sinensis*, native to the eastern USA and East Asia. Wisterias have hanging clusters of bluish, white, or pale mauve flowers, and pinnate leaves (leaflets on either side of the stem). They are grown against walls as ornamental plants. (Genus *Wisteria*, family Leguminosae.)

wisteria



(Image © Research Machines plc)

This leguminous climbing shrub is named after US anatomist Caspar Wistar (1761-1818). The clusters of pealike, often purple flowers make this a handsome ornamental and it is often grown to cover walls, conservatories, and verandas.

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witch hazel

any of a group of flowering shrubs or small trees belonging to the witch hazel family, native to North America and East Asia, especially *H. virginiana*. An astringent extract prepared from the bark or leaves is used in medicine as an eye lotion and a liniment to relieve pain or stiffness. (Genus *Hamamelis*, family Hamamelidaceae.)

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woad

biennial plant native to Europe, with arrow-shaped leaves and clusters of small yellow flowers. It was formerly cultivated for a blue dye extracted from its leaves. Ancient Britons used the blue dye as a body paint in battle. (Genus *Isatis tinctoria*, family Cruciferae.)

Woad

Go to site

Detailed resource relating to this plant. It contains an informative description of the plant and its habitat. There are also notes on its cultivation and the possible medicinal uses of woad, which include acting as an astringent.

Wöhler, Friedrich (1800-1882)

German chemist who in 1828 became the first person to synthesize an organic compound (urea) from an inorganic compound (ammonium cyanate). He also devised a method in 1827 that isolated the metals aluminium, beryllium, yttrium, and titanium from their ores.

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wolf

any of two species of large wild dogs of the genus *Canis*. The **grey** or **timber wolf** *C. lupus*, of North America and Eurasia, is highly social, measures up to 90 cm/3 ft at the shoulder, and weighs up to 45 kg/100 lb. It has been greatly reduced in numbers except for isolated wilderness regions. The **red wolf** *C. rufus*, generally more slender and smaller (average weight about 15 kg/35 lb) and tawnier in colour, may not be a separate species, but a grey wolf-coyote hybrid. It used to be restricted to southern central USA, but is now thought to be extinct in the wild.

Arctic wolf

(Image © Corel)

An Arctic wolf in its camouflage winter coat. Wolves feed on small mammals and birds, occasionally attacking larger animals, such as reindeer or sheep, or eating berries and carrion when prey is scarce.

timber wolf

(Image © Corel)

A timber wolf *Canis lupus* howling. Wolves live in open country and forests, hunting in packs by day. They have great stamina and can usually outrun their prey, which may be as large as a deer or elk. They are strong swimmers and sometimes pursue deer into the water.

Snow Wolves

Go to site

Companion to a US Public Broadcasting Service (PBS) television programme, this site follows the reintroduction of wolves into Yellowstone National Park from their initial placement in 1995 to the autumn of 1996. It includes a section on the filmmaker's diary, sound and image galleries, and the script to the television programme that was first shown in August 1997. You can also find links to wolf resources and a trivia quiz.

Wild Wolves

Go to site

'What's in a wolf's howl - a calling card, a warning, or an invitation?' This site includes information about the relationship between wolves and dogs, lets you hear a wolf howl, and also includes a quiz.

wolfram

alternative name for tungsten.

wolframite

iron manganese tungstate, $(Fe,Mn)WO_4$, an ore mineral of tungsten. It is dark grey with a submetallic surface lustre, and often occurs in hydrothermal veins in association with ores of tin.

Wollaston, William Hyde (1766-1828)

English chemist and physicist who discovered in 1804 how to make malleable platinum. He went on to discover the new elements palladium in 1804 and rhodium in 1805. He also contributed to optics through the invention of a number of ingenious and still useful measuring instruments.

wolverine

Gulo gulo, largest land member of the weasel family (Mustelidae), found in Europe, Asia, and North America.

It is stocky in build, and about 1 m/3.3 ft long. Its long, thick fur is dark brown on the back and belly and lighter on the sides. It covers food that it cannot eat with an unpleasant secretion. Destruction of habitat and trapping for its fur have greatly reduced its numbers.

womb

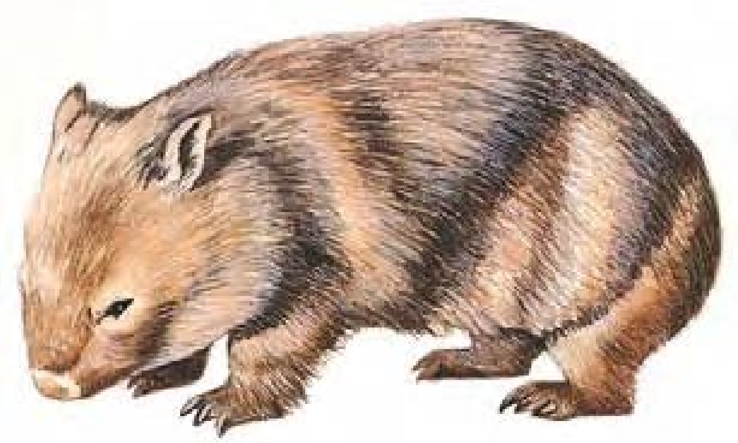
common name for the uterus.

wombat

any of a family (Vombatidae) of burrowing, herbivorous marsupials, native to Tasmania and southern Australia. They are about 1 m/3.3 ft long, heavy, with a big head, short legs and tail, and coarse fur.

The two living species include the **common wombat** *Vombatus ursinus* of Tasmania and southeastern Australia, and *Lasiorhirnus latifrons*, the **plains wombat** of southern Australia.

wombat



(Image © Research Machines plc)

The wombat is a powerfully built marsupial. There are three species found in Australia and one in Tasmania. In some ways, they resemble badgers, being large burrowing animals, building burrows up to 30 m/100 ft long with a nest chamber at the end.

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wood

hard tissue beneath the bark of many perennial plants; it is composed of water-conducting cells, or secondary xylem, and gains its hardness and strength from deposits of lignin.
Hardwoods, such as oak, and **softwoods**, such as pine, have commercial value as structural material and for furniture.

The central wood in a branch or stem is known as **heartwood** and is generally darker and harder than the outer wood; it consists only of dead cells. As well as providing structural support, it often contains gums, tannins, or pigments which may impart a characteristic colour and increased durability. The surrounding **sapwood** is the functional part of the xylem that conducts water.

The **secondary xylem** is laid down by the vascular cambium which forms a new layer of wood annually, on the outside of the existing wood and visible as an annual ring when the tree is felled; see dendrochronology.

Commercial wood can be divided into two main types: hardwood, containing xylem vessels and obtained from angiosperms (for example, oak); and softwood, containing only tracheids, obtained from gymnosperms (for example, pine). Although in general softwoods are softer than hardwoods, this is not always the case: balsa, the softest wood known, is a hardwood, while pitch pine, very dense and hard, is a softwood. A superhard wood is produced in wood-plastic combinations (WPC), in which wood is impregnated with liquid plastic (monomer) and the whole is then bombarded with gamma rays to polymerize the plastic.

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woodcock

either of two species of wading birds, genus *Scolopax*, of the family Scolopacidae, which have barred plumage and long bills, and live in wet woodland areas. They belong to the long-billed section of the snipes, order Charadriiformes.

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woodland

area in which trees grow more or less thickly; generally smaller than a forest. Temperate climates, with four distinct seasons a year, tend to support a mixed woodland habitat, with some conifers but mostly broad-leaved and deciduous trees, shedding their leaves in autumn and regrowing them in spring. In the Mediterranean region and parts of the southern hemisphere, the trees are mostly evergreen.

Temperate woodlands grow in the zone between the cold coniferous forests and the tropical forests of the hotter climates near the Equator. They develop in areas where the closeness of the sea keeps the climate mild and moist.

Old woodland can rival tropical rainforest in the number of species it supports, but most of the species are hidden in the soil. A study in Oregon, USA, in 1991 found that the soil in a single woodland location contained 8,000 arthropod species (such as insects, mites, centipedes, and millipedes), compared with only 143 species of reptile, bird, and mammal in the woodland above.

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woodlouse

any of the several families of mostly terrestrial crustaceans of the order Isopoda (especially the sow bugs, genera *Onisais* and *Porcellio*) that live in damp places under rocks or fallen timber. They have rounded oval, evenly segmented bodies, flat undersides, and 14 legs. Some species of sow bugs can roll up when threatened. The pillbugs (family Armadillidiidae) typically roll up. Rock slaters (family Ligiidae) are amphibious on ocean beaches.

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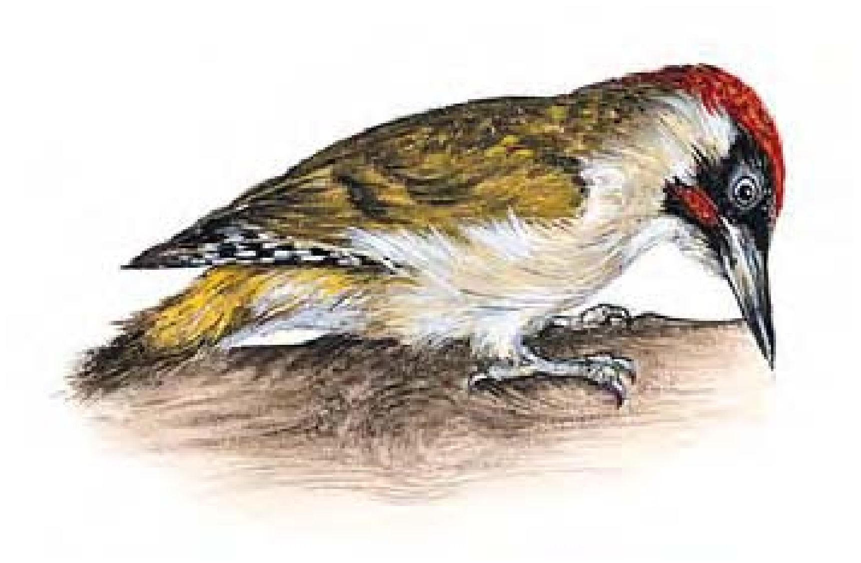
woodpecker

bird of the family Picidae, order Piciformes. They are adapted for climbing up the bark of trees, and picking out insects to eat from the crevices. The feet, though very short, are usually strong; the nails are broad and crooked and the toes placed in pairs, two forward and two backward. As an additional support their tail feathers terminate in points, and are uncommonly hard. Woodpeckers have a long extensile tongue, which has muscles enabling the bird to dart it forth and to retract it again quickly. There are about 200 species worldwide.

woodpecker



(Image © Research Machines plc)

The green woodpecker is, in some areas, called the yaffle, a name supposedly resembling its call. Like other woodpeckers, it feeds on the larvae of wood-boring insects which it digs from tree trunks, but it also feeds on the ground, hopping along as it searches for ants and seeds.

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wood pitch

by-product of charcoal manufacture, made from **wood tar**, the condensed liquid produced from burning charcoal gases. The wood tar is boiled to produce the correct consistency. It has been used since ancient times for caulking wooden ships (filling in the spaces between the hull planks to make them watertight).

Woodward, Robert Burns (1917-1979)

US chemist who worked on synthesizing a large number of complex molecules. These included quinine in 1944, cholesterol in 1951, chlorophyll in 1960, and vitamin B_{12} in 1971. He was awarded the Nobel Prize for Chemistry in 1965 for his work in organic synthesis.

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wood wasp

or horntail

moderately large wasp that is black or metallic blue, often with yellow bandings. The long lancelike ovipositor (egg-laying organ) of the female wood wasp is used for drilling holes into wood. Usually a single egg is deposited into each hole, and the larva on hatching bores through the heart wood causing much damage.

classification

The wood wasp is in the family Siricidae, suborder Symphyta, order Hymenoptera, class Insecta, phylum Arthropoda.

The common wood wasp *Sirex juvencus* is about 30 mm/1.1 in long and blue-black with a metallic sheen. The male may be distinguished from the female by its short triangular spine or horn at the tip of its abdomen and also by a brown-red stripe on its back. The female lays her eggs in conifers.

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woodworm

common name for the larval stage of certain wood-boring beetles. Dead or injured trees are their natural target, but they also attack structural timber and furniture.

Included are the furniture beetle *Anobium punctatum*, which attacks older timber; the powder-post beetle genus *Lyctus*, which attacks newer timber; the deathwatch beetle, whose presence always coincides with fungal decay; and wood-boring weevils. Special wood preservatives have been developed to combat woodworm infestation, which has markedly increased since about 1950.

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wool

natural hair covering of the sheep, and also of the llama, angora goat, and some other mammals. The domestic sheep *Ovis aries* provides the great bulk of the fibres used in textile production. A by-product of wool production is lanolin.

history

Sheep have been bred for their wool since ancient times. Hundreds of breeds were developed in the Middle East, Europe, and Britain over the centuries, several dozen of which are still raised for their wool today. Most of the world's finest wool comes from the merino sheep, originally from Spain. In 1797 it was introduced into Australia, which has become the world's largest producer of merino wool; South Africa and South America are also large producers. Wool from crossbred sheep (usually a cross of one of the British breeds with a merino) are produced in New Zealand. Since the 1940s, blends of wool with synthetic fibre have been developed for textiles.

Textiles: Wool

Go to site

Part of the Textiles-Online Web site, this page explains all about wool. It is split into five sections: 'History of the use of wool', 'Production of wool', 'Care of your woollen garment', 'Properties of wool', and 'Uses'. Use the contents at the top of the page to get to a section quickly and the links at the bottom to investigate the properties of other textiles and fibres.

Woolcott, Marion Post (1910-1990)

US documentary photographer. She is best known for her work for the Farm Security Administration (with Walker Evans and Dorothea Lange), showing the conditions of poor farmers in the late 1930s in Kentucky and the deep South.

Woolley, (Charles) Leonard (1880-1960)

English archaeologist. After taking part in an expedition to Nubia 1907-11, he excavated the Hittite city of Carchemish in Syria until 1914; Tell el Amarna in Egypt; Atchana (the ancient Alalakh) in the Hatay near Antioch on the Turkish-Syrian border 1935-39 and 1946-49; and brought to light the ancient Sumerian civilization at Ur in Iraq.

In 1929 Woolley claimed that silt deposits at Ur attested to a flood that might have given rise to the Bible story.

Besides his scholarly excavation reports, he published popular accounts of his work which helped to promote archaeology to a nonspecialist audience. Titles include *Ur of the Chaldees* 1929, *Digging Up the Past* 1930, and *A Forgotten Kingdom* 1953.

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word

in computing, a group of bits (binary digits) that a computer's central processing unit treats as a single working unit. The size of a word varies from one computer to another and, in general, increasing the word length leads to a faster and more powerful computer. In the late 1970s and early 1980s, most microcomputers were 8-bit machines. During the 1980s 16-bit microcomputers were introduced and 32-bit microcomputers are now available. Mainframe computers may be 32-bit or 64-bit machines.

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word processing

input, amendment, manipulation, storage, and retrieval of text. A computer system that runs such software is known as a **word processor**. Since word-processing programs became available to microcomputers, the method has largely replaced the typewriter for producing letters or other text. Typical facilities include insert, delete, cut and paste, reformat, search and replace, copy, print, mail merge, and spelling check.

The leading word-processing programs include Microsoft Word, the market leader, Lotus WordPro, and Corel WordPerfect.

Electronic and Online Publishing

computerized publishing

Most publishing is now 'electronic' in the sense that books, magazines, and newspapers are prepared on computers and exist as computer files before they are printed on paper. Often there are advantages to giving readers access to the electronic versions of publications as well as - or even instead of - the printed versions.

Today, writers and journalists usually create their texts on computers using word processing programs, but if not, typewritten copy is easily scanned to convert it into electronic form. Many illustrations are also produced on computers using **paint programs**, and the use of digital cameras is becoming increasingly common - though again, images created by more traditional means can easily be scanned. Designers and layout artists then assemble the materials and lay them out on computers running desktop publishing programs, before sending the finished pages to a computer-based photo-typesetter.

Print publications have lots of advantages. Paper is pleasant to handle, easy to read, and very portable: you can read it almost anywhere. On the other hand, print has its drawbacks. Paper is expensive, and articles are often cut to fit the space available. Printing and distributing paper is expensive and takes time.

Printed materials are expensive to store and almost impossible to search. Electronic publishing offers solutions to all these problems.

publishing online

Suppose a publisher makes the electronic copy of a newspaper or magazine available online, perhaps on the Internet's World Wide Web. No paper is used and disk space is cheap, so online publishing costs very little. Articles don't have to be cut (though there is of course a limit to the amount people are willing to read online). Online publishing is fast, and readers can access material as soon as it becomes available: within minutes, instead of the next day, next week or next month. Online publishing transcends geographical boundaries: the humblest local paper can be read everywhere from New York to London to Delhi to Tokyo. Delivery costs are low because there are no newsagents to pay, and no postal charges: readers pick up the bills for their online sessions. Also, computer-based publications are simple to store (on disk) and every word can be searched electronically.

does it pay?

But electronic publishing also has its drawbacks. The main problem is getting money for it. People are used to paying for printed publications, and advertisers are used to paying to have their messages included. It's much harder to get people to pay for online publications, especially on the Web, where almost everything is free. Few advertisers are convinced by the small banners they are usually offered on Web pages, and may be aware that many users object to the delays and costs involved in downloading them. Anyway, why should companies advertise when they can simply open their own Web sites? Things may change when **micropayment** systems come into widespread use, and readers can be debited a few pennies for accessing a site, but the economics of Internet publishing are far from proven.

At the moment, newspapers and magazines, TV, and radio stations, news agencies, and book publishers are making content freely available on the Web because they are competing for 'mindshare'. Perhaps they want to find out if they can attract and hold an audience online, or perhaps they're afraid of missing out because 'everyone else is doing it'. But don't count on things staying that way. Publishers are not in business to lose money.

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work

in physics, a transfer of energy from one system to another, caused when the point of application of a force moves in the direction of the force. Work is done when, for example, a wire is stretched, or a gas is compressed, or a ball is thrown. No work is done when the point of application moves at right angles to the force; for example, when an object is whirled in a circle on the end of a piece of string (a centripetal, or centre-seeking, force acts on the object, while its motion is always at right angles to the line connecting it to the centre of the circle). Although work is measured in joules, it should not be confused with energy (the capacity to do work, which is also measured in joules) or with power (the rate of doing work, measured in joules per second).

Work is equal to the product of the force used and the distance moved by the object in the direction of that force. If the force is F newtons and the distance moved is d metres, then the work W joules is given by: $W = Fd$. For example, the work done when a force of 10 newtons moves an object 5 m against resistance is 50 joules.

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workstation

high-performance desktop computer with strong graphics capabilities, traditionally used for engineering (CAD and CAM), scientific research, and desktop publishing. From 1985 to 1995 workstations were frequently based on fast RISC (reduced instruction-set computer) chips running the Unix operating system. However, the market is under attack from 'Wintel' PCs with Intel Pentium processors running Microsoft Windows NT, which are cheaper and run PC software as well as workstation programs. By 1997, four of the five leading workstation manufacturers – DEC, Hewlett-Packard, IBM, and Silicon Graphics Inc., but not Sun Microsystems – had committed themselves to supporting NT.

World Conservation Union

or International Union for the Conservation of Nature (IUCN)

organization established by the United Nations to promote the conservation of wildlife and habitats as part of the national policies of member states.

It has formulated guidelines and established research programmes, for example International Biological Programme (IBP), and set up advisory bodies such as Survival Commissions (SSC). In 1980, it launched the **World Conservation Strategy** to highlight particular problems, designating a small number of areas as **World Heritage Sites** to ensure their survival as unspoiled habitats (for example, Yosemite National Park in the USA, and the Simen Mountains in Ethiopia). It also compiles the **Red Data List of Threatened Animals**, classifying species according to their vulnerability to extinction.

According to its list of endangered species published in 2003, 25% of all mammal species and 12.4% of all bird species are threatened with extinction.

World Heritage List

Go to site

United Nations list of 506 sites all across the world that are considered to be an essential part of the 'world's cultural and natural heritage'. This site contains a page on all the sites with a brief description, photo, and the year each one was added to the list.

World Meteorological Organization

agency, part of the United Nations since 1950, that promotes the international exchange of weather information through the establishment of a worldwide network of meteorological stations. It was founded as the International Meteorological Organization in 1873 and its headquarters are now in Geneva, Switzerland.

World Meteorological Organization

Go to site

Internet voice of the World Meteorological Organization, a UN division coordinating global scientific activity related to climate and weather. The site offers ample material on the long-term objectives and immediate policies of the organization. It also disseminates important information on WMO's databases, training programmes, and satellite activities, as well as its projects related to the protection of the environment.

World Wide Fund for Nature

WWF; formerly the World Wildlife Fund

international organization established in 1961 to raise funds for conservation by public appeal. Projects include conservation of particular species, for example, the tiger and giant panda, and special areas, such as the Simen Mountains, Ethiopia.

World Wildlife Fund

former and US name of the World Wide Fund for Nature.

Worldwide Fund for Nature

Go to site

Online base of the international wildlife charity. As well as giving information about current campaigns and encouraging you to join, there is a wealth of well-presented information here about the natural world, including quizzes, interactive maps, and a regularly updated news section.

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worm

any of various elongated, limbless invertebrates belonging to several phyla. Worms include the flatworms, such as flukes and tapeworms; the roundworms or nematodes, such as the eelworm and the hookworm; the marine ribbon worms or nemerteans; and the segmented worms or annelids.

worm: echiuroid worm

The male of the marine echiuroid worm *Bonellia* is only a few millimetres long and lives as a parasite in the female's uterus.

worm: Pompeii worm

The Pompeii worm *Alvinella pompejana* lives in hydrothermal vents. Its bottom end is exposed to temperatures of 80°C/176°F but its top end is at 20°C/68°F.

worm: quantities

More than half the phyla of the animal kingdom are worms.

Worm World

Go to site

Lively guide for children, with information on topics such as worms' bodies, how to make a worm bin, and different types of worm, plus an art gallery and some worm jokes.

WORM

acronym for write once read many times

in computing, a storage device, similar to a CD-ROM. The computer can write to the disk directly, but cannot later erase or overwrite the same area. WORMs are mainly used for archiving and back-up copies.

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wormwood

any of a group of plants belonging to the daisy family and mainly found in northern temperate regions, especially the aromatic herb *A. absinthium*, the leaves of which are used in the alcoholic drink absinthe. Tarragon is closely related to wormwood. (Genus *Artemisia*, family Compositae.)

W particle

elementary particle, one of the intermediate vector bosons responsible for transmitting the weak nuclear force. The W particle exists as both W^+ and W^-

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wrack

any of the large brown seaweeds characteristic of rocky shores. The bladder wrack *F. vesiculosus* has narrow, branched fronds up to 1 m/3.3 ft long, with oval air bladders, usually in pairs on either side of the midrib or central vein. (Genus *Fucus*.)

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wrasse

any bony fish of the family Labridae, found in temperate and tropical seas. They are slender and often brightly coloured, with a single long dorsal fin. They have elaborate courtship rituals, and some species can change their colouring and sex. Species vary in size from 5 cm/2 in to 2 m/6.5 ft.

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wren

any of the family Troglodytidae of small birds of the order Passeriformes, with slender, slightly curved bills, and uptilted tails.

wren

The testes of the tiny male Australian fairy wren account for one-tenth of his body weight. He can produce more sperm than any other bird, and ejaculates 8.3 billion sperm at a time. (A human male manages about 4 million.)

Wright

Orville (1871-1948) and Wilbur (1867-1912)

US inventors; brothers who pioneered piloted, powered flight. Inspired by Otto Lilienthal's gliding, they perfected their piloted glider in 1902. In 1903 they built a powered machine, a 12-hp 341-kg/750-lb plane, and became the first to make a successful powered flight, near Kitty Hawk, North Carolina. Orville flew 36.6 m/120 ft in 12 seconds; Wilbur, 260 m/852 ft in 59 seconds.

Both brothers became interested in flight at early ages. They devised a wing-control system and added a rudder and a balancing tail to existing gliders. By 1903 they had built and flown a power-driven plane; they received a patent in 1906 and in 1909 set up the American Wright Corp to produce planes for the War Department. After Wilbur's death Orville did research and served on the National Advisory Committee for Aeronautics 1915-48.

How We Made the First Flight

Go to site

Guide through the processes which the Wright brothers went through in order to creat the first powered flight. This site is well-illustrated and written in an engaging first-person tone, with sections such as 'Initial preparations', 'Weight and thrust', and, of course 'Flight!'.

Wilbur Wright: Letter Concerning the Wright Brother's Aviation Experiments, 13 May 1900

Go to site

Part of the American Memory presentation of the US Library of Congress, this page is a letter written by Wilbur Wright to an engineer friend, in which he describes his and his brother's experiments, comments on the need for collaboration among those attempting to design flying machines, and suggests faith in the prospect of future crewed flights. It includes an article that provides historical perspective. Click on the thumbnail image of the letter to increase its size.

Wright, Sewall (1889-1988)

US geneticist and statistician. During the 1920s he helped modernize Charles Darwin's theory of evolution, using statistics to model the behaviour of populations of genes.

Wright's work on genetic drift centred on a phenomenon occurring in small isolated colonies where the chance disappearance of some types of gene leads to evolution without the influence of natural selection.

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write protection

device on computer disks and tapes that provides data security by allowing data to be read but not deleted, altered, or overwritten.

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wrought iron

fairly pure iron containing some beads of slag, widely used for construction work before the days of cheap steel. It is strong, tough, and easy to machine. It is made in a puddling furnace, invented by Henry Colt in England in 1784. Pig iron is remelted and heated strongly in air with iron ore, burning out the carbon in the metal, leaving relatively pure iron and a slag containing impurities. The resulting pasty metal is then hammered to remove as much of the remaining slag as possible. It is still used in fences and gratings.

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wt

abbreviation for **weight**.

Wundt, Wilhelm Max (1832-1920)

German physiologist who regarded psychology as the study of internal experience or consciousness. His main psychological method was introspection; he also studied sensation, perception of space and time, and reaction times.

WWF

abbreviation for World Wide Fund for Nature (formerly World Wildlife Fund).

WYSIWYG

acronym for what you see is what you get

in computing, a program that attempts to display on the screen a faithful representation of the final printed output is said to use a WYSIWYG display. For example, a WYSIWYG word processor would show actual page layout - line widths, page breaks, and the sizes and styles of type.

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x

in mathematics, an unknown quantity.

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xanthophyll

yellow pigment in plants that, like chlorophyll, is responsible for the production of carbohydrates by photosynthesis.

X chromosome

larger of the two sex chromosomes, the smaller being the Y chromosome. These two chromosomes are involved in sex determination. In humans, whether a person is male or female is determined by the particular combination of the two sex chromosomes in the body cells. In females both the sex chromosomes are the same - two X chromosomes (XX). In males the two are different - one X chromosome and one Y chromosome (XY). The Y chromosome is shorter than the X. Genes on these chromosomes determine a person's sex. Genes carried on the X chromosome produce the phenomenon of sex linkage.

As a result of meiosis gametes from a female each contain one X chromosome. However, gametes from a male are of two kinds. Half of the gametes contain an X chromosome and half contain a Y chromosome. If an X-carrying gamete from a male fertilizes a female gamete the result will be a female. If a Y carrying gamete from a male fertilizes a female gamete, the result will be a male.

Early in the development of a female embryo, one of the X chromosomes becomes condensed so that most of its genes are inactivated. If this inactivation is incomplete, skeletal defects and mental retardation result.

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xenon

chemical symbol Xe

(Greek xenos 'stranger')

colourless, odourless, gaseous, non-metallic element, atomic number 54, relative atomic mass 131.30. It is grouped with the noble gases (rare gases) and was long believed not to enter into reactions, but is now known to form some compounds, mostly with fluorine. It is a heavy gas present in very small quantities in the air (about one part in 20 million).

Xenon is used in bubble chambers, light bulbs, vacuum tubes, and lasers. It was discovered in 1898 in a residue from liquid air by Scottish chemists William Ramsay and Morris Travers.

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xenophobia

fear (phobia) or strong dislike of strangers or anybody foreign or different.

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xerography

dry, electrostatic method of producing images, without the use of negatives or sensitized paper, invented in the USA by Chester Carlson in 1938 and applied in the Xerox photocopier.

An image of the document to be copied is projected on to an electrostatically charged photo-conductive plate. The charge remains only in the areas corresponding to its image. The latent image on the plate is then developed by contact with ink powder, which adheres only to the image, and is then usually transferred to ordinary paper or some other flat surface, and quickly heated to form a permanent print.

Applications include document copying, enlarging from microfilm, preparing printing masters for offset litho printing and dyeline machines, making X-ray pictures, and printing high-speed computer output.

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xerophyte

plant adapted to live in dry conditions. Common adaptations to reduce the rate of transpiration include a reduction of leaf size, sometimes to spines or scales; a dense covering of hairs over the leaf to trap a layer of moist air (as in edelweiss); water storage cells; sunken stomata; and permanently rolled leaves or leaves that roll up in dry weather (as in vinemesquite grass). Many desert cacti are xerophytes.

X/Open

in computing, multivendor computer industry body formed in 1984 to ratify and support the use of Unix as an open operating system. In February 1996, X/Open merged with the Open Software Foundation to form The Open Group.

X-ray

band of electromagnetic radiation in the wavelength range 10^{-12} to 10^{-8} m (between gamma rays and ultraviolet radiation; see electromagnetic waves). Applications of X-rays make use of their short wavelength (as in X-ray diffraction) or their penetrating power (as in medical X-rays of internal body tissues). X-rays are dangerous and can cause cancer.

X-rays with short wavelengths pass through most body tissues, although dense areas such as bone prevent their passage, showing up as white areas on X-ray photographs. The X-rays used in radiotherapy have very short wavelengths that penetrate tissues deeply and destroy them.

Because of their short wavelength, X-rays can be diffracted by the atoms in crystalline substances. An arrangement of a pattern of dots is formed on a photographic plate that provides information about the structure of the crystal.

X-rays were discovered by German experimental physicist Wilhelm Röntgen in 1895 and formerly called röntgen rays. They are produced when high-energy electrons from a heated filament cathode strike the surface of a target (usually made of tungsten) on the face of a massive heat-conducting anode, between which a high alternating voltage (about 100 kV) is applied.

What is Medical Imaging?

introduction

Wilhelm Conrad Röntgen, a physicist at the university of Wirzburg, Germany, discovered 'a new kind of ray' on 8 November 1895. He called this radiation X-rays. Röntgen was investigating the behaviour of cathode rays (electrons) in cathode ray tubes. The tube consisted of a glass envelope and when a high voltage discharge was passed through this tube, a faint light was produced. Röntgen had enclosed his cathode tube in black cardboard to prevent this light from escaping. He then darkened his laboratory room to be sure that there were no light leaks in the cardboard cover. Upon passing a high tension electric discharge through the tube, he noticed a faint light glowing. The source of the light was the fluorescence of a small piece of paper coated with barium platinocyanide. His conclusion was that some unknown type of ray was produced when the tube was energized. Thus, the great discovery of X-rays was made. There is no doubt that Röntgen's scientific contemporaries were startled by his discovery, but you can imagine the reaction of the non-scientific population when they learned of the new ray that could see through solid objects! It has even been reported that shy Victorian ladies of the period started bathing with their clothes on because they suspected 'those wicked scientists' of watching through the walls. Medical practitioners, however, soon realized the potential of the X-ray and its value for diagnosis. Developments in ultrasound and nuclear medicine mean that X-rays are no longer the only method of producing diagnostic images. The technological changes and scientific developments have led to the X-ray Department becoming a Medical Imaging Department, where there is a wide variety of imaging techniques undertaken.

radiography

In radiography, images are produced by X-rays for diagnosis. These images can be 'plain', showing only bony structures, or they can be 'contrast studies', showing soft tissue such as arteries and veins or organs such as the stomach or kidneys by means of an iodine or barium-based contrast agent introduced by an injection into a vein or by drinking a solution of the contrast agent. The final product, the 'radiograph' or 'X-ray', results when an X-ray cassette placed under the area of interest is exposed to a certain amount of X-ray energy. Once exposed, a latent image is formed on the X-ray film within the cassette and requires processing to produce the actual image. The processing of radiographic film is rather like developing film from a standard camera - it involves the film being placed in a bath of developer at a certain temperature and for a certain amount of time, then it requires washing, fixing, washing again, and finally drying. This procedure has traditionally been done manually, but in the last 15-20 years it has become automated and in some departments a darkroom is no longer required. In **computed radiography**, conventional film is replaced by systems with a digital image which can be viewed, stored and transmitted electronically.

computed tomography (CT)

In computed tomography, images are again produced by X-rays but, as their name suggests, the images are computerized and show transverse sectional views through the human body. This is a very precise form of radiography and the thickness of the sectional image produced can range from 2 to 12 mm. The whole body can be imaged this way.

magnetic resonance imaging

Magnetic resonance images are produced by a strong magnet and radio waves rather than by X-rays. The patient is placed inside the magnet and radio waves are applied. Once the radio waves are stopped, the patient gives off a signal which is transmitted to a computer which then produces the image. Once again, the whole body can be examined with this method of image production. However, should the patient have metal implants such as plates or joints, they cannot be placed into the magnet.

ultrasound scans

Ultrasound scans produce images by using sound waves similar to sonar rather than X-rays. Ultrasound is used to image soft tissue structures such as the liver, gall bladder, spleen, kidneys and unborn babies in their mother's womb.

nuclear medicine scans

In nuclear medicine, images are produced by the effect of a radioisotope taken by the patient, on different parts of the body. A computer detects the amount of isotope in the patient's body and an image showing the concentration of isotope is then produced. This form of imaging can be used to image bone, lungs and soft tissue organs such as the liver and spleen. Technological advances have not only increased the number of imaging techniques available but have also enhanced how images are produced and how they are stored and distributed. Picture Archive and Communication Systems (PACS) enables images which are produced digitally, such as MRI, CT, and Nuclear Medicine images, to be stored on optical disk or digital linear tape. This in turn enables the images to be viewed on workstations which sit on the same network, whether those workstations are within the imaging department, on a ward or clinic in the hospital, or in a doctor's home or surgery. The information obtained from these examinations can differentiate between different organs without the need for the patient to undergo surgical procedures. The ability to send images to the place where they are required as soon as they are produced saves time and personnel, which in these times of cost savings and the need to cut surgical waiting lists increases the importance of the Medical Imaging Department.

The Technology of Healing: A Century of Medicine

viewing the body

The detection of the X-ray in 1895 by Wilhelm Conrad Röntgen opened the modern era of technological medicine. The use of X-rays in hospitals and even on the battlefields of World War I for diagnostic purposes was one of the most rapid disseminations of a new medical technique. The wonders of X-rays and radioactivity were in fact used for dubious purposes, such as the treatment of acne or heavy menstrual periods, in the years between the two world wars, until the dangers of exposure were more fully documented and understood, leading to ever stricter regulation until today's principle of ALARA - as low as reasonably attainable. Other imaging techniques - ways of seeing into the body - have been developed in the 20th century. Wartime radar research was translated into ultrasound high-frequency sound-wave technology, which is now widely used in the monitoring of fetuses within the womb and to detect disease. The 1970s saw the development of computed tomography (CT or CAT) scanning by two British researchers, Godfrey Hounsfield and James Ambrose. Magnetic resonance imaging (MRI) produces images of the body by beaming radio waves into a patient lying in a strong magnetic field. Another consequence of the discovery of radioactivity by Antoine-Henri Becquerel in 1896 has been the use of radioactive isotopes for diagnosis and therapeutic purposes, especially for cancer, creating the new speciality of nuclear medicine.

antibiotics

Nearly fifty years after Louis Pasteur advanced the germ theory of infection, Alexander Fleming of St Mary's Hospital, London discovered the role of antibiotics in treating bacterial infections in 1928 when he observed the disinfecting properties of bread mould which proved to contain penicillin. In 1939 the Australian-born researcher Howard Florey and German-born Ernst Chain managed to isolate and manufacture penicillin which became an important asset to the Allies in World War II to keep the troops fit against tropical diseases and to hasten the healing of wounds. The range of antibacterial agents has proliferated greatly in the second half of the century, to the point where they are regarded as overused in many situations in both developed and developing countries. This increases the possibility of the emergence of resistance among new strains of bacteria and among patients who receive antibiotics too frequently or for the wrong purposes. Equally effective drugs such as the sulphonamides, streptomycin, and aspirin have been developed and major pharmaceutical companies have emerged to manufacture them. Their production was often based on techniques used for the manufacture of chemical weapons during the two major wars of the century.

vaccination

One of the triumphs of the century has been the eradication of the smallpox variola virus, the only naturally occurring disease to have been wiped out from the human population. This was achieved in 1980 (nearly two hundred years after Edward Jenner first introduced vaccination against smallpox) by massive immunization and case hunting. At the end of the century there was debate as to whether or not to destroy the last existing research samples of the smallpox virus. Many virologists are reluctant to permit the deliberate elimination of a virus that may have important genetic information. However this achievement was overshadowed for many by the appearance of what appear to be even more virulent viruses, such as Ebola and AIDS/HIV in the 1970s and 1980s.

Dr Jonas Salk had developed the inactivated polio vaccine and Dr Albert Sabin the live polio vaccine in the 1950s and by the end of the century the World Health Organization hoped to have eliminated the virus in Europe and the Eastern Mediterranean regions. Vaccines were developed in the post-war period for measles, mumps, rubella, hepatitis B, and other diseases. Several anti-malarial drugs have been developed and the life cycle of the disease carrier – the mosquito – was studied closely to aid the fight against the various strains of malaria that still appear in both developed and developing countries. The growth of international travel has made diseases such as this hard to overcome and the goal at the end of the century is control rather than elimination of malaria.

victims of research

An area of concern that has emerged at the end of the century has been the use of nonconsenting subjects in the development of these advances. The polio vaccines and many other medicines were tested on American prison inmates who were not fully informed of the dangers to which they were being subjected. Some experiments involved children with learning difficulties who had no one to protect their interests; many experiments involved poor African Americans who were not fully informed of their position. In May 1997 President Clinton apologized to the survivors of the Tuskegee Syphilis Study, where many participants were not offered appropriate treatment even after it was known that penicillin was an effective medication for this debilitating disease. Similarly, the president's Advisory Committee on Human Radiation Experiments reported in October 1995 that many individuals had been subjected to dangerous levels of radiation as part of medical research which they did not fully understand and to which they had not given informed consent. Some observers likened these activities to the medical experimentation in Nazi concentration camps for which German doctors had been condemned at the Nürnberg Trials. President Clinton made more funding available for bioethical studies as part of his reparation for the offences against medical ethics that his government was acknowledging.

Stricter guidelines for the use of human subjects in medical research were advanced in various countries and by international agencies in the second half of the 20th century but there is still an awareness, as we move into the new millennium, that careful monitoring and vigilance is required by ethics committees overseeing this research. The advent of computer technology has vastly increased the range of clinical trials being conducted in the development of pharmaceuticals and therapies, and some observers have expressed concern about the opportunity for fraud and abuse of individual patients as researchers and doctors enrol thousands of people in these studies. Some minority groups, on the other hand, argue that they are being discriminated against and are very keen to participate in trials for potential cures of conditions such as AIDS/HIV.

clinical trials

There were great advances throughout the century in the field of biostatistics, and the computerization of information storage and retrieval made extensive statistical studies of the effects of medicines and therapies possible after World War II. The procedures for clinical trials were developed in large part by Austin Bradford Hill when he carried out the first randomized trial to determine the effectiveness of the antibiotic drug streptomycin in 1946. Cancer clinical trials were developed by Marvin Zellen and other American researchers in the 1950s.

Not all the new medications subjected to clinical trials were in fact beneficial. Thalidomide proved to be teratogenic – causing birth defects when given to pregnant women to help with morning sickness, although it is now being used again to treat leprosy and AIDS.

birth control

One of the great breakthroughs of the century was the development of the hormone-based birth control pill by Carl Djerassi and others in the 1950s, and the freedom it gave women to time their reproduction. Various forms of birth control have been disseminated in the effort to stem the growth of the world's population. In the last third of the century the understanding of the menstrual cycle and menopause led to the development of Hormone Replacement Therapy and other modifiers of the side effects of hormonal imbalances. Research at the turn of the 20th century in this field is especially focused on developing a contraceptive pill for men.

genetics

At much the same time as Djerassi was developing the contraceptive pill, Crick and Watson identified the structure of DNA as a double helix. This new understanding together with technical developments such as the electron microscope ushered in an era of research into genes which culminated at the end of the century in the project to map the human genome - the sequence of genes on the 23 pairs of human chromosomes. Following the achievement of in vitro and ex utero human fertilization, and the transformation of fertility and reproductive treatments into a form of medical technology in the second half of the 20th century, there is some considerable apprehension about the prospects of genetic engineering and cloning that may become possible in the early years of the next millennium. The ethical considerations of such 'engineering' are already under close scrutiny.

surgery

Advances in surgery too have proceeded at a rapid pace, particularly as the 20th century was drawing to a close. The first heart transplant operation was performed by the South African surgeon Christiaan Barnard in 1967, and now major organ replacement surgery has become almost commonplace in the developed world. The development of laser surgery and 'keyhole' surgery has made day surgery more common and increased access throughout the world to what were once major procedures. Replacement of hips, joints, and lenses have improved the quality of life for many people. These procedures, however, are still expensive and the health economists of developed countries in particular are now trying both to create new formulas for ensuring fair access to these treatments as older people live longer, and to resist any move to 'ration' medical procedures.

work and ill health

Another area of great progress was the field of occupational health, as epidemiologists refined their techniques and the cause-and-effect relationships between various industries or occupations and particular illnesses were able to be established in replicated studies. Environmental health hazards too were progressively identified, and this field of medicine grew after the publication of Rachel Carson's book *Silent Spring* alerted the world to the dangers of chemical and radiation pollutants. One of the areas of contention at the end of the century remained around the hypothesis that men working in civilian and military nuclear plants might be exposed to radiation which could damage their sperm and therefore pass on birth defects to their children. New technologies such as cellular telephones will be subjected to close epidemiological investigation in the coming years.

meeting new challenges

One of the clearest consequences of the increasing contribution of technology to medicine - including information technology - is the 'information explosion' which trainee doctors and those who are already in practice have to contend with. The UK General Medical Council observed in a major statement on undergraduate medical training, *Tomorrow's Doctors* (1991), that half of what a medical student learns at university will be out of date within a decade or two - and no one knows which half. This realization has deeply affected medical education, which now increasingly concentrates on teaching doctors how to learn and keep their knowledge up to date rather than expecting to cover the whole of medical knowledge in five years of university teaching. There has also been a shift towards more practical medical teaching. The old 'apprenticeship' model of the last century gave way to the emergence of university-based medical teaching rather than hospital observation in the first half of the 20th century, but as the new millennium approached some of the advantages of 'on the job learning' were more appreciated, and efforts were being made to structure the practical learning of undergraduates more coherently and to correlate it with classroom teaching and learning. Other changes in the profession of medicine continue to be triggered by the fact that, in the UK and USA at least, more than one-half of medical students are now women. Historically, medical students had to work long hours without sleep. These work patterns are being phased out in the European region as dangerous to the well-being of both the doctors and the patients. General practitioners in the UK have negotiated a new way of responding to 'out of hours' calls to give them more protected time for family life. Nurses are concerned to define and upgrade their role in relation to the medical profession and the 'nurse practitioner' is emerging as an amalgam of some of the functions of both professions.

Patients too have changed. Mass media - from women's magazines to television health programmes - have educated patients to an unprecedented level and in many countries 'patients' charters' have emerged as people become more knowledgeable and assertive about medical care. While many of the challenges of the 19th century have been met, the 20th century has brought some of its own. Fair access to the best in medical care will probably be the first global challenge for medicine in the new millennium.

X-ray: Discovery of

the bones in his wife's hands

On 8 November 1895, German physicist Wilhelm Conrad Röntgen (1845-1923) discovered X-rays - by accident. This key discovery in atomic physics transformed medical diagnosis, and later provided a powerful tool in cancer therapy.

Röntgen was investigating the effects of electricity discharged through gases at low pressures to produce a beam of cathode rays (or electrons). Röntgen used a Crookes tube: an improved vacuum tube invented by British chemist and physicist William Crookes (1832-1919). He directed a narrow beam of rays from the tube, which was covered with black cardboard, onto a screen in a darkened room. He noticed a faint light on a nearby bench, caused by fluorescence from another screen.

the unknown rays

Röntgen knew that cathode rays could only travel a few centimetres through air. This other screen was about a metre away from his Crookes tube; he realized that he had discovered a new phenomenon. For six weeks, he worked feverishly to find out all about the new rays. Because their nature was unknown, he called them X-rays. On 2 December 1895, he made the first X-ray photograph, of his wife's hand. It shows that the bones in her hands were deformed by polyarthritis.

Röntgen announced his discovery on 28 December 1895. He accurately described many of the properties of X-rays. They are produced at the walls of the discharge tube by cathode rays; like light, they travel in straight lines and cast shadows; most bodies are transparent to them in some degree; they can blacken photographic plates, and cause some chemical substances to fluoresce; unlike cathode rays, they are not deflected by magnetic fields.

the uses of X-rays

All this created tremendous scientific excitement. In 1901, Röntgen received the first Nobel Prize for Physics for his discovery. Initially, X-rays were used to examine the bones of the skeleton: effectively the start of radiology, or the use of X-rays for medical purposes. Fractures could be seen clearly, as could embedded foreign bodies such as bullets or needles. Accidentally swallowed objects were accurately located. For the first time, surgeons knew in advance of operating exactly what to do.

the barium meal

Solid objects and bones could be clearly visualized on photographic film, recently developed by George Eastman (1854-1932) in the USA. However, it was hard to distinguish the soft tissues of the body. US physician Walter Bradford Cannon (1871-1945), who researched digestive problems and pioneered the use of X-rays in studying the alimentary canal, invented the 'barium meal' in 1897. Barium salts are relatively impervious to X-rays; by swallowing a solution of them before radiology, the patient's digestive system is selectively thrown into relief on the X-ray film. By the 1930s, X-ray examination was routine medical practice, particularly in examining the lungs for tuberculosis.

the damaging effects

As X-rays traverse living tissue, they also damage it. This danger to health was only understood much later, and both Röntgen and his assistant suffered X-ray poisoning. The destructive nature of radiation can be harnessed therapeutically. By focusing X-radiation on a tumour, its tissue is destroyed. When a cancer is not widely disseminated within the body, radiation therapy is a powerful weapon in the fight against cancer. Other forms of radiation, from radioactive sources for example, can be similarly employed.

tomography

Traditional radiology now accounts for no more than half of medical photography. In tomography, an interesting extension of the medical uses for X-rays, they are used to photograph a selected plane of the human body. Tomography was first demonstrated successfully in 1928. In 1973, British engineer Godfrey Newbold Hounsfield (1919-) invented computerized axial tomography (CAT), in which a computer assembles a high-resolution X-ray picture of a 'slice' through the body (or head) of a patient from information provided by detectors rotating around the patient. CAT can detect very small changes in the density of living tissue.

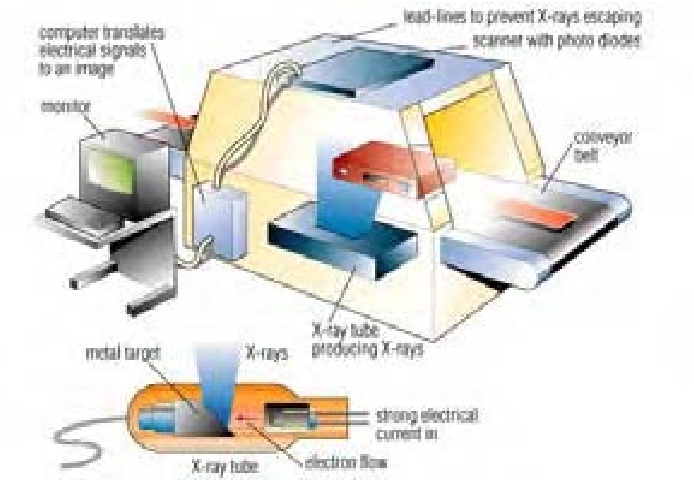
At first, such scanners were used to diagnose diseases of the brain: now, improved machines can scan an entire body. With Allan Macleod Cormack (1924-1998), the South African physicist who independently developed the mathematical basis for computer-assisted X-ray tomography, Hounsfield received the 1979 Nobel Prize for Physiology or Medicine for the development of CAT.

from X-rays to radioactivity

Röntgen's discovery of X-rays led directly to the discovery of radioactivity by French physicist Antoine Henri Becquerel (1852-1908). In 1896 Becquerel was searching for X-rays in the fluorescence seen when certain salts absorb ultraviolet radiation: from the Sun, for example. He placed his test salt on a photographic plate wrapped in black paper, reasoning that any X-radiation given off by a fluorescing salt would fog the film. By chance, he left a test salt in a drawer near a wrapped plate. When the plate was developed, it had fogged.

The salt could not have fluoresced in the dark; some radiation other than X-rays must be responsible. His test salt was potassium uranyl sulphate, a salt of uranium; Becquerel had discovered radioactivity.

X-ray


lead-lines to prevent X-rays escaping
scanner with photo diodes
computer translates electrical signals to an image
monitor
conveyor belt
X-ray tube producing X-rays
metal target
X-rays
strong electrical current in
X-ray tube
electron flow

(Image © Research Machines plc)

An X-ray image. The X-rays are generated by high-speed electrons impinging on a tungsten target. The rays pass through the specimen and on to a photographic plate or imager.

X-ray astronomy

detection of X-rays from intensely hot gas in the universe. Such X-rays are prevented from reaching the Earth's surface by the atmosphere, so detectors must be placed in rockets and satellites. The first celestial X-ray source, Scorpius X-1, was discovered by a rocket flight in 1962.

Since 1970, special satellites have been put into orbit to study X-rays from the Sun, stars, and galaxies. These include the Chandra X-Ray Observatory and the Röntgen Satellite. Many X-ray sources are believed to be gas falling into neutron stars and black holes.

X-Ray Astronomy

Go to site

Impressive X-ray resource at the Max Planck-Institut für Extraterrestrische Physik. There are details of X-ray missions, institute projects, and publications, and a well-organized image gallery.

X-ray diffraction

method of studying the atomic and molecular structure of crystalline substances by using X-rays. X-rays directed at such substances spread out as they pass through the crystals owing to diffraction (the slight spreading of waves around the edge of an opaque object) of the rays around the atoms. By using measurements of the position and intensity of the diffracted waves, it is possible to calculate the shape and size of the atoms in the crystal. The method has been used to study substances such as DNA that are found in living material.

X-ray diffraction analysis

use of X-rays to study the atomic and molecular structure of crystalline substances such as ceramics, stone, sediments, and weathering products on metals. The sample, as a single crystal or ground to powder, is exposed to X-rays at various angles; the diffraction patterns produced are then compared with reference standards for identification.

X-ray fluorescence spectrometry

technique used to determine the major and trace elements in the chemical composition of such materials as ceramics, obsidian, and glass. A sample is bombarded with X-rays, and the wavelengths of the released energy, or fluorescent X-rays, are detected and measured. Different elements have unique wavelengths, and their concentrations can be estimated from the intensity of the released X-rays. This analysis may, for example, help an archaeologist in identifying the source of a material.

X-ray telescope

in astronomy, telescope designed to receive electromagnetic waves in the X-ray part of the spectrum. X-rays cannot be focused by lenses or mirrors in the same way as visible light, and a variety of alternative techniques is used to form images. Because X-rays cannot penetrate the Earth's atmosphere, X-ray telescopes are mounted on satellites, rockets, or high-flying balloons.

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xylem

transport tissue found in vascular plants, whose main function is to conduct water and dissolved mineral nutrients from the roots to other parts of the plant. The water is ultimately lost by transpiration from the leaves (see leaf). Xylem is composed of a number of different types of cell, and may include long, thin, usually dead cells known as tracheids; fibres (schlerenchyma); thin-walled parenchyma cells; and conducting vessels.

Transpiration is the loss of water, in the form of water vapour, from leaves of a plant to the air outside the leaf. The loss of water from the leaves drives the movement of water and minerals in the xylem. This is important because many plant cells need the minerals as nutrients. Xylem tissue is usually found close to the other transport tissue in plants, phloem, which transports sugars and amino acids (see protein). In non-woody plants phloem and xylem are found in bundles (called veins if they are in a leaf).

In most angiosperms (flowering plants) water is moved through these vessels. Most gymnosperms and pteridophytes lack vessels and depend on tracheids for water conduction. Non-woody plants contain only primary xylem, derived from the procambium, whereas in trees and shrubs this is replaced for the most part by secondary xylem, formed by secondary growth from the actively dividing vascular cambium. The cell walls of the secondary xylem are thickened by a deposit of lignin, providing mechanical support to the plant; see wood.

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yak

species of cattle *Bos grunniens*, family Bovidae, which lives in wild herds at high altitudes in Tibet. It stands about 2 m/6 ft at the shoulder and has long shaggy hair on the underparts. It has large, upward-curving horns and humped shoulders. It is in danger of becoming extinct.

In the wild, the yak is brown or black, but the domesticated variety, which is half the size of the wild form, may be white. It is used for milk, meat, leather, and as a beast of burden. The yak is protected from extremes of cold by its thick coat and by the heat produced from the fermentation in progress in its stomach.

yak

(Image © Research Machines plc)

Yaks ploughing in Tibet. The yak is a mainstay of the economy, providing meat, milk, and leather, and serving as a pack and saddle animal. Their dried dung also serves as fuel on the treeless plateaus. Wild yaks have been greatly reduced in number and are now an endangered species.

yak

(Image © Corel)

A domestic yak and suckling calf in Tibet, on a high plateau in the Himalayas. Yaks are kept for milking, wool, and for meat, as well as being used as pack animals. Domestic yaks are smaller than the scarce wild yaks, due to cross-breeding with cattle.

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yam

any of a group of climbing plants cultivated in tropical regions; the starchy tubers (underground stems) are eaten as a vegetable. The Mexican yam (*D. composita*) contains a chemical that is used in the contraceptive pill. (Genus *Dioscorea*, family Dioscoreaceae.)

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yapok

nocturnal opossum*Chironectes minimus* found in tropical South and Central America. It is about 33 cm/1.1 ft long, with a 40 cm/1.3 ft tail. It has webbed hind feet and thick fur, and is the only aquatic marsupial.

The female has a watertight pouch.

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yard

symbol yd

unit of length, equivalent to 3 feet (0.9144 m).

In the USA, it is sometimes used to denote a cubic yard (0.7646 cubic meters), as of topsoil.

yard

The foot, yard, and inch owe their length to Henry I of England. He decreed that one yard was the length of his extended arm, measured from nose to fingertip.

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yardang

ridge formed by wind erosion from a dried-up riverbed or similar feature, as in Chad, China, Peru, and North America. On the planet Mars yardangs occur on a massive scale.

---

yarn

thread produced by drawing and twisting together fibres or filaments.

There are two main categories of yarn: single, continuous filament yarn and spun yarn.
Continuous filament yarn is made when two or more filaments are drawn and twisted together (which stretches the filament slightly). Synthetic fibre is initially produced as single filaments. Silk is the only naturally-occurring single filament fibre.
Spun yarn is made from shorter (or staple) fibres. These include all natural fibres except silk, but may also include synthetic filaments which have been cut to form staple fibres. Staple fibres are made into a yarn by combing (to straighten the fibres), drawing, and twisting (spinning). Staple yarns tend to be bulkier, softer, and less lustrous than continuous filament yarns, which are usually used for smooth, shiny fabrics. However, continuous filament yarns can be given different textures, by different texturing and bulking processes.

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yarrow

or milfoil

perennial herb belonging to the daisy family, with feathery, scented leaves and flat-topped clusters of white or pink flowers. It is native to Europe and Asia. (*Achillea millefolium*, family Compositae.)

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yaws

contagious tropical disease common in the West Indies, West Africa, and some Pacific islands, characterized by red, raspberrylike eruptions on the face, toes, and other parts of the body, sometimes followed by lesions of the bones; these may progress to cause gross disfigurement. It is caused by a spirochete (*Treponema pertenue*), a bacterium related to the one that causes syphilis. Treatment is by antibiotics.

Y chromosome

smaller of the two sex chromosomes. In male mammals it occurs paired with the other type of sex chromosome (X), which carries far more genes. The Y chromosome is the smallest of all the mammalian chromosomes and is considered to be largely inert (that is, without direct effect on the physical body), apart from containing the genes that control the development of the testes. There are only 20 genes discovered so far on the human Y chromosome, far fewer than on all other human chromosomes.
In humans, whether a person is male or female is determined by the particular combination of the two sex chromosomes in the body cells. In females both the sex chromosomes are the same - two X chromosomes (XX). In males the two are different - one X chromosome and one Y chromosome (XY). The Y chromosome is shorter than the X. Genes on these chromosomes determine a person's sex (sex determination).

As a result of meiosis gametes from a female each contain one X chromosome. However, gametes from a male are of two kinds. Half of the gametes contain an X chromosome and half contain a Y chromosome. If an X carrying gamete from a male fertilizes a female gamete the result will be a female. If a Y carrying gamete from a male fertilizes a female gamete, the result will be a male.

In humans, about one in 300 males inherits two Y chromosomes at conception, making him an XYY triploid. Few if any differences from normal XY males exist in these individuals, although at one time they were thought to be emotionally unstable and abnormally aggressive. In 1989 the gene determining that a human is male was found to occur on the X as well as on the Y chromosome; however, it is not activated in the female.

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yd

abbreviation for yard.

year

unit of time measurement, based on the orbital period of the Earth around the Sun. The **tropical year** (also called equinoctial and solar year), from one spring equinox to the next, lasts 365.2422 days (nearly 3651/4 days). It governs the occurrence of the seasons, and is the period on which the calendar year is based. Every four years is a leap year, when the four quarters of a day are added as one extra day. A year on Mercury is only 88 days; a year on Mars is 23 months.

The **sidereal year** is the time taken for the Earth to complete one orbit relative to the fixed stars, and lasts 365.26 days (about 20 minutes longer than a tropical year). The difference is due to the effect of precession, which slowly moves the position of the equinoxes. The **anomalistic year** is the time taken by any planet in making one complete revolution from perihelion to perihelion; for the Earth this period is about five minutes longer than the sidereal year due to the gravitational pull of the other planets. The **calendar year** consists of 365 days, with an extra day added at the end of February each leap year. **Leap years** occur in every year that is divisible by four, except that a century year is not a leap year unless it is divisible by 400. Hence 1900 was not a leap year, but 2000 was.

Chinese year

The Chinese year is traditionally divided into 12 lunar months (13 months in a leap year), beginning at the second new Moon after the winter solstice. The year is also divided into 24 periods of 15-16 days, according to the movement of the Sun. This calendar is sometimes referred to as the Chinese agricultural calendar or the farmer's calendar because it follows the tropical (solar) year and is closely related to changes in the seasons.

Chinese solar term	English translation	Gregorian date (approx)
Li Chun	spring begins	4/5 February
Yu Shui	rain water	19/20 February
Jing Zhe	insects waken	5/6 March
Chun Fen	vernal equinox	20/21 March
Qing Ming	clear and bright	4/5 April
Gu Yu	grain rains	20/21 April
Li Xia	summer begins	5/6 May
Xiao Man	grain fills	20/21 May
Mang Zhong	grain in ear	5/6 June
Xia Zhi	summer solstice	21/22 June
Xiao Shu	slight heat	6/7 July
Da Shu	great heat	22/23 July
Li Qiu	autumn begins	7/8 August
Chu Shu	heat ends	23/24 August
Bai Lu	white dew	7/8 September
Qui Fen	autumn equinox	23/24 September
Han Lu	cold dew	8/9 October
Shuang Jiang	frost descends	23/24 October
Li Dong	winter begins	7/8 November
Xiao Xue	little snow	22/23 November
Da Xue	heavy snow	7/8 December
Dong Zhi	winter solstice	22/23 December
Xiao Han	little cold	5/6 January
Da Han	severe cold	20/21 January

year 2000

another name for the Millennium Bug

yeast

one of various single-celled fungi (see fungus) that form masses of tiny round or oval cells by budding. When placed in a sugar solution the cells multiply and convert the sugar into alcohol and carbon dioxide. Yeasts are used as fermenting agents in baking, brewing, and the making of wine and spirits. Brewer's yeast (*S. cerevisiae*) is a rich source of vitamin B. (Especially genus *Saccharomyces*; also other related genera.)

yeast artificial chromosome

YAC

fragment of DNA from the human genome inserted into a yeast cell. The yeast replicates the fragment along with its own DNA. In this way the fragments are copied to be preserved in a gene library. YACs are characteristically between 250,000 and 1 million base pairs in length. A cosmid works in the same way.

yeheb nut

small tree found in Ethiopia and Somalia, formerly much valued for its nuts as a food source. Although cultivated as a food crop in Kenya and Sudan, it is now critically endangered in the wild and is only known to survive at three sites. Overgrazing by cattle and goats has prevented regrowth, and the taking of nuts for consumption prevents reseeding. Although reintroduction would be possible from cultivated trees, the continuing grazing pressure would make establishment unlikely without proper management. (Genus *Cordeauxia adulis*.)

yellow archangel

flowering plant belonging to the mint family, found over much of Europe. It grows up to 60 cm/2 ft tall and has nettlelike leaves and rings, or whorls, of yellow flowers growing around the main stem; the lower lips of the flowers are streaked with red in early summer. (Genus *Lamiastrum galeobdolon*, family Labiatae.)

yellow fever

or yellow jack

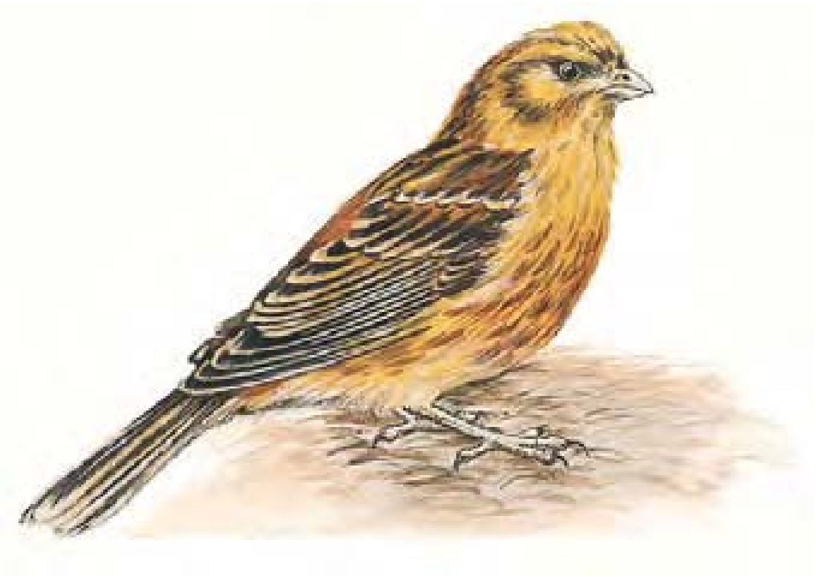
acute tropical viral disease, prevalent in the Caribbean area, Brazil, and on the west coast of Africa. The yellow fever virus is an arbovirus transmitted by mosquitoes. Its symptoms include a high fever, headache, joint and muscle pains, vomiting, and yellowish skin (jaundice, possibly leading to liver failure); the heart and kidneys may also be affected. The mortality rate is 15%, with 91% of all cases occurring in Africa.

Before the arrival of Europeans, yellow fever was not a problem because indigenous people had built up an immunity. The disease was brought under control after the discovery that it is carried by the mosquito *Aëdes aegypti*. The first effective vaccines were produced by Max Theiler (1899-1972) of South Africa, for which he was awarded the 1951 Nobel Prize for Physiology or Medicine. The World Health Organization (WHO) estimates there are about 200,000 cases of yellow fever each year in Africa, with 30,000 deaths (2003).

yellowhammer

Eurasian bird *Emberiza citrinella* of the bunting family Emberizidae, order Passeriformes. About 16.5 cm/6.5 in long, the male has a yellow head and underside, a chestnut rump, and a brown-streaked back. The female is duller.

yellowhammer



(Image © Research Machines plc)

A pair of yellowhammers, or yellow buntings, *Emberiza citrinella*. The male has a bright yellow head and underparts; the female's plumage is less colourful.

Yerkes Observatory

astronomical centre in Williams Bay, Wisconsin, founded by George Hale in 1897. It houses the world's largest refracting optical telescope, with a lens of diameter 102 cm/40 in.

Yerkes Observatory

Go to site

Home page of the Yerkes Observatory, including a virtual tour of the observatory and a tour around a virtual museum about the history of the observatory. This site also includes information about current research and some images of space phenomena.

yeti

(Tibetan yeh 'rocky place', teh 'animal')

name given by the Sherpas of east Nepal to an unidentified animal of the Himalayas, also known as the abominable snowman.

The creature reputedly inhabits the deserts of scree at an altitude of about 4,000–5,000 m/13,000–16,000 ft. Photographs claiming to show footprints, 15–30 cm/6–12 in long with a broad heel and separated toe, have been the subject of much debate.

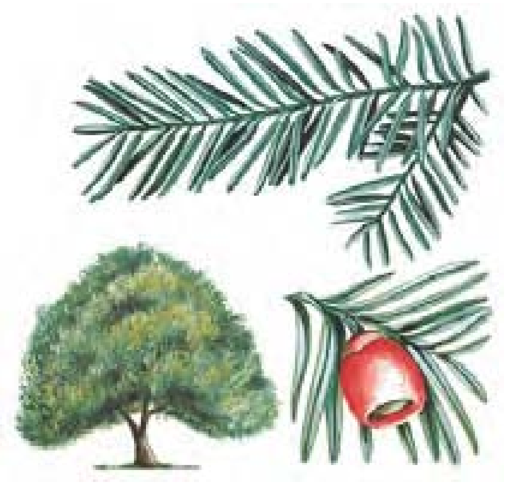
yew

any of a group of evergreen coniferous trees native to the northern hemisphere. The dark green flat needlelike leaves and bright red berrylike seeds are poisonous; the wood is hard and close-grained. (Genus *Taxus*, family Taxaceae.)

The western or Pacific yew (*T. brevifolia*) is native to North America. English yew (*T. baccata*) is widely cultivated as an ornamental tree. The wood was formerly used to make longbows.

The anticancer drug taxol is synthesized from the bark of the Pacific yew.

yew



(Image © Research Machines plc)

The yew is a slow-growing evergreen, the longest living of all European trees, probably reaching ages of 1,000 years. The seeds are enclosed in a fleshy covering called an aril which is eaten by birds; the seed itself is poisonous, as is the rest of the tree.

yield point

or elastic limit

stress beyond which a material deforms by a relatively large amount for a small increase in stretching force. Beyond this stress, the material no longer obeys Hooke's law.

Yixian formation

in palaeontology, a Chinese geological formation in the the rural province of Liaoning that is yielding a wealth of extraordinarily well-preserved fossils. The fossils date from 150 to 120 million years ago (late Jurassic or early Cretaceous) and include those of hundreds of early birds, such as *Confuciusornis*, with feathers, lizards with full skin, and mammals with hair.

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yolk

store of food, mostly in the form of fats and proteins, found in the eggs of many animals. It provides nourishment for the growing embryo.

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yolk sac

sac containing the yolk in the egg of most vertebrates. The term is also used for the membranous sac formed below the developing mammalian embryo and connected with the umbilical cord.

Young, John Watts (1930-)

US astronaut. His first flight was on *Gemini 3* in 1965, followed by *Gemini 10* in 1966. In 1969 he flew the command module of *Apollo 10* and in 1972 commanded *Apollo 16*, which landed on the Moon. He and Charles Duke collected 90 kg/200 lb of Moon rocks. Young was commander of the first flight of a space shuttle, *Columbia*, in 1981, and commanded it on the ninth space-shuttle flight in 1983.

He was named chief of the Astronaut Office in 1975 and later became associate (technical) director of the Johnson Space Center.

Young, Thomas (1773-1829)

English physicist, physician, and Egyptologist who revived the wave theory of light and identified the phenomenon of interference in 1801. He also established many important concepts in mechanics.

In 1793, Young recognized that focusing of the eye (accommodation) is achieved by a change of shape in the lens of the eye, the lens being composed of muscle fibres. He also showed that astigmatism is due to irregular curvature of the cornea. In 1801, he became the first to recognize that colour sensation is due to the presence in the retina of structures that respond to the three colours red, green, and violet.

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ytterbium

chemical symbol Yb

soft, lustrous, silvery, malleable, and ductile metallic element of the lanthanide series, symbol Yb, atomic number 70, relative atomic mass 173.04. It occurs with (and resembles) yttrium in gadolinite and other minerals, and is used in making steel and other alloys.

In 1878 Swiss chemist Jean-Charles de Marignac gave the name ytterbium (after the Swedish town of Ytterby, near where it was found) to what he believed to be a new element. French chemist Georges Urbain (1872-1938) discovered in 1907 that this was in fact a mixture of two elements: ytterbium and lutetium.

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yttrium

chemical symbol Y

silver-grey, metallic element, atomic number 39, relative atomic mass 88.905. It is associated with and resembles the rare-earth elements (lanthanides), occurring in gadolinite, xenotime, and other minerals. It is used in colour-television tubes and to reduce steel corrosion.

The name derives from the Swedish town of Ytterby, near where it was first discovered in 1788. Swedish chemist Carl Mosander (1797-1858) isolated the element in 1843.

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yucca

any of a group of plants belonging to the lily family, with over 40 species found in Latin America and the southwestern USA. The leaves are stiff and sword-shaped and the flowers, which grow on upright central spikes, are white and bell-shaped. (Genus *Yucca*, family Liliaceae.)

Yuccas grow in dry soils where nitrate salts, required for protein manufacture, are in short supply. They have therefore evolved the ability to use ammonia, absorbed from animal urine, instead. Feeding extracts of yucca to livestock has been shown to reduce unpleasant ammoniacal smells from factory farms.

Z

in physics, the symbol for **impedance** (electricity and magnetism).

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zebra

black and white striped member of the horse genus *Equus* found in Africa; the stripes serve as camouflage or dazzle and confuse predators. It is about 1.5 m/5 ft high at the shoulder, with a stout body and a short, thick mane. Zebras live in family groups and herds on mountains and plains, and can run at up to 60 kph/40 mph. Males are usually solitary.

The **mountain zebra** *E. zebra* was once common in Cape Colony and Natal and still survives in parts of South Africa and Angola. It has long ears and is silvery-white with black or dark-brown markings.
Grevy's zebra *E. grevyi*, at 1.6 m and 450 kg, is the largest member of the horse family. It has finer and clearer markings than the mountain zebra and inhabits Ethiopia and Somalia. Whereas other zebra species have a harem system, Grevy's males defend territories that females pass through to graze. The species is classified as endangered.
Burchell's or the **common zebra** *E. burchelli* is medium in size, has white ears, a long mane, and a full tail; it roams the plains north of the Orange River in South Africa.

zebra

(Image © Corel)

Zebra live in family groups of up to six females and their young, with one male. They feed on grass, leaves, and bark, grazing in the daytime. Individuals recognize each other by pattern, voice, and scent.

Grevy's Zebra

Go to site

Illustrated guide to the (Grevy's) zebra including information about genus, size, lifespan, habitat, gestation, diet, and a series of fun facts.

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zebu

any of a species of cattle*Bos indicus* found domesticated in East Asia, India, and Africa. It is usually light-coloured, with large horns and a large fatty hump near the shoulders. It is used for pulling loads and is held by some Hindus to be sacred. There are about 30 breeds.

Zebus have been crossbred with other species of cattle in hot countries to pass on their qualities of heat tolerance and insect resistance. In the USA, they are called Brahman cattle.

Zelenchukskaya

site of what was formerly the world's largest single-mirror optical telescope, with a mirror of 6 m/19.7 ft diameter, in the Caucasus Mountains of Russia. At the same site is the RATAN 600 radio telescope, consisting of radio reflectors in a circle of 600 m/2,000 ft diameter. Both instruments are operated by the Special Astrophysical Observatory of the Russian Academy of Sciences in St Petersburg.

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zenith

uppermost point of the sky, immediately above the observer; the nadir is below, diametrically opposite. See celestial sphere.

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zeolite

any of the hydrous aluminium silicates, also containing sodium, calcium, barium, strontium, or potassium, chiefly found in igneous rocks and characterized by a ready loss or gain of water. Zeolites are used as 'molecular sieves' to separate mixtures because they are capable of selective absorption. They have a high ion-exchange capacity and can be used to separate petrol, benzene, and toluene from low-grade raw materials, such as coal and methanol.

Zhubov scale

scale for measuring ice coverage, developed in the former USSR. The unit is the **ball**; one ball is 10% coverage, two balls 20%, and so on.

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zidovudine

formerly AZT

antiviral drug used in the treatment of AIDS; see AZT.

Ziegler, Karl (1898-1973)

German organic chemist. He shared the Nobel Prize for Chemistry in 1963 with Giulio Natta of Italy for work on the chemistry and technology of large polymers. He combined simple molecules of the gas ethylene (ethene) into the long-chain plastic polyethene (polyethylene).

Ziegler and Natta discovered in 1953 a family of stereo-specific catalysts capable of introducing an exact and regular structure to various polymers. This discovery formed the basis of nearly all later developments in synthetic plastics, fibres, rubbers, and films derived from such olefins as ethylene (ethene) and butadiene (but-1,2:3,4-diene).

ZIFT

acronym for Zygote Inter-Fallopian Transfer

modified form of in vitro fertilization in which the fertilized ovum is reintroduced into the mother's Fallopian tube before the ovum has undergone its first cell division. This mimics the natural processes of fertilization (which normally occurs in the Fallopian tube) and implantation more effectively than older techniques.

Zimbabwe

or Great Zimbabwe

(Shona zimbabwe 'house of stone')

extensive stone architectural ruins 27 km/17 mi southeast of Victoria in Mashonaland, Zimbabwe. The site was occupied from the 3rd century AD, but the massive stone structures date from the 10th-15th centuries AD. They were probably the work of the Shona people, who established their rule in about AD 1000 and mined minerals for trading.

The new state of Zimbabwe took its name from these ruins, and the national emblem is a bird derived from soapstone sculptures of fish eagles found there. The site comprises hill ruins with the earliest dwellings (10th century AD), a series of stone-walled enclosures on a granite outcrop known as the Acropolis, a massive elliptical building, or Great Enclosure, with 10-m/30-ft stone walls, a ritual or political site known as the Temple, and a conical tower built in a later phase.

Porcelain of the Ming period and golden ornaments have been found in the ruins. Gold, copper, tin, and iron were all mined by the Shona.

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zinc

chemical symbol Zn

(Germanic Zinke 'point')

hard, brittle, bluish-white, metallic element, atomic number 30, relative atomic mass 65.37. The principal ore is sphalerite or zinc blende (zinc sulphide, ZnS). Zinc is hardly affected by air or moisture at ordinary temperatures; its chief uses are in alloys such as brass, in coating metals (for example, galvanized iron), and in making batteries. Its compounds include zinc oxide, used in ointments (as an astringent) and cosmetics, paints, glass, and printing ink.

Zinc is an essential trace element in most animals; adult humans have 2-3 g/0.07-0.1 oz of zinc in their bodies. There are more than 300 known enzymes that contain zinc.

Zinc has been used as a component of brass since the Bronze Age, but it was not recognized in Europe as a separate metal until the 16th century. It was isolated in 1746 by German chemist Andreas Sigismund Marggraf (1709-1782). The name derives from the shape of the crystals on smelting.

zinc ore

mineral from which zinc is extracted, principally sphalerite (Zn,Fe)S, but also zincite, ZnO_2, and smithsonite, $ZnCO_3$, all of which occur in mineralized veins. Ores of lead and zinc often occur together, and are common worldwide; Canada, the USA, and Australia are major producers.

zinc oxide

ZnO

white powder, yellow when hot, that occurs in nature as the mineral zincite. It is used in paints and as an antiseptic in zinc ointment; it is the main ingredient of calamine lotion.

zinc sulphide

ZnS

yellow-white solid that occurs in nature as the mineral sphalerite (also called zinc blende). It is the principal ore of zinc, and is used in the manufacture of fluorescent paints.

zinnia

any of a group of annual plants belonging to the daisy family, native to Mexico and South America; notably the cultivated hybrids of *Z. elegans* with brightly coloured daisylike flowers. (Genus *Zinnia*, family Compositae.)

zipper

fastening device used in clothing, invented in the USA by Whitcomb Judson in 1891, originally for doing up shoes. It has two sets of interlocking teeth, meshed by means of a slide that moves up and down. It became widely used in the clothing industry in the 1930s.

zircon

zirconium silicate, $ZrSiO_4$, a mineral that occurs in small quantities in a wide range of igneous, sedimentary, and metamorphic rocks. It is very durable and is resistant to erosion and weathering. It is usually coloured brown, but can be other colours, and when transparent may be used as a gemstone.

Zircons contain abundant radioactive isotopes of uranium and so are useful for uranium-lead dating to determine the ages of rocks.

zirconium

chemical symbol Zr

(Germanic zircon, from Persian zargun 'golden')

lustrous, greyish-white, strong, ductile, metallic element, atomic number 40, relative atomic mass 91.22. It occurs in nature as the mineral zircon (zirconium silicate), from which it is obtained commercially. It is used in some ceramics, alloys for wire and filaments, steel manufacture, and nuclear reactors, where its low neutron absorption is advantageous.

It was isolated in 1824 by Swedish chemist Jöns Berzelius. The name was proposed by English chemist Humphry Davy in 1808.

zodiac

zone of the heavens containing the paths of the Sun, Moon, and planets. When this was devised by the ancient Greeks, only five planets were known, making the zodiac about 16° wide. In astrology, the zodiac is divided into 12 signs, each 30° in extent: Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, and Pisces. These do not cover the same areas of sky as the astronomical constellations.

The 12 astronomical constellations are uneven in size and do not between them cover the whole zodiac, or even the line of the ecliptic, much of which lies in the constellation of Ophiuchus.

signs of the zodiac

To remember the order of the signs of the zodiac:

The Ram, the Bull, the Heavenly Twins,
And next the Crab, the Lion shines,
The Virgin and the Scales,
The Scorpion, Archer, and Sea-Goat,
The Man that bears the watering-pot,
And Fish with glittering tails.

Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Saggitarius, Capricorn, Aquarius, Pisces

zodiac constellations

To remember the constellations of the zodiac:

A **t**ense **g**rey **c**at **l**ay **v**ery **l**ow, **s**neaking **s**lowly, **c**ontemplating **a** **p**ounce

Aries, **T**aurus, **G**emini, **C**ancer, **L**eo, **V**irgo, **L**ibra, **S**corpio, **S**agittarius, **C**apricorn, **A**quarius, **P**isces

Signs of the zodiac

Sign	Element	Symbol	Dates
Aries	Fire	ram	21 March-20 April
Taurus	Earth	bull	20 April-21 May
Gemini	Air	twins	21 May-21 June
Cancer	Water	crab	21 June-23 July
Leo	Fire	lion	23 July-23 August
Virgo	Earth	virgin	23 August-23 September
Libra	Air	balance	23 September-23 October
Scorpio	Water	scorpion	23 October-22 November
Sagittarius	Fire	archer	22 November-22 December
Capricorn	Earth	goat	22 December-20 January
Aquarius	Air	water bearer	20 January-19 February
Pisces	Water	fishes	19 February-21 March

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zodiacal light

cone-shaped light sometimes seen extending from the Sun along the ecliptic (that is, the path that the Sun appears to follow each year as it is orbited by Earth), visible after sunset or before sunrise. It is due to thinly spread dust particles in the central plane of the Solar System. It is very faint, and requires a dark, clear sky to be seen.

The dust is thought to be produced mainly by colliding asteroids and active comets, though a small amount probably originates from outside the Solar System. Astronomers estimate that some 10,000 tonnes/11,023 tons of this dust hits the Earth each year.

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zoidogamy

type of plant reproduction in which male gametes (antherozoids) swim in a film of water to the female gametes. Zoidogamy is found in algae, bryophytes, pteridophytes, and some gymnosperms (others use siphonogamy).

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zone standard time

or standard time

time in any of the 24 time zones, each an hour apart, into which the Earth is divided. The respective times depend on their distances, east or west of Greenwich, England. In North America the eight zones (Atlantic, Eastern, Central, Mountain, Pacific, Alaska, Hawaii-Aleutian, and Samoa) use the mean solar times of meridians 15° apart, starting with 60° longitude. (See also time.)

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zone system

in photography, a system of exposure estimation invented by Ansel Adams that groups infinite tonal gradations into ten zones, zone 0 being black and zone 10 white. An f-stop change in exposure is required from zone to zone.

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zone therapy

alternative name for reflexology.

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zoo

abbreviation for ZOOlogical gardens

place where animals are kept in captivity. Originally created purely for visitor entertainment and education, zoos have become major centres for the breeding of endangered species of animals; a 1984 report identified 2,000 vertebrate species in need of such maintenance.

Notable zoos exist in New York, San Diego, Toronto, Chicago, London, Paris, Berlin, Moscow, and Beijing (Peking). Many groups object to zoos because they keep animals in unnatural conditions alien to their habitat.

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zoology

branch of biology concerned with the study of animals. It includes any aspect of the study of animal form and function - description of present-day animals, the study of evolution of animal forms, anatomy, physiology, embryology, behaviour, and geographical distribution.

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zoom lens

photographic lens that, by variation of focal length, allows speedy transition from long shots to close-ups.

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zoonosis

any infectious disease that can be transmitted to humans by other vertebrate animals. Probably the most feared example is rabies. The transmitted micro-organism sometimes causes disease only in the human host, leaving the animal host unaffected.

Z particle

in physics, an elementary particle, one of the intermediate vector bosons responsible for carrying the weak nuclear force. The Z particle is neutral.

Zsigmondy, Richard Adolf (1865-1929)

Austrian-born German chemist who devised and built an ultramicroscope in 1903. The microscope's illumination was placed at right angles to the axis. (In a conventional microscope the light source is placed parallel to the instrument's axis.) Zsigmondy's arrangement made it possible to observe particles with a diameter of one 10-millionth of a millimetre. He was awarded the Nobel Prize for Chemistry in 1925 for the elucidation of heterogeneity of colloids.

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zucchini

small variety of marrow, *Cucurbita pepo*, of the Cucurbitaceae family. It is cultivated as a vegetable and harvested before it is fully mature, at 15-20 cm/6-8 in. In the UK it is known as a courgette.

Zweig, George (1937-)

Russian-born US theoretical physicist who, along with US physicist Murray Gell-Mann, developed the quark theory. They developed a theory based on three quarks as the fundamental building blocks of the hadrons.

Zwicky, Fritz (1898-1974)

Swiss astronomer. He predicted the existence of neutron stars in 1934. He discovered 18 supernovae and determined that cosmic rays originate in them.

Zwicky observed that most galaxies occur in clusters, each of which contains several thousand galaxies. He made spectroscopic studies of the Virgo and Coma Berenices clusters and calculated that the distribution of galaxies in the Coma Berenices cluster was statistically similar to the distribution of molecules in a gas when its temperature is at equilibrium. Beginning 1936, he compiled a catalogue of galaxies and galaxy clusters in which he listed 10,000 clusters.

zwitterion

ion that has both a positive and a negative charge, such as an amino acid in neutral solution. For example, glycine contains both a basic amino group (NH_2) and an acidic carboxyl group (COOH); when these are both ionized in aqueous solution, the acid group loses a proton to the amino group, and the molecule is positively charged at one end and negatively charged at the other.

Zworykin, Vladimir Kosma (1889-1982)

Russian-born US electronics engineer who invented a television camera tube and developed the electron microscope.

zygote

ovum (egg) after fertilization but before it undergoes cleavage to begin embryonic development.